ASSESSMENT OF THE NATIONAL AND REGIONAL POTENTIAL FOR THE APPLICATION OF HIGH-EFFICIENCY COGENERATION AND EFFICIENT DISTRICT HEATING

December 2016

ASSESSMENT OF THE NATIONAL AND REGIONAL POTENTIAL FOR THE APPLICATION OF HIGH-EFFICIENCY COGENERATION AND EFFICIENT DISTRICT HEATING

Gestore dei Servizi Energetici

December 2016

This report has been drawn up in compliance with Article 10 of Legislative Decree No 102/2014 implementing Directive 2012/27/EU on energy efficiency

Observations, information and clarifications: studi@gse.it

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Executive Summary

Article 14 of Directive 2012/27/EU on energy efficiency provides that Member States are to carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling.

Article 10 of Legislative Decree No 102 of 4 July 2014, which transposed Directive 2012/27/EU, provides that Gestore dei Servizi Energetici (GSE) is to prepare and submit to the Ministry of Economic Development a report containing said assessment, taking the year 2013 as the baseline.

The report is divided into three main sections containing:

- a **description of the demand for thermal energy** (Chapter 1), with reference to the year 2013, by sector, with details of the energy sources used, types of usage, geographical location, etc.;
- an **overview of the national supply of thermal energy** (Chapters 2, 3 and 4), including a description of the Italian thermoelectric mix in 2013, with details of the proportion produced from cogeneration and high-efficiency cogeneration, the energy sources used and the geographical location of the plants; an analysis of the existing district heating (DH) infrastructure and associated operating data; and a snapshot of the other methods of supplying heat (direct uses);
- the **identification,** using technical and economic criteria, of the proportion of energy demand that could potentially be met by high-efficiency cogeneration plants or efficient district heating systems (Chapters 5 and 6) which, when compared against existing capacity, gives an estimated **theoretical potential increase in high-efficiency cogeneration and efficient district heating**.

Demand for thermal energy

In **2013**, the **gross domestic consumption of energy** in Italy came to **160 Mtoe**. The **end use of energy** amounted to **118.7 Mtoe**: the **transport** sector had the highest consumption (38.7 Mtoe, representing 33 % of the total), followed by the **residential** sector (34.2 Mtoe, 29 %), **industry** (27 Mtoe, 23 %), **services** (15.9 Mtoe, 13 %) and agriculture (2.6 Mtoe, 2 %).

The development of energy consumption shows a declining trend. In the industry sector there has been a noticeable downward trend in consumption since 2005. By contrast, consumption in the residential sector is increasing slightly. Together, the two sectors accounted for about 80 % of total energy consumption in 2013.

Consumption for heating and cooling came to around **62.4 Mtoe** in 2013, equivalent to 71 % of consumption in the sectors analysed.

The **highest share** of **consumption for heating and cooling (48 %)** is generated by the **residential sector**. Next are industry (36 %) and services (15 %), while agriculture only accounts for a negligible share of consumption for heating.

The **main energy source used for heating and cooling** is **natural gas (58 %)**, followed by petroleum products (15 %) and renewables (13 %).

In 2013 the total demand for **residential** heating and cooling exceeded **29.6 Mtoe**, including almost 25 Mtoe for space heating and about 2.8 Mtoe for domestic hot water production.

The main energy sources used to meet the demand for space heating are **natural gas** (60 %) and solid biomass (26 %). Petroleum products are only used marginally (9 %).

More than 60 % of demand for winter heating and 46 % of demand for domestic hot water are in **climate condition area E**, mainly represented by northern Italy and the Apennines. Almost 50 % of heat demand is concentrated in areas with significant heat density, in excess of 30 kWh/m^2.

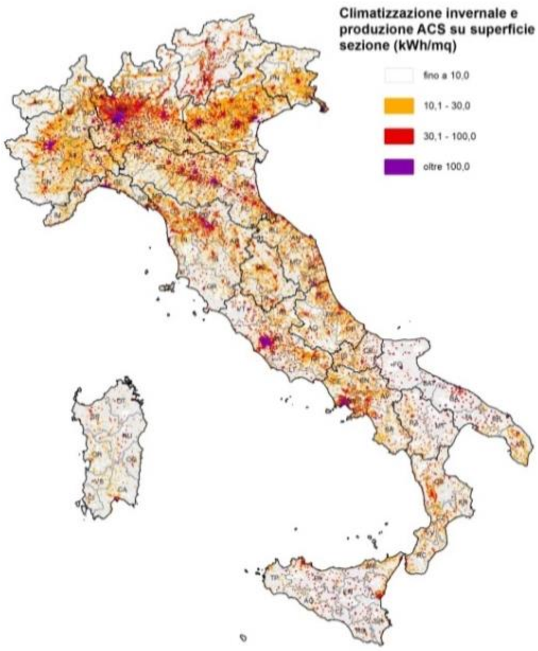
In the **service sector**, consumption for heating and cooling amounted to **9.6 Mtoe** in 2013 (8.2 Mtoe excluding electricity consumption for air conditioning).

Consumption in the service sector is concentrated in healthcare (16 %) and **sports facilities** (15 %), followed by **hotels and public offices** (both making up about 12 %).

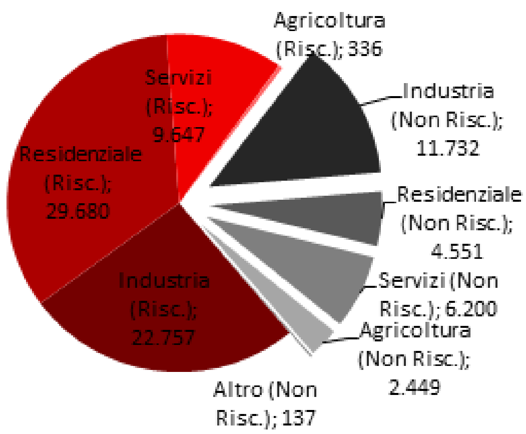
Natural gas accounted for almost 89 % of this consumption, petroleum products 7 %, and derived heat and renewable energy sources 2 %.

In the **industrial** sector, thermal consumption amounted to **22.7 Mtoe** and mainly derived from the use of fossil fuels. The rest (around 19 %) consisted of derived heat, including self-produced heat from cogeneration. The highest energy consumption in industry is by **refineries** and **ceramics** and **glass works**, followed by iron and steel plants and the chemical and petrochemical industries.

Density of residential consumption for winter heating and domestic hot water production. Year 2013



Breakdown of consumption in 2013 in the sectors examined in this study, between the part used for heating and cooling (in red) and the part put to other uses (grey) (data in ktoe)



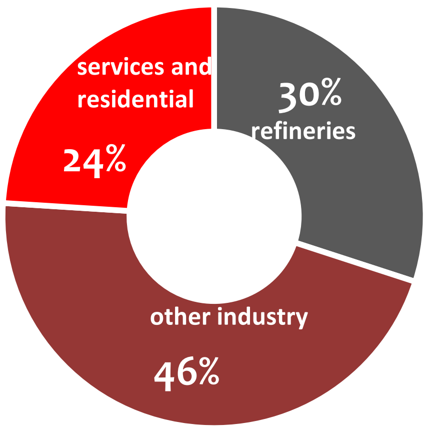
Climitazzione invernale e produzione ACS su superficie sezione (kWh/mq)	Winter heating and domestic hot water (DHW) production in the census zone area (kWh/m²)
Fino a	Up to
Oltre	Above

Agricoltura (Risc.)	Agriculture (heating)
Industria (Non Risc.)	Industry (non-heating)
Residenziale	Residential
Servizi	Services
Altro	Other

Supply of thermal energy

At the end of 2013, Italy had **total installed electrical capacity of 128.4 GW**, including 79.2 GW (62 %) consisting of thermal power stations (fossil fuels, geothermal, bioenergy and waste), with **23.2 GW from CHP plants**. **Gross electricity production totalled 290 TWh in 2013,** of which 192 TWh was from thermal power plants, including **91 TWh generated by CHP plants.** Between 1990 and 2007, CHP plants in Italy increased their output from 16.6 TWh to 107.6 TWh. In recent years, the trend has been fluctuating, peaking in 2010 and then dropping in 2013 back to 2005 levels.

Sectors using heat generated by high-efficiency cogeneration plants in 2013



High-efficiency cogeneration

The number of thermal power plants classed as **high-efficiency cogeneration plants**[1] totalled 1 025, with an electrical capacity of **13.1 GW** and high-efficiency cogeneration of electricity and heat of **26.1 TWhe** and **31.3** TWht respectively.

With regard to the **sectors using high-efficiency CHP**, the heat generated was used as follows: **76 % by the industrial sector** (30 % refineries and 46 % other manufacturing industries); and **24 % by the residential and service sectors**, mostly via **district heating** infrastructure. The industrial sector is therefore the largest end user of high-efficiency CHP solutions, particularly for **refineries**, **basic chemicals** and **petrochemicals** and **paper**.

District heating

In **2013**, the thermal energy fed into **district heating** networks amounted to **11 375 GWh**, while the **thermal energy supplied to customers amounted to 9 600 GWh. Losses** during heat distribution came to **1 774 GWh** (**16 % of the energy** fed into the grid). By contrast, the cooling energy supplied to users via district heating networks was very low, at just 102 GWh. The existing district heating networks are **almost exclusively found in northern parts of the country**. Of these, 68 % are

[1] The number of units, total generation capacity and gross electricity output refer to the total number of units which applied to GSE for recognition as high-efficiency units. The electricity produced in high-efficiency cogeneration and cogenerated useful heat refer only to the units which met the requirements for high-efficiency CHP.

located in three Regions (**Piedmont, Lombardy, Trentino-Alto Adige**) where **81 % of the thermal energy from district heating** is located.

The thermal energy produced by the plants serving the district heating networks is **80 % derived from fossil fuels** and the remaining **20 % from renewables** (including in both cases the respective share of waste). A fairly large number of the smaller **networks are supplied predominantly by renewables**; these make up **60 % of the total existing networks**.

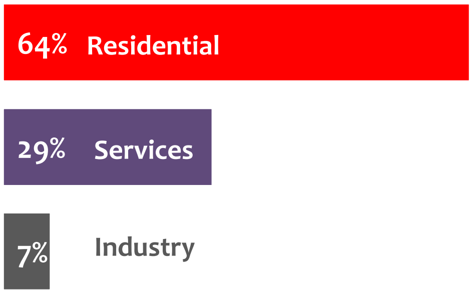
Most of Italy's existing district heating systems already comply with the efficiency requirements laid down by Directive 2012/27/EU. Today, only 24 % of networks, producing about 29 % of the energy supplied to district heating networks, do not currently meet the high-efficiency requirements laid down by the Directive.

A total of 95 % of the energy delivered through district heating networks is used for space heating and DHW production; only 5 % is delivered for the production of process heat in the industrial sector.

Heating demand in the residential sector has proved to be the **determining factor** to date for the development of existing district heating networks, considering that:

- **64 % of the energy supplied** by DH networks goes to the **residential** sector;
- 1 % of the existing networks only supply negligible energy to the residential sector;
- 98 % of the energy supplied by DH networks is located in areas with colder winters (climate condition areas E-F).

Use of heat supplied by DH networks for heating



Methodology and assumptions used for analysing the potential of high-efficiency cogeneration

The potential for developing high-efficiency cogeneration has been assessed by analysing the characteristics of the demand for and supply of thermal energy for the residential, service and industrial sectors as described in subsequent chapters.

- **For each sector, demand points** with similar energy requirements were grouped together. The heat and power requirements of individual demand points and of the group as a whole were then measured.
- **For each typical demand point, the high-efficiency CHP plants currently in operation were characterised** to identify the current degree of penetration, plant specifications and typical operating parameters.
- **By calculating the correct plant size for each typical demand point and simulating their operating conditions**, the **proportion of heating and power demand that could be supplied by cogeneration plants** was identified. This **technical potential** for the development of cogeneration is intended as a 'theoretical maximum', since it does not take into account the economic and financial aspects.
- **Based on the legislation in force and current market trends** (technology costs, commodity prices, tariff mechanisms, existing support systems, etc.), an **economic analysis** of the hypothetical cogeneration plants was carried out. Using the net present value (NPV) and internal rate of return (IRR), a **feasibility rate** was defined for each

initiative, ranging from 0 % for a negative NPV to 100 % for initiatives with an IRR of more than 15 %. To calculate NPV, a weighted average cost of capital (WACC) of 5 % was considered. For initiatives with an intermediate IRR of between 5 % and 15 %, the feasibility rate was assumed to range between 0 % and 100 %. The **economic potential of** high-efficiency cogeneration was thus determined by **multiplying the feasibility percentage by the technical potential** described above.

- The results of the technical and economic potential of high-efficiency cogeneration 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 sectoral level.**

The resulting economic potential should be interpreted as probabilistic, partly because the estimates, while having a rational basis (assuming that the user seeks the maximum economic efficiency in energy supply), completely ignore certain **non-technical factors and barriers which are not purely economic** (availability of funding, industrial and management policies, decision-making processes, permits, bureaucratic procedures, etc.) and which can significantly reduce (or indeed improve) the feasibility of the project.

The assessment of the technical and economic potential was accompanied by an **assessment of the benefits**, such as **primary energy savings** and **greenhouse gas (GHG) emission savings**, associated with the development of the potential of high-efficiency CHP. Furthermore, in compliance with the provisions of Legislative Decree No 102/2014 and Directive 2012/27/EU, the analysis of the technical and economic potential of high-efficiency CHP has **taken into account the scenarios for development of heat demand over the next 10 years**, examining how sectoral variations in consumption can influence the assessment of high-efficiency CHP potential.

Potential for HE CHP in the residential sector

The **development of high-efficiency CHP in the residential sector to date,** albeit with a sizeable number of installations (estimated at 163 units or 16 % of the total high-efficiency CHP units installed in Italy) is **somewhat low** in terms of energy output. The installed electrical capacity amounts to **4.7 MWe**, equivalent to just **0.03 % of the total high-efficiency CHP capacity** installed in Italy, while cogenerated heat is just under 10 GWh and covers only **0.003 % of 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** and **short-lived**, with strong **load fluctuations over time** and possible **time mismatch between demand for heat and for power**.

In addition, residential customers mainly require the installation of micro-CHP installations (< 50 kW), which have **not yet achieved economies of scale making them fully competitive under the current market conditions.** This has a significant impact on the 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 the **poorer electrical performance compared with larger-sized systems**. This prevents the production of electricity at competitive costs vis-à-vis the prices on the electricity market, forcing plants to generate electricity only where self-consumption or net metering are possible.

From a pricing perspective, micro-CHP systems in the civil sector may be eligible for a **higher reduction in excise duty** than other sectors. The schemes supporting high-efficiency CHP systems, in particular **white certificates**, despite including **elements designed to increase the premium** for small-size installations, are unable to offset the higher investment and operating costs. Lastly, the recent legislation on efficient systems for demand points means that in multi-apartment buildings, the electricity demand point of a cogenerator serving the entire building **can only serve the common services** (such as lifts, common area lighting, electrical consumption of the heating system, etc.) and cannot serve electricity use of individual dwellings, since these are classed as different consumption units from the common demand point. This significantly restricts electricity demand, **creating a strong imbalance between the thermal and electrical load**, and is thus unsuitable for CHP solutions. Thus, this framework **restricts to a significant degree electricity self-consumption**, which is one of the main economic drivers for the sector.

Although the possible areas of application of **micro-CHP systems** suggest a significant technical development potential, **the economic analysis of these applications yielded negative results. This effectively rules out – in the current market and regulatory framework – any substantial growth in installed high-efficiency CHP capacity in the residential sector**.

Potential for HE CHP in the service sector

The survey of **high-efficiency CHP plants in operation in the service sector** revealed the existence of around 200 units with an overall electrical capacity of **287 MWe**, roughly equivalent to 20 % of the total number and **2.1 % of the electrical capacity of all high-efficiency CHP plants** in operation in Italy. In terms of output, the useful heat and electricity produced by CHP systems cover around **1 % of the heat and power demand of the service sector**.

The high-efficiency CHP applications with the **highest capacity** are found in the **hospital** and **airports** sectors, where approximately 80 % of service sector capacity is installed. By contrast, the **highest number** of applications are found in **healthcare**, **sports facilities** and **hotels**, which account for around 75 % of high-efficiency CHP installations.

Based on an analysis of existing plants and the characterisation of heating demand in the various service subsectors, **typical demand points with a high demand for heat combined with significant electricity consumption were selected, such as hospitals, sports facilities and hotels**. These customers tend to have **high demand for heat throughout the year**, not only in the winter months, resulting in high hours of operation of the CHP system and therefore a faster return on investment.

The results obtained from the analysis of the economic potential show **interesting growth margins for high-efficiency CHP in the service sector**. The high-efficiency CHP systems installed in **large healthcare facilities** (hospitals, clinics, care homes, etc.) and in **sports facilities (with swimming pools)** are found to be particularly profitable. The **high NPV and IRR** suggest that all the economic conditions for investing in such solutions are met. For **large hotels**, the results of the economic simulation are less clear-cut: the positive NPV and an IRR of 9 % suggest **moderate cost-effectiveness**; thus differences between individual hotels (e.g. borrowing conditions, differences in energy demand, etc.) can determine **whether or not each project is cost effective.** For small medical facilities and hotels, however, the results of the economic simulation were rather unfavourable. This would suggest that the technical and economic conditions are not conducive to the development of high-efficiency CHP applications in the current market and regulatory environment.

Overall, the **incremental economic potential** for the development of high-efficiency CHP is estimated in the service sector to be **5.8 TWht** and **4.1 TWhe** in terms of heat and power, and about **1.1 GWe** in terms of electrical capacity. The economic growth potential of high-efficiency CHP is **considerable when compared with the existing scenario in the service sector** (more than triple). At the same time, it is **relatively low when compared with all high-efficiency CHP plants in existence**, indicating growth of 8 %.

As for the potential benefits associated with realising this potential, the estimated **primary energy savings are 259 ktoe**. This would mean a **reduction of around 1 % in primary energy consumption in the sector**. The proposed high-efficiency CHP solutions would reduce CO_2 emissions by almost 30 % compared to the baseline (production using gas boilers and drawn from the electricity grid). Overall, **the CO_2 savings** achievable by realising the estimated incremental economic potential come to around **0.96 $MtCO_{2eq}$, or 3 % of the greenhouse gas emissions of the entire service sector in 2013**.

Potential for high-efficiency CHP in the industrial sector

The industrial sector **has largely been responsible for the development of high-efficiency CHP in recent years**. In 2013, approximately 283 units were present with an installed capacity of **8.77 GWe**. This corresponds to cogenerated heat and power of **23.2 TWht and 18.3 TWe** respectively, representing in energy terms **about 70 % of all national high-efficiency CHP plants** and **approximately 10 % of heat and power consumption in the industrial sector**.

The results obtained from an assessment of the **development potential of high-efficiency CHP are extremely mixed, depending on the industrial sector in question.** Some of the more **energy-intensive sectors** (e.g. refineries, iron and steel, pulp and paper), where there is a considerable advantage in investing in self-producing high-efficiency CHP plants, **seem to have already saturated much of the technical development potential**. This saturation of potential is **more apparent for power than for heat**. There are a number of reasons for this:

- the **most energy-intensive industries have already invested in self-producing CHP installations for several years now**, with the aim of reducing energy costs;
- the CHP system's H/E ratio tends to **favour electricity** for technical and economic reasons, on account of the **higher price of electricity** and the **easier management of surplus electricity production rather than surplus heat**. This is due to the possibility of feeding surplus electricity into the grid, which in the past also benefited from generous feed-in tariffs;
- over the years, some energy-intensive industries have developed **diversified business lines** that include the **wholesale of electricity** among their core operations;
- some energy-intensive industries affected by the economic crisis have a large amount of **capacity** that in recent years has been **under-utilised**, and which indirectly also covers the scope for growth of other industrial operations in the same sector.

For these sectors it might be possible, **at the end of the useful life of the assets**, to convert some of the plants to **reduce electrical capacity and increase heat recovery**. Possible options include converting condensing combined cycles into counter-pressure combined cycles, or even simple turbogas plants, and of condensing steam cycles into counter-pressure cycles.

Other **less energy-intensive sectors** (food, mechanical engineering, production of building materials, textiles, timber, rubber and furniture production) technically still offer the **growth potential of high-efficiency CHP, although this is not always as cost effective**.

The **incremental economic potential** for heat and power from high-efficiency CHP in the industrial sector is estimated to be **10.9 TWht and 8.4 TWhe** respectively, and about **2.3 GWe** in terms of electrical capacity. This potential is mainly concentrated in the **food sector** (in almost all of its various subsectors), in the **manufacture of building materials** (mainly in ceramics industries), and in the **chemical and petrochemical** sectors.

As for the potential benefits associated with realising this economic potential, the estimated **primary energy savings are 636 ktoe**. This would translate as a **reduction of around 1 % in primary energy consumption** in the sector, with **CO_2 savings of 2.2 $MtCO_{2eq}$, or about 2 % of the GHG emissions of the entire** industrial sector in 2013.

Methodology and assumptions used for the analysis of DH potential

The potential for efficient district heating was analysed by **mapping heat demand**, identifying the **areas technically suitable for district heating**, or those with a **linear heat density able to justify the infrastructure investment.**

The results obtained provide an overall indication of the development potential of efficient district heating, based on the following sources:

- use of **natural gas cogeneration in the areas served by methane pipelines;**
- use of **wood biomass in areas not served by methane pipelines;**
- **waste-to-energy systems**, in accordance with the Prime Ministerial Decree of 10 August 2016.

The analysis, carried out at a municipal level, verified the economic feasibility of the investments, assessing the costs and revenues associated with the development and operation of the network and systems by a potential investor, assuming that the sales price to the end customer would be competitive with the price of the replaced fuel (gas or LPG in areas not served by methane pipelines).

The cost-effectiveness of the initiatives was analysed on the basis of the net present value (NPV) of each network, considering a **30-year valuation period** and assuming a weighted average cost of capital (WACC) of 5 %. The economic potential was obtained by selecting only projects with **positive NPV**. Moreover, a **cost-effectiveness percentage 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. The hurdle rate was set at 5 % in the event of extension of an existing district heating network, and at 7 % in the case of development of an entirely new infrastructure. In cases with an IRR between the hurdle rate and the 15 % threshold, the share of cost-effectiveness was determined proportionally.

Since the revenues from district heating networks have been set on the basis of the reference prices of heat in the residential sector with conventional solutions (via ad hoc equivalence formulas), **assessment of the cost-effectiveness for investors can be used at least partly to assess cost-effectiveness for final users**.

The results of the analysis must be interpreted as providing an **overall view** and are useful for identifying the most cost effective initiatives through a comparative assessment. Clearly, 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 cost-effectiveness of efficient district heating infrastructure is very sensitive, not only to **urban characteristics** and the **local heat demand intensity**, but also to the wholesale and retail **prices of the different fuels**.

Since district heating infrastructure has a particularly long useful life, special care must be taken when considering the results of the economic potential assessment: the results are based on a snapshot of the current situation, both in terms of energy prices and the cost and performance of the technology, which is then roughly extrapolated over the next 30 years. In addition, such an extended timeframe could be affected by long-term changes in energy consumption, caused by factors such as increased energy efficiency, the electrification of consumption and the marketing of new technologies.

Potential for DH from natural gas cogeneration

Regarding the **economic development potential of district heating from natural gas cogeneration, feasible in Municipalities served by methane pipelines**, the average value of the annualised cost of heat generation, supplied by cost effective networks, is 71 €/MWh, compared with an estimated retail price of 94.8 €/MWh. This **margin**, which includes capital expenditure, operating costs and financial charges, is strongly influenced not only by the **gas prices charged to domestic customers**, but also by the **different tax rates** (reduced VAT of 10 % is applied to DH from high-efficiency CHP and renewable sources for residential customers) and **excise duties** (the excise duty on industrial use applied to DH is lower than the excise duty on municipal use charged to residential gas customers).

In view of the long useful life considered for this type of infrastructure, a strong correlation exists between cost-effectiveness and the retail price of natural gas, with which DH competes, and changes in the volume of consumption by connected customers. Furthermore, the potential identified should be compared with alternative methods of meeting heat demand (e.g. heat pumps or heating systems that run on renewable energy) which might be more cost effective than district heating.

By applying 2014 prices, the **economic potential for DH using high-efficiency gas cogeneration is 8.1 TWh**, representing a **potential increase of 1.2 TWh compared to the 6.9 TWh of annual heat supplied to customers of DH gas cogeneration plants in 2013**.

Potential for district heating from biomass

As to the **economic potential for the development of DH networks using biomass** in municipalities not served by methane pipelines, the average value of the annualised cost of supplying heat to customers was calculated to be 103 €/MWh, against an average retail price of the heat supplied of 140.1 €/MWh. This **margin**, which includes capital expenditure, operating costs and financial charges, is strongly influenced by the **high sales price of LPG for heating**, the **lower procurement cost of biomass** and the **different tax rates** (reduced VAT of 10 % for DH from high-efficiency CHP and renewables for residential customers).

The **availability of local, inexpensive biomass** is crucial for the economic viability of DH, together with the future trend in consumption by connected customers, given the long useful life of the infrastructure.

The theoretical cost of biomass of 20 €/MWh is based on the average annual value recorded in 2014 by the Chamber of Commerce of Milan for virgin wood chips with bark for industrial use, from forest management (moisture in the product at source 45 %; Lower Heating Value (LHV): 2.5 MWh/t).

By applying 2014 prices, the **economic potential for DH using biomass is 1.6 TWh**, representing a **potential increase of 0.7 TWh compared with the 0.9 TWh of annual heat supplied to customers of DH biomass plants in 2013.**

Potential for district heating from waste

To assess the role of waste in the growth potential of DH, it is also important to estimate its availability for incineration in the near future, since this is quota-based. To this end, the analysis of the technical potential for district heating fuelled by waste is based on the authorised treatment capacity for existing and planned incinerators. This amounts to 8.4 million tonnes of waste, with an estimated input energy content of 25.6 TWh.

Based on the authorised capacity, the **potential contribution of recoverable heat from waste incineration for the purpose of district heating was estimated at 3.2 TWh**, equivalent to an **increase of 2 TWh** of heat delivered to customers, compared with 1.2 TWh in 2013.

Potential increase in the efficiency of existing DH networks

The **heat losses during heat distribution by district heating networks in 2013** amounted to 1.77 TWh, equivalent to **16** % of the heat supplied to the networks.

If each network were upgraded to the best heat distribution efficiency in accordance with the European Commission's guidelines, network losses could theoretically be limited to **10** %. The reduction of losses in the existing networks would yield a **saving of 684 GWh of heat**.

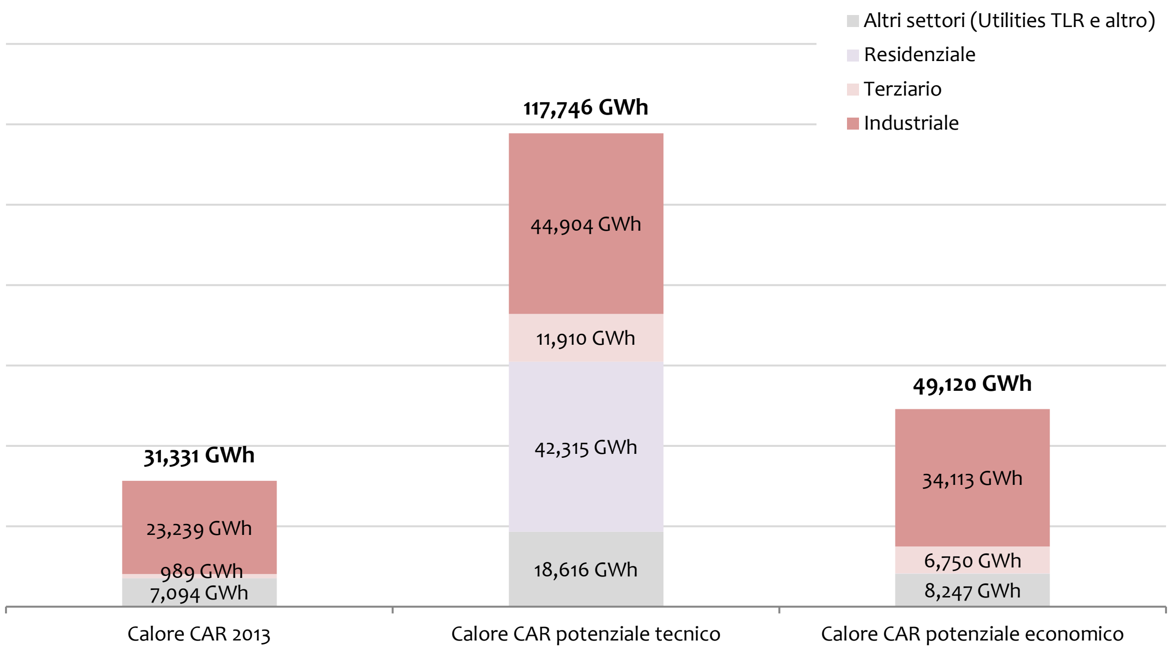
Total heat losses from heat distribution in DH networks

Summary of the results of the development potential of high-efficiency CHP and DH

The economic potential of high-efficiency CHP was found to be, given the current market and regulatory conditions, 49.1 TWh (4 224 ktoe) of useful heat. Compared with the overall production of useful heat from high-efficiency CHP in 2013, equivalent to 31.3 TWh (2 694 ktoe), the potential increase is 17.8 TWh (1 529 ktoe).

Of this increase in useful heat from high-efficiency CHP, 61 % is linked to self-producing high-efficiency CHP plants in the industrial sector (10.8 TWh), 32 % from high-efficiency CHP plants in the service sector (5.8 TWh), and 6 % (1.2 TWh) from high-efficiency CHP plants operated by energy utilities involved in district heating. The residential sector has no economic potential under the current market conditions and cost of the technologies.

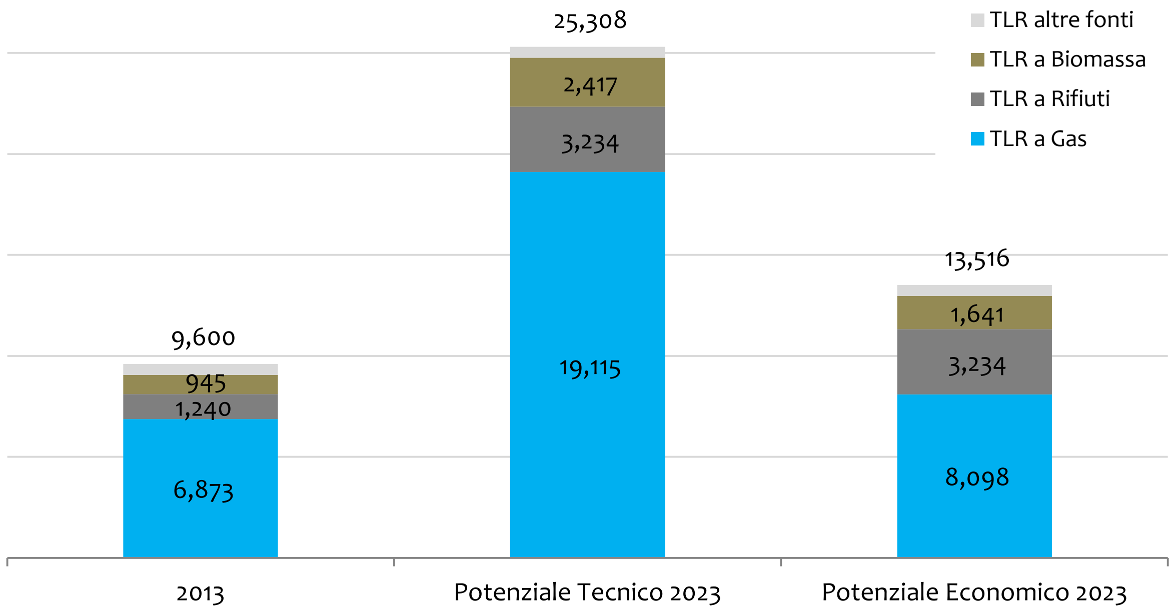
Comparison of the current level of useful heat production from high-efficiency CHP (2013) and its technical and economic potential by sector of use



Altri settori (Utilities TLR e altro)	Other sectors (DH Utilities and other)
Residenziale	Residential
Terziario	Services
Industriale	Industrial
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

In the district heating sector, the economic potential was determined to be 13.5 TWh (1 160 ktoe). Compared with the heat supplied by DH in 2013, which amounted to 825 ktoe, the potential increase through efficient district heating is estimated to be 335 ktoe. This potential increase in energy from district heating is based on the production of heat from natural gas, which contributes 1 225 GWh (or 105 ktoe, of which 84 ktoe from cogeneration), biomass exploitation, which contributes 696 GWh (60 ktoe), and waste-to-energy, which contributes a further 1 994 GWh (171 ktoe).

Figure 1 Comparison between the current level of energy supplied by DH (2013) and its technical and economic potential by source [GWh]



TLR altre fonti	Other sources DH
TLR a Biomassa	Biomass DH
TLR a Rifiuti	Waste DH
TLR a Gas	Gas DH
Potenziale tecnico	Technical potential
Potenziale economico	Economic potential

Introduction

Article 14 of Directive 2012/27/EU on energy efficiency provides that by 31 December 2015, Member States are to carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling.

Article 10 of Legislative Decree No 102 of 4 July 2014, which implemented Directive 2012/27/EU, provides that the Energy Services Operator (Gestore dei Servizi Energetici - GSE) is to prepare and submit to the Ministry of Economic Development a report containing said assessment, taking the year 2013 as the baseline for the assessment.

The information to be supplied in the report is listed in Annex 3 to the Decree. In particular, the study must include:

- a description of the demand for heating and cooling and its projected evolution up to 2023;
- maps showing the heating and cooling demand areas, in particular municipalities and urban areas with a plot ratio of at least 0.3 and industrial areas with total annual energy consumption for heating and cooling in excess of 20 GWh;
- a map of the existing and planned district heating and cooling infrastructure;
- a map of the supply of heating and cooling, in particular electricity generation installations with a total annual electricity output of more than 20 GWh, waste-to-energy plants and existing and planned cogeneration installations;
- assessment of the demand for heating and cooling which can be met by high-efficiency CHP, high efficiency micro-CHP and efficient district heating and cooling;
- identification of the potential for increasing high-efficiency CHP, by modernising industrial and power-generation installations or other plants producing waste heat, or by constructing new installations;
- identification of the potential energy efficiency of district heating and district cooling infrastructure;
- an estimate of possible primary and GHG emission savings.

This report describes, for the year 2013, overall demand by sector, providing further details on the individual demand components that could be satisfied by efficient district heating or high-efficiency cogeneration installations (chapter 1). The description of heat demand is accompanied by maps providing information on climate condition areas, municipalities with a suitable plot ratio (>0.3), energy consumption for heating and for the production of domestic hot water (DHW) and on industrial sites categorised by consumption classes.

The report then provides an overview of the national supply of heat (chapters 2, 3 and 4). The study opens with a description of Italy's thermoelectric mix in 2013, then focuses on cogeneration plants, especially high-efficiency CHP, describing the most widely used technologies and sectors served (chapter 2). Understanding of the analysis of thermoelectric plants, cogeneration plants and high-efficiency CHP is assisted by maps showing their distribution in Italy, with details on installed capacity, types, sources and technologies used.

The current status of existing district heating and district cooling infrastructure is described, with an analysis of sectors of use, sources used and geographical distribution. Maps are included, with details of the heat supplied, sources used and the efficiency of existing networks (chapter 3).

After in-depth analysis of cogeneration and district heating, an overview is provided of the direct uses of heat sources by households and businesses (chapter 4). Moreover, an estimate is provided of the annual theoretical availability of biomass and waste heat from industrial processes for heat generation.

Lastly, the potential increase in high-efficiency cogeneration and efficient district heating is assessed (chapters 5 and 6).

Assessment of the growth potential of high-efficiency CHP was based on analysis of the demand for heat and electricity by the residential, service and industrial sectors, at the greatest level of detail in terms of geographical distribution and uses. The potential for high-efficiency CHP was analysed by assessing the possible applications in each use sector on the basis of the characterisation and geographical location of the different types of customers. For each type of customer identified, specific technical and economic feasibility criteria were applied. Each sector – residential, services and industrial – was addressed separately, in the light of the substantial differences.

Assessment of the growth potential of district heating is based on a detailed estimate of the demand for thermal energy by sector, type of use and geographical zone, and on parametric estimates, derived from analysis of district heating networks in Italy. Starting from that information, heat demand was characterised at municipality level by sector and type of use, and the share of demand currently covered by district heating networks was assessed. The potential development of district heating was then estimated, in light of the main technical and economic factors influencing its uptake.

As required by Article 10(1) of Legislative Decree No 102/2014, the study was divided geographically by Regions and Autonomous Provinces.

The report is accompanied by a summary of the policies and targets established for cogeneration and district heating, and by an overview of the incentive schemes promoting their development and uptake. Lastly, a detailed survey is made of the Region's Energy and Environmental Plans (Piani Energetico-Ambientali Regionali – PEAR) and of the other Regional acts setting out development scenarios and policies promoting the spread of high-efficiency cogeneration and district heating and district cooling.

1 The demand for heating and cooling

1.1 Introduction

This chapter describes the heat demand of Italian households and businesses in the year 2013, in the context of the national energy system.

The survey is based on the official statistical data published each year by Eurostat on consumption by sector. These data are used to calculate energy consumption by type of use (space, production of domestic hot water, cooking, process uses and other uses), which is further broken down by geographical area.

The data analysis required was extremely complex because, unlike electricity generation, which is a well-established statistical field, the data on heat generation in Italy to date is far patchier: it is often not measured and is in any case harder to measure (consider for example direct biomass consumption in the residential sector in boilers, fireplaces, etc.). As a consequence it was necessary to derive through various calculations final consumption for heating and cooling by sector (heating, DHW, process heat, cooling) relying on Eurostat data, ENEA RAEE-PAEE indicators, RdS studies and ISTAT data.

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

The report opens with a description of overall heat demand; it then provides details on the individual areas of the greatest interest for this study, i.e. those that can be served by efficient district heating systems or high-efficiency cogeneration plants.

1.2 The national energy balance

In 2013, the gross domestic consumption of energy in Italy came to 160 Mtoe, including more than 6 Mtoe of non-energy uses. The national production of primary sources covers about 23 % of domestic consumption and is mainly made up of renewable sources (23.5 Mtoe), followed by gas (6.3 Mtoe) and petroleum (5.85 Mtoe).

As to breakdown by type of use, more than 120 Mtoe are employed in processing. After processing losses of 24.85 Mtoe, 96 Mtoe of secondary sources are generated, consisting mainly of refined petroleum products (almost 71 Mtoe), electricity (17 Mtoe) and derived heat (5.2 Mtoe).

Final energy uses amount to 118.7 Mtoe (from the use of those primary sources that are not processed further and of secondary sources). The greatest consumption is in transport (32.6 %), followed by the residential sector (28.8 %), industry (22.7 %), services (13.4 %) and agriculture (2.3 %).

Table 1 – Summary energy balance of Italy, 2013 (data in ktoe)

ktoe	All products	Solid fuels	Oil products	Gas	Renewables	Wastes (non ren.)	Derived heat	Electricity
+ **Primary production**	**36 868**	**46**	**5 849**	**6 335**	**23 500**	**1 138**	**0**	**0**
+ Net import	124 723	13 461	54 150[2]	50 564	2 925	0	0	3 623
+ Stock changes	595	486	-326	488	-54	0	0	0
- Bunkers	2 179	0	2 179	0	0	0	0	0
Gross inland consumption	**160 007**	**13 994**	**57 495**	**57 387**	**26 371**	**1 138**	**0**	**3 623**
Transformation input	**120 888**	**13 273**	**75 542**	**21 008**	**10 207**	**857**	**0**	**0**
+ Conventional Thermal Power Stations	47 007	10 559	4 517	21 008	10 065	857	0	0
+ District heating plants[3]	127	0	0	0	127	0	0	0
+ Refineries	71 025	0	71 025	0	0	0	0	0
+ Other (Coke-ovens, Blast furnaces..)	2 728	2 714	0	0	15	0	0	0
Transformation output	**96 034**	**1 805**	**70 968**	**1 004**	**7**	**0**	**5 169**	**17 081**
+ Conventional Thermal Power Stations	22 160	0	0	0	0	0	5 079	17 081
+ District Heating Plants	90	0	0	0	0	0	90	0
+ Refineries	70 968	0	70 968	0	0	0	0	0
+ Other (Coke-ovens, Blast furnaces..)	2 816	1 805	0	1 004	7	0	0	0
Exchanges and transfers, returns	**-51**	**0**	**-51**	**0**	**-7 675**	**0**	**0**	**7 675**
+ Interproduct transfers	0	0	0	0	-7 675	0	0	7 675
+ Returns from petrochem. Industry	-51	0	-51	0	0	0	0	0
Consumption of the energy branch	**7 494**	**35**	**3 033**	**1 133**	**0**	**0**	**1 448**	**1 845**
+ Own Use in Ele., CHP and Heat Plants	945	0	0	0	0	0	1	944
+ Pumped storage power stations balance	51	0	0	0	0	0	0	51
+ Oil and Natural Gas extraction plants	835	0	0	786	0	0	18	31
+ Oil refineries (Petroleum Refineries)	4 837	0	3 033	264	0	0	1 078	462
+ Other (coke ovens, coal mines…)	826	35	0	83	0	0	351	357
Distribution losses	**2 253**	**0**	**0**	**412**	**0**	**0**	**19**	**1 822**
Final non-energy consumption	**6 339**	**130**	**5 760**	**450**	**0**	**0**	**0**	**0**
Final energy consumption	**118 696**	**2 361**	**43 757**	**35 387**	**8 496**	**281**	**3 702**	**24 712**
+ Industry	26 995	2 361	2 735	8 896	275	281	2 560	9 887
+ Transport	38 703	0	35 495	1 031	1 251	0	0	926
+ Services	15 847	0	611	7 259	171	0	154	7 651
+ Residential	34 231	0	2 709	18 073	6 759	0	931	5 760
+ Agriculture / Forestry	2 602	0	1 957	128	20	0	20	477
+ Fishing	183	0	150	0	22	0	0	11
+ Non-specified (Other)	137	0	100	0	0	0	37	0
Statistical differences	**320**	**0**	**320**	**0**	**0**	**0**	**0**	**0**

Source: elaboration of Eurostat data

[2] 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 internal consumption is lower than processing sector inputs.

[3] In this table, Eurostat associates the term *district heating plants* with simple boilers. Only consumption from renewable energy sources (RES) is shown, although the chapter on district heating shows fossil fuel consumption in boilers. This discrepancy will be corrected in subsequent years.

1.2.1 Consumption for heating and cooling

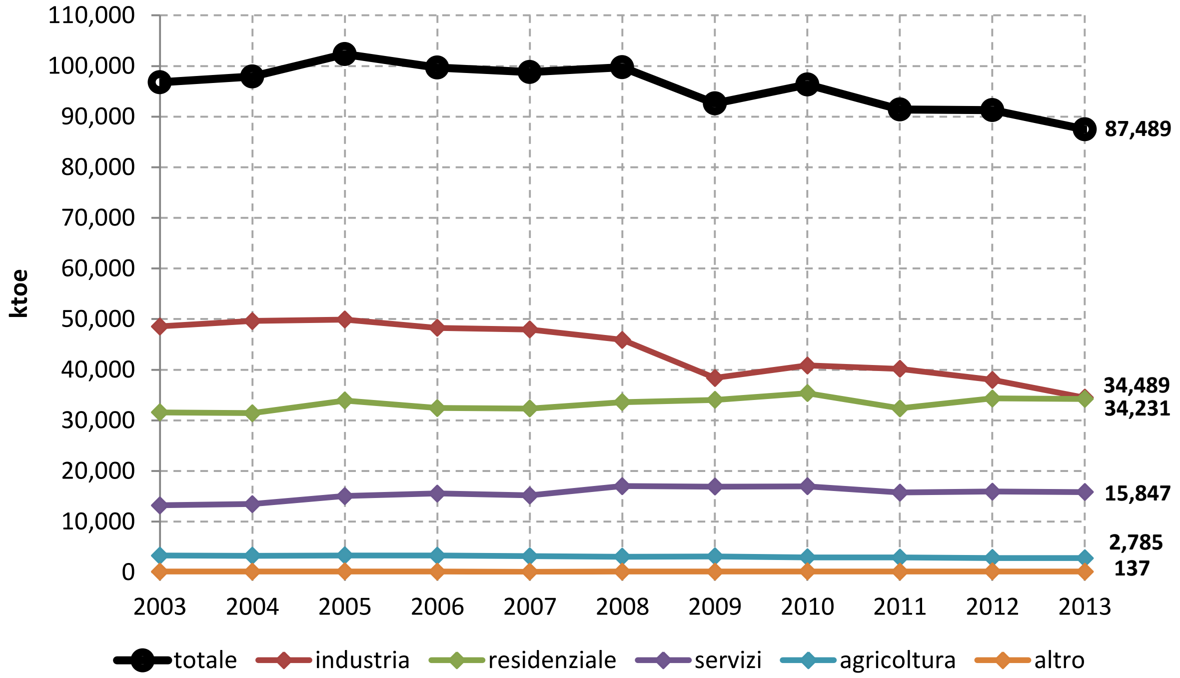
As specified in the sections covering each sector, consumption for heating and cooling is defined starting from Eurostat data on consumption in the sectors of interest, shown below. Firstly, we have selected energy consumption in the sectors covered by this study, separating the share of energy consumption for transport from total consumption, intended as the sum of the final consumption and consumption by the energy sector.

Table 2 – Energy consumption by the sectors covered by this study (ktoe)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
residential	31 590	31 425	33 922	32 424	32 340	33.612	34 041	35 393	32 378	34 348	34 231
services	13 218	13 469	15 053	15 569	15 182	17 019	16 920	16 979	15 751	15 931	15 847
industry[4]	48 553	49 631	49 910	48 282	47 973	45 904	38 372	40 841	40 193	38 001	34 489
agriculture	3 284	3 274	3 322	3 288	3 177	3 085	3 122	2 940	2 924	2 824	2 785
other	124	141	162	137	116	125	141	160	147	159	137
Total	**96 770**	**97 940**	**102 369**	**99 699**	**98 787**	**99 746**	**92 596**	**96 313**	**91 395**	**91 263**	**87 488**

Source: elaboration of Eurostat data

Figure 2 – Development of energy consumption over the 2003-2013 period in the sectors covered by this study



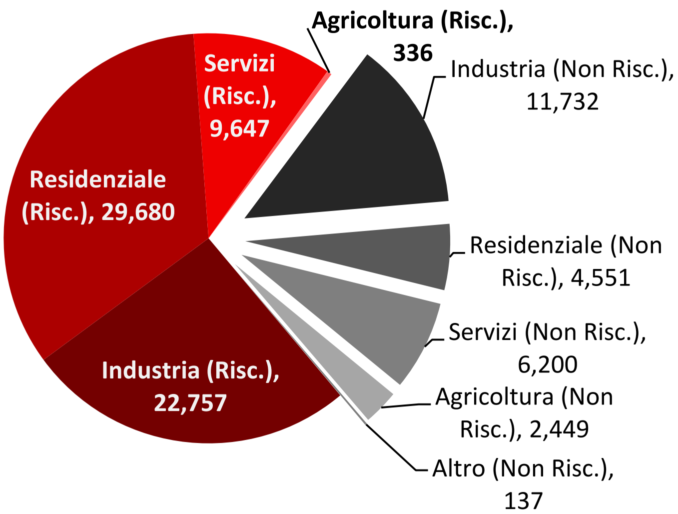
[4] Includes consumption by the energy industry. Thus, the figures include consumption by the auxiliaries of electricity generation installations and derived heat, pumping plants (specifically the difference between energy for pumping and energy generated by pumping), consumption for energy purposes (net of the consumption of raw materials) of refineries, coke ovens and hydrocarbon plants.

Totale	Total
Industria	Industry
Residenziale	Residential
Servizi	Services
Agricoltura	Agriculture
Altro	Other

The development of energy consumption shows a declining trend. In 2013, the value came to about 87.5 Mtoe, the lowest in the past ten years. The trend is mostly driven by the industrial sector, which has been declining since 2005. On the other hand, consumption by the residential sector has gone up, reaching 34.2 Mtoe in 2013, close to consumption by industry. Together, the two sectors accounted for about 80% of total energy consumption in 2013.

The consumption described above includes some components not associated with heating. Removing this share (which includes the operation of works vehicles, lighting and other electrical uses), consumption for heating and cooling in 2013 came to about 62.4 Mtoe and accounted for 71 % of total energy consumption of the sectors analysed (industry, including the energy sector, services, residential, agriculture, other). In the following chart, the total of consumption types defined herein is coloured in red. Thus, for each sector the parts in grey are excluded.

Figure 3 – Breakdown of consumption in 2013, in the sectors examined in this study, between the part used for heating and cooling (in red) and the part put to other uses (grey) (data in ktoe)



The highest share of consumption for heating and cooling (48 %) is generated by the residential sector. The next largest shares are taken up by industry (36 %) and services (15 %), while agriculture only accounts for a negligible share of consumption for heating.

Table 3 – Overall consumption by the sectors analysed and share for heating and cooling in 2013 (ktoe)

	Overall energy consumption	Consumption for heating and cooling	Distribution of energy consumption for heating and cooling
Industry	34 489	22 757	66 %
Residential	34 231	29 680	87 %
Services	15 847	9 647	61 %
Agriculture	2 785	336	12 %
Other	137	0	0 %
Total	**87 489**	**62 420**	**71 %**

The preceding table shows that the residential sector makes up most of the consumption (87 %) for heating and cooling as previously defined.

Table 4 – Consumption for heating and cooling in Italy in 2013, by source (ktoe)

	petroleum products	natural gas	coal	electricity	derived heat	renewable sources and waste	Total
residential	2 709	18 073	0	1 209	931	6 759	29 680
services	612	7 259	0	1 451	154	171	9 647
industry	5 768	10 030	2 396		4 008	556	22 757
agriculture	146	128			20	42	336
Total	9 235	35 490	2 396	2 660	5 113	7 527	62 420

As for the sources used for heating and cooling, the main one is natural gas (57 %), followed by petroleum products (15 %) and by renewable energy sources (12 %).

The data do not include the renewable thermal energy supplied by heat pump equipment. To date, this energy, which is the difference between the total thermal energy supplied by the systems and that needed to operate them, is not calculated in ordinary energy statistics. At Eurostat level however, the option of considering it is being explored, by including ambient heat among renewable energy sources.

Note that the share of heating and cooling consumption on which this study focuses does not coincide with the total demand presented in the preceding tables. This is because it is assumed that a certain share of the demand for heating and cooling cannot be covered by district heating or cogeneration systems, for reasons explained in the following sections. The following graph illustrates the successive stages in identifying demand for the purposes of the study. Specifically, 'non-thermal' components of consumption are shown in grey, thermal components that are not relevant are shown in orange, and demand for heating – on which all subsequent analysis will be carried out – is shown in green.

Figure 4 – Breakdown of consumption in 2013, in the sectors examined in this study, between the relevant part used for heating and cooling (in green), the non-relevant part used for heating and cooling (orange) and the part put to other uses (grey) (data in ktoe)

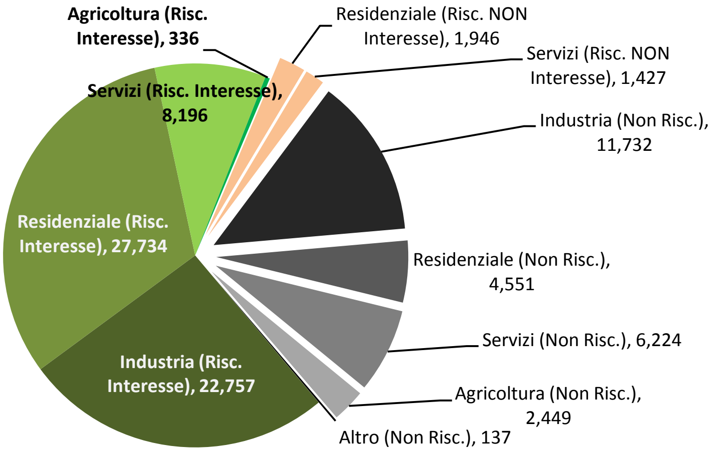


Table 5 shows that, in the sectors analysed, 67 % of energy consumption falls within the scope of this study.

Table 5 – Overall consumption of the sectors analysed and share for heating and cooling in 2013 relevant to this study (ktoe)

	Overall energy consumption	Consumption for heating and cooling relevant to this study	Relevant share of heating on the total
Industry	34 489	22 757	66 %
Residential	34 231	27 734	81 %
Services	15 847	8 196	52 %
Agriculture	2 785	336	12 %
Other	137	0	0 %
Total	**87 489**	**59 023**	**67 %**

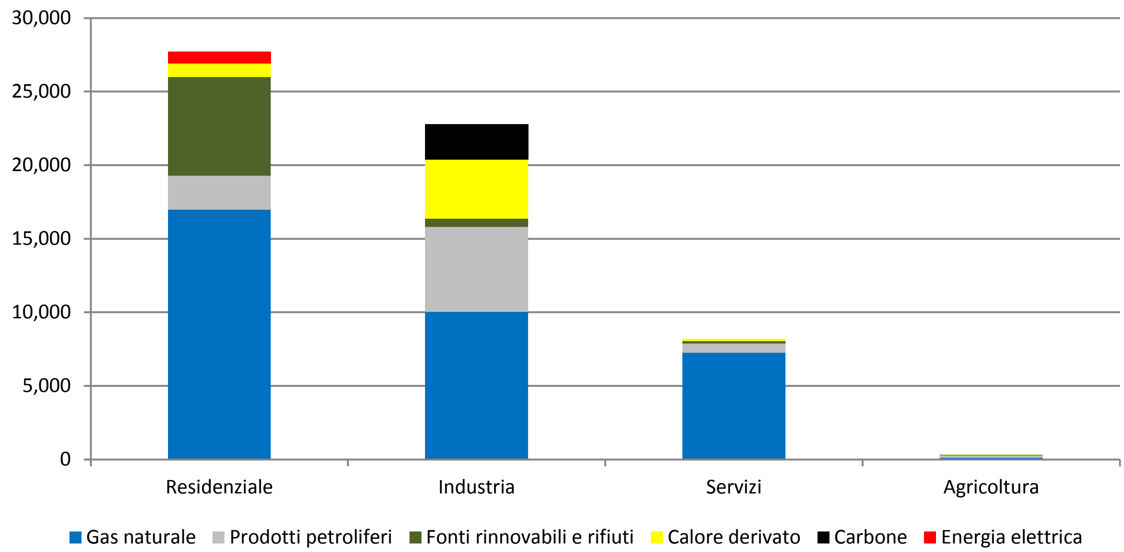
Table 6 – Consumption for heating and cooling in Italy (ktoe) relevant to the assessments made in this study

	petroleum products	natural gas	coal	electricity	derived heat	renewable sources and waste	Total
residential	2 307	16 968	0	811	931	6 717	27 734
services	611.5	7259	0	0	153.9	171.1	8 196
industry	5 768	10 030	2 396	0	4 008	556	22 757
agriculture	146	128	0	0	20	42	336
Total	8 833	34 385	2 396	811	5 113	7 486	59 023

Source: elaboration of Eurostat data

Natural gas is the energy source contributing the most to consumption of the share relevant to this report (see preceding table). Natural gas supplies 58 % of the total, 61 % in the residential sector and almost the entire amount in services (89 %). Most of the petroleum products (65 %) are used in industry, while coal and electricity are exclusive sources, respectively, of industry and the residential sector. Renewable energy sources cover 24 % of consumption by the residential sector while derived heat is mainly used by industry.

Figure 5 – Consumption in 2013 for heating, relevant to the study, broken down by sector and energy source (data in ktoe)



Residenziale	Residential
Industria	Industry
Servizi	Services
Agricoltura	Agriculture
Gas naturale	Natural gas
Prodotti petroliferi	Petroleum products
Calore derivato	Derived heat
Carbone	Coal
Energia elettrica	Electricity

1.2.2 Derived heat

The overall consumption of derived heat[5] recorded in Italy between 2003 and 2013 in the different sectors is set out in the following table.

Table 7 – Consumption of derived heat in Italy between 2004 and 2013 (data in ktoe)

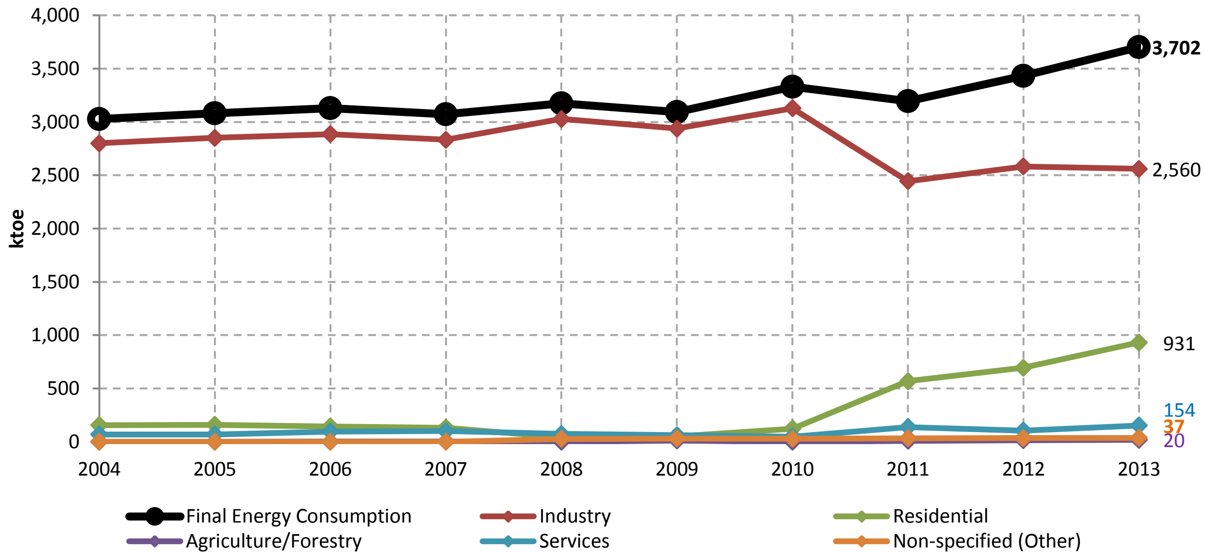
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	1 501	**1 529**	**1 861**	**1 811**	**1 564**	**1 225**	**1 573**	**2 021**	**1 491**	**1 448**
Own Use in Electricity, CHP and Heat Plants	0	0	0	0	0	0	0	1	1	1
Consumption in Oil and gas extraction	39	40	45	35	17	20	56	17	20	18
Consumption in Petroleum Refineries	613	624	986	1 004	958	1 066	953	1 105	968	1 078
Consumption in Coal Mines	0	0	0	0	0	0	0	0	2	2
Consumption in Coke Ovens	0	0	0	1	1	2	2	3	2	4
Consumption in Non-specified (Energy)	849	865	829	770	588	138	563	895	499	345
Distribution Losses	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**17**	**21**	**19**
Final Energy Consumption	**3 027**	**3 082**	**3 129**	**3 072**	**3 174**	**3 094**	**3 332**	**3 196**	**3 433**	**3 702**
Industry	2 801	2 852	2 886	2 834	3 029	2 938	3 129	2 445	2 583	2 560
Iron and Steel	50	51	6	3	5	267	38	43	125	87
Non-Ferrous Metals	0	0	0	1	1	1	0	1	1	1
Chemical and Petrochemical	1 086	1 106	1 038	1 061	1 103	1 086	1 048	1 132	909	1 243
Non-Metallic Minerals	98	100	113	97	101	74	78	84	100	108
Mining and Quarrying	11	11	21	16	11	0	0	0	0	0
Food and Tobacco	195	198	179	213	222	177	159	241	278	266
Textile and Leather	84	86	68	62	62	29	43	45	42	40
Paper, Pulp and Print	704	717	739	770	645	544	515	589	844	564
Transport Equipment	112	114	114	90	98	97	171	101	90	79
Machinery	23	23	27	22	22	18	20	24	23	15
Wood and Wood Products	15	15	40	21	32	33	29	32	32	27
Construction	0	0	0	0	0	0	0	0	0	0
Non-specified (Industry)	423	430	542	477	728	612	1 027	152	138	129
Residential	156	159	144	133	43	52	123	568	694	931
Agriculture/Forestry	1	1	2	3	1	13	1	9	16	20
Services	69	70	97	101	74	62	49	139	105	154
Non-specified (Other)	0	0	0	0	27	31	29	34	35	37

Source: elaboration of Eurostat data

[5] Derived heat is defined as heat produced in renewable and non-renewable energy plants 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.).

The final consumption of derived heat has increased by 22 % over the past ten years. The largest increase was recorded in the residential sector (almost 500 %) and in services (more than 120 %); this gain was partly offset by a decline in consumption by industry (-8.6 %). Consumption by the energy sector has remained relatively stable (-3.6 %).

Figure 6 – Trend in the period 2003 -2013 in the consumption of derived heat, by consumption sector (data in ktoe)



The following table illustrates changes in the mix of energy sources which over time have led to the production of derived heat[6].

Cogeneration systems always supply more than 98 % of the derived heat. As to sources, natural gas covers constantly 60 % of production, followed by petroleum products (21 % in 2013), mostly used by self-producers and contracting strongly (-27 % from 2004), and by renewable energy sources (16 % in 2013), which have increased significantly over the past decade (by more than 400 % from 2004).

[6] Please note that no separate data are available on production by simple boilers fed by non-renewable sources.

Table – 8 Production of derived heat (figures in ktoe)

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Heat only plants[7]	**Main activity**	**0**	**0**	**0**	**0**	**0**	**0**	**68**	**78**	**89**	**90**
	Geothermal	*0*	*0*	*0*	*0*	*0*	*0*	*14*	*14*	*16*	*16*
	Solid biofuels excluding charcoal	*0*	*0*	*0*	*0*	*0*	*0*	*53*	*64*	*74*	*74*
	Biogases	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CHP plants	**Main activity**	**1 649**	**1 735**	**1 985**	**1 991**	**1 930**	**1 837**	**2 212**	**2 604**	**2 681**	**3.079**
	Other Bituminous Coal	*38*	*34*	*46*	*37*	*13*	*0*	*18*	*30*	*29*	*30*
	Coke Oven Gas	*27*	*38*	*28*	*7*	*10*	*12*	*11*	*16*	*32*	*30*
	Blast Furnace Gas	*12*	*19*	*10*	*8*	*11*	*7*	*12*	*15*	*53*	*34*
	Other Recovered Gases	*1*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*
	Refinery Gas	*6*	*7*	*60*	*50*	*46*	*51*	*73*	*76*	*34*	*43*
	LPG (Liquefied Petroleum Gases)	*13*	*7*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Gas / Diesel Oil	*4*	*5*	*4*	*1*	*1*	*2*	*1*	*3*	*1*	*1*
	Residual Fuel Oil	*203*	*109*	*66*	*45*	*40*	*26*	*24*	*14*	*27*	*48*
	Other Petroleum Products	*61*	*28*	*161*	*175*	*170*	*180*	*187*	*148*	*151*	*252*
	Natural Gas	*1 096*	*1 256*	*1 325*	*1 464*	*1 417*	*1 384*	*1 656*	*1 639*	*1 801*	*1.828*
	Industrial Waste	*1*	*0*	*2*	*1*	*0*	*0*	*0*	*0*	*1*	*1*
	Municipal Waste (Renewable)	*47*	*65*	*96*	*61*	*67*	*48*	*55*	*83*	*70*	*83*
	Municipal Waste (Non-Renewable)	*47*	*65*	*96*	*61*	*67*	*48*	*55*	*83*	*70*	*83*
	Solid biofuels excluding charcoal	*72*	*80*	*67*	*68*	*74*	*42*	*78*	*153*	*260*	*432*
	Biogases	*23*	*22*	*23*	*11*	*13*	*15*	*19*	*322*	*132*	*195*
	Biodiesels	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Other Liquid Biofuels	*0*	*0*	*0*	*0*	*1*	*23*	*24*	*22*	*20*	*20*
	Autoproducers	**2 879**	**2 876**	**3 004**	**2 892**	**2 808**	**2 482**	**2 625**	**2 551**	**2 173**	**2.000**
	Other Bituminous Coal	*31*	*37*	*26*	*10*	*11*	*5*	*12*	*9*	*3*	*5*
	Coke Oven Gas	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Blast Furnace Gas	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	Crude Oil	*3*	*3*	*3*	*2*	*0*	*0*	*0*	*0*	*0*	*0*
	Refinery Gas	*351*	*344*	*339*	*334*	*347*	*289*	*341*	*389*	*406*	*386*
	LPG (Liquefied Petroleum Gases)	*4*	*6*	*8*	*8*	*10*	*13*	*9*	*7*	*9*	*5*
	Naphtha	*0*	*0*	*0*	*0*	*39*	*59*	*43*	*41*	*26*	*25*
	Other Kerosene	*0*	*0*	*0*	*0*	*2*	*0*	*1*	*0*	*0*	*1*
	Gas / Diesel Oil	*2*	*2*	*1*	*1*	*1*	*0*	*0*	*0*	*0*	*1*
	Residual Fuel Oil	*762*	*773*	*841*	*758*	*704*	*695*	*520*	*426*	*259*	*224*
	Petroleum Coke	*4*	*6*	*177*	*209*	*160*	*153*	*142*	*170*	*74*	*77*
	Other Petroleum Products	*65*	*44*	*57*	*52*	*25*	*25*	*99*	*109*	*97*	*10*
	Natural Gas	*1 600*	*1 630*	*1 518*	*1 488*	*1 474*	*1 195*	*1 421*	*1 361*	*1 276*	*1.243*
	Industrial Waste	*26*	*2*	*3*	*3*	*3*	*3*	*0*	*0*	*0*	*2*
	Municipal Waste (Renewable)	*8*	*6*	*7*	*5*	*7*	*8*	*7*	*3*	*1*	*1*
	Municipal Waste (Non-Renewable)	*8*	*6*	*7*	*5*	*7*	*8*	*7*	*3*	*1*	*1*
	Solid biofuels excluding charcoal	*12*	*13*	*14*	*13*	*12*	*19*	*16*	*29*	*12*	*12*
	Biogases	*3*	*4*	*3*	*6*	*3*	*5*	*5*	*5*	*6*	*6*
	Other Liquid Biofuels	*0*	*0*	*0*	*0*	*4*	*5*	*1*	*0*	*2*	*3*
Total gross production		**4 528**	**4 611**	**4 990**	**4 882**	**4 738**	**4 319**	**4 905**	**5 233**	**4 944**	**5 169**

Source: elaboration of Eurostat data

[7] The term '*heat only plants*' refers solely to production from renewables, although the chapter on district heating includes fossil fuel consumption in boilers. This discrepancy will be corrected in subsequent years.

1.2.3 Variability of consumption

This section describes some summary data showing that the consumption of energy for heating is strongly influenced by geographical factors – in particular the significant climate differences between the different areas of the country – and by seasonal factors, which diversify overall consumption between the different months of the year.

1.2.3.1 Geographical factor

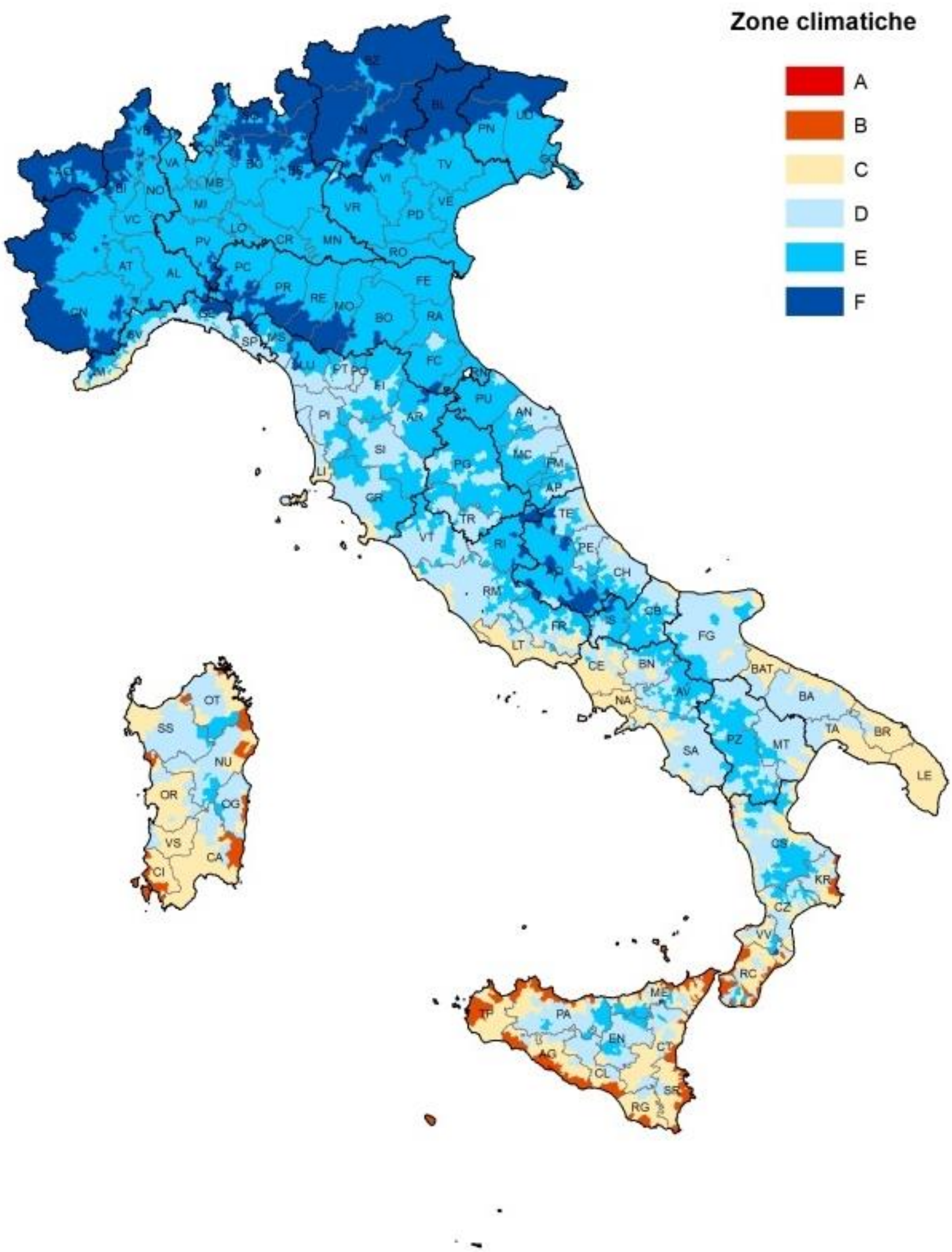
Climate conditions are well represented by the Degree Days (DD) indicator, which is defined by Presidential Decree No 412/1993 as 'the sum, extended to all the days of an annual conventional heating period, of the positive daily differences only between indoor temperature, conventionally set at 20 °C, 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 condition areas.

Table 9 – Climate condition areas defined by Presidential Decree 412/1993

Climate condition area	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 7 – National map of climate condition areas



Zone climatiche	Climate condition area

About 42 % of the Italian population in 2013 lived in Regions falling on average in climate condition area E, 25 % in zone D, 31 % in zone C and only 2 % in zone F.

Table 10 – Population of the Italian regions as at 31 December 2013 and climate conditions

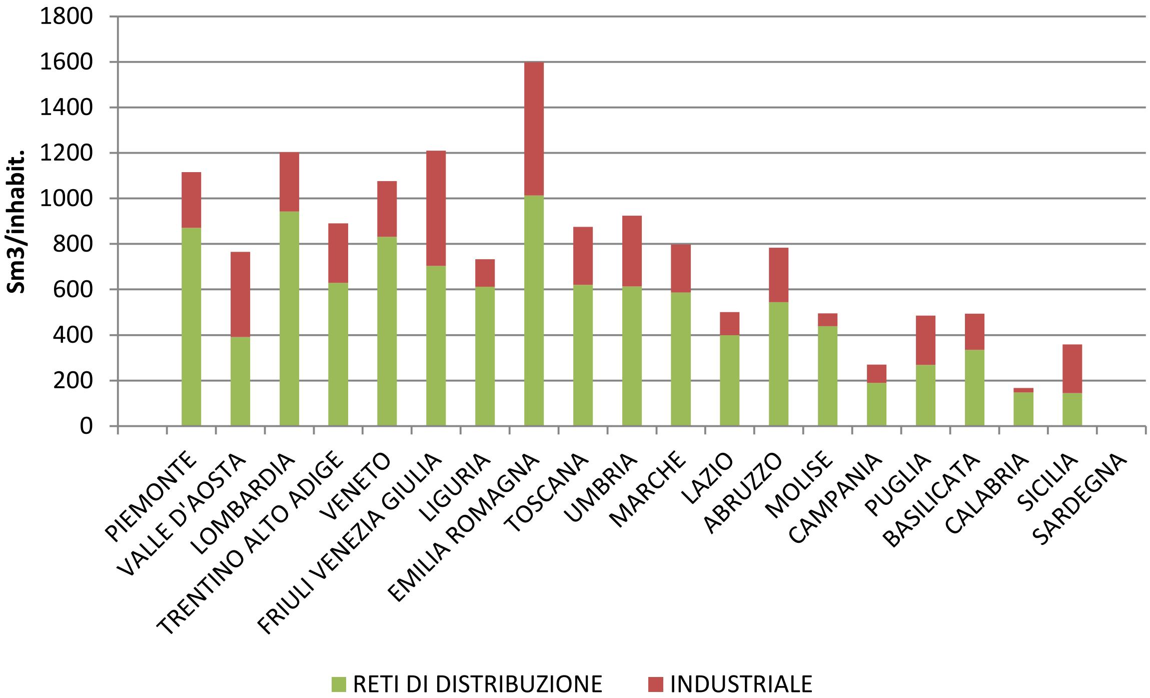
Regions	Population	Number of households	Number of cohabitations	Average DD[8]
Piedmont	4 436 798	2 015 733	2 691	2 706
Aosta Valley	128 591	61 390	103	3 170
Lombardy	9 973 397	4 396 094	3 352	2 508
Trentino-Alto Adige	1 051 951	443 007	718	3 230
Veneto	4 926 818	2 048 851	2 309	2 487
Friuli Venezia Giulia	1 229 363	561 120	550	2 403
Liguria	1 591 939	783 483	924	1 498
Emilia Romagna	4 446 354	1 989 082	2 402	2 384
Tuscany	3 750 511	1 638 328	1 733	1 817
Umbria	896 742	381 257	477	2 110
Marche	1 553 138	644 763	687	1 973
Lazio	5 870 451	2 636 282	3 369	1 562
Abruzzo	1 333 939	558 407	470	1 868
Molise	314 725	131 216	160	2 009
Campania	5 869 965	2 149 601	1 473	1 240
Apulia	4 090 266	1 578 936	1 198	1 342
Basilicata	578 391	232 624	256	1 965
Calabria	1 980 533	794 518	877	1 343
Sicily	5 094 937	2 034 234	2 803	1 025
Sardinia	1 663 859	712 764	820	1 180
Italy	60 782 668	25 791 690	27 372	1 921

Source: elaboration of ISTAT data

A good 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, shown in the following chart. The graph shows clearly that the greatest amounts of gas are supplied to local distribution networks in central and northern Italy, with the exception of the Valle D'Aosta and Trentino where gas is often replaced by biomass, while values in the south are lower. Note moreover that Sardinia has no methane gas supply.

Figure 8 – Natural gas conveyed per inhabitant in 2013 (chart plotted 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/m^3)

[8] Degree days are shown as the average of the values of municipalities in a given region, weighted by the population of each municipality.

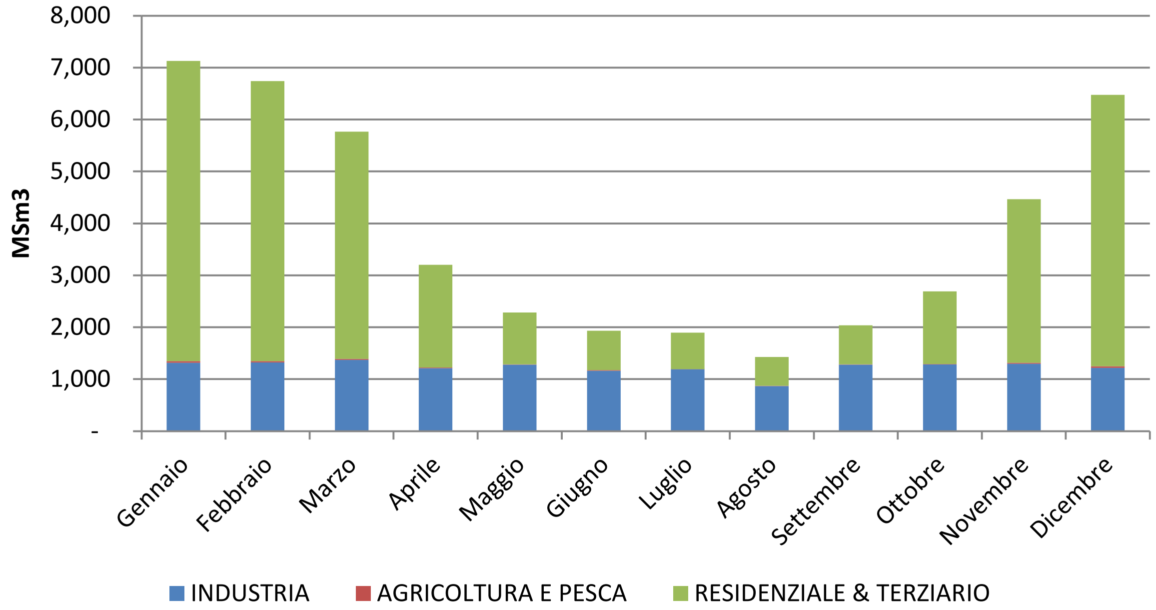


RETI DI DISTRIBUZIONE	DISTRIBUTION NETWORKS
INDUSTRIALE	INDUSTRIAL

1.2.3.2 Seasonal variations

Natural gas consumption varies significantly in the course of the year, as shown by the following chart. While gas consumption remains constant in the industrial sector, except for the month of August, when production tends to slow down, the residential and service sectors show a marked contraction from April to October, when temperatures are usually higher than in the rest of the year.

Figure 9 – Monthly consumption of natural gas in 2013 (Ministry of Economic Development) (Millions of standard cubic metres at 38.1 MJ/m³)



Gennaio	January
Febbraio	February
Marzo	March
Aprile	April
Maggio	May
Giugno	June
Luglio	July
Agosto	August
Settembre	September
Ottobre	October
Novembre	November
Dicembre	December
INDUSTRIA	INDUSTRY
AGRICOLTURA E PESCA	AGRICULTURE AND FISHERIES
RESIDENZIALE & TERZIARIO	RESIDENTIAL AND SERVICES

1.3 Residential sector

1.3.1 Breakdown of consumption by use

The total consumption recorded in Italy in the residential sector, between 2003 and 2013, is shown in the following table, by energy source. These data do not take into account the consumption of renewable thermal energy[9] supplied by heat pumps.

Table 11 – Consumption by the residential sector in Italy (data in ktoe)

PRODUCT/TIME	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Solid fuels	16	8	7	7	6	4	4	4	4	3	0
Other Bituminous Coal	1	8	7	7	6	4	4	4	4	3	0
Coke Oven Coke	16	0	0	0	0	0	0	0	0	0	0
Total petroleum products	5 205	5 338	5 324	4 714	3 923	3 940	3 789	3 325	3 079	2 809	2 709
Liquified petroleum gas (LPG)	1 537	1 501	1 551	1 427	1 358	1 458	1 382	1 371	1 245	1 206	1 192
Other kerosene	44	31	20	19	11	10	9	9	9	0	7
Gas/diesel oil (without bio components)	3 310	3 589	3 539	3 134	2 469	2 386	2 314	1 907	1 792	1 588	1 506
Total fuel oil	313	218	214	135	84	86	84	38	33	14	4
Gas	17 273	17 937	18 746	17 017	15 942	16 015	16 821	18 698	17 990	18 117	18 073
Natural gas	17 273	17 937	18 746	17 017	15 942	16 015	16 821	18 698	17 990	18 117	18 073
Gas Works Gas	0	0	0	0	0	0	0	0	0	0	0
Derived heat	0	156	159	144	133	43	52	123	568	694	931
Renewable energies	3 506	2 261	3 929	4 726	6 556	7 729	7 449	7 263	4 707	6 754	6 759
Solar thermal	13	14	21	27	41	52	66	99	104	115	124
Solid biofuels (excluding charcoal)	3 448	2 202	3 866	4 611	6 428	7 653	7 336	7 113	4 552	6 594	6 592
Biogas	0	0	0	0	0	0	0	0	0	0	0
Charcoal	43	42	39	48	46	21	44	50	50	43	41
Biodiesels	0	0	0	38	39	0	0	0	0	0	0
Other liquid biofuels	0	0	0	0	0	0	0	0	0	0	0
Geothermal Energy	2	2	2	2	2	2	2	1	1	2	1
Electrical energy	5 590	5 726	5 758	5 816	5 780	5 880	5 926	5 980	6 031	5 972	5 760
All products	**29 333**	**30 450**	**31 313**	**29 455**	**27 242**	**27 327**	**28 814**	**31 667**	**31 322**	**34 349**	**34 231**

Source: elaboration of Eurostat data

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

Starting from Eurostat data, consumption of each source for each use has been defined, in order to isolate consumption for heating. This separation was performed by updating and comparing the results of specific studies performed by ENEA[10], taking into account the indications provided by the survey on the energy consumption of households carried out by ISTAT (in particular the estimate on the prevalence of heat pumps)[11] and the data supplied by GSE within the system for the monitoring of renewable energy sources in Italy (SIMERI).

In 2013 the total demand for heating and cooling by Italian households exceeded 29.5 Mtoe, including almost 25 Mtoe for space heating and about 2.8 Mtoe for domestic hot water production.

Table 12 – Consumption in the residential sector in Italy (data in ktoe) in 2013 broken down by use

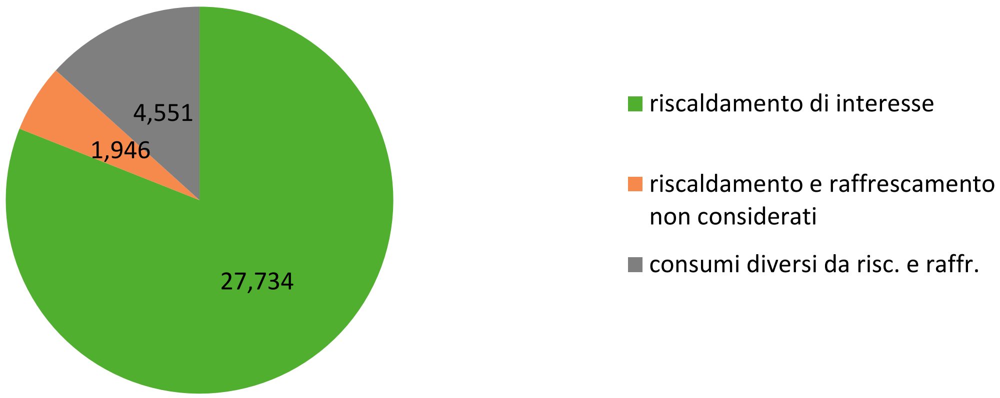
	petroleum products	natural gas	coal	electricity	derived heat	renewable sources	Total
Heating and cooling	**2 709**	**18 073**	**0**	**1 209**	**931**	**6 759**	**29 680**
Winter heating	*2 159*	*14 991*	*0*	*377*	*813*	*6 560*	*24 900*
Summer cooling				*119*			*119*
Domestic hot water	*148*	*1 977*	*0*	*435*	*117*	*157*	*2 834*
Cooking uses	*402*	*1 105*	*0*	*278*		*41*	*1 827*
Other electrical uses				**4 551**			**4 551**
Total residential	**2 709**	**18 073**	**0**	**5 760**	**931**	**6 759**	**34 231**

Since the aim of this study is to assess the potential for expansion of efficient district heating or high-efficiency cogeneration systems, further calculations had to be performed to establish the components of heating and cooling consumption which can be technically and practically covered by those systems. This has led to exclusion from the demand for heat of uses for cooking and cooling, which on initial assessment have been considered not easy to cover by efficient district heating or high-efficiency cogeneration. The consumption for heating relevant to subsequent assessments is thus for the residential sector 27.7 Mtoe, 90 % of which for winter heating and the remaining 10 % for domestic hot water.

[10] Rapporto annuale Efficienza Energetica 2014 (Annual report on energy efficiency 2014). ENEA. Rapporto Energia e Ambiente 2009-2010 (Energy and the Environment Report 2009-2010), ENEA.-

[11] The total capacity of heat pumps in operation has been reconstructed from data supplied by trade associations, and the share of residential use has been obtained from the above-mentioned survey. The winter operating parameters have been taken from Commission Decision No 2013/114/EU. For cooling, a demand of 20 kWh/m^2 is assumed, applied to the areas calculated from the above-mentioned Istat survey, adjusted for the different use rates of the equipment (obtained from the same survey).

Figure 10 – Consumption for heating and cooling selected out of the total in the service sector. Year 2013 (data in ktoe)



Riscaldamento di interesse	Relevant heating
Riscaldamento e raffrescamento non considerati	Heating and cooling not considered
Consumi diversi da risc. e raffr.	Consumption other than heating and cooling

1.3.2 Heating demand: geographical distribution

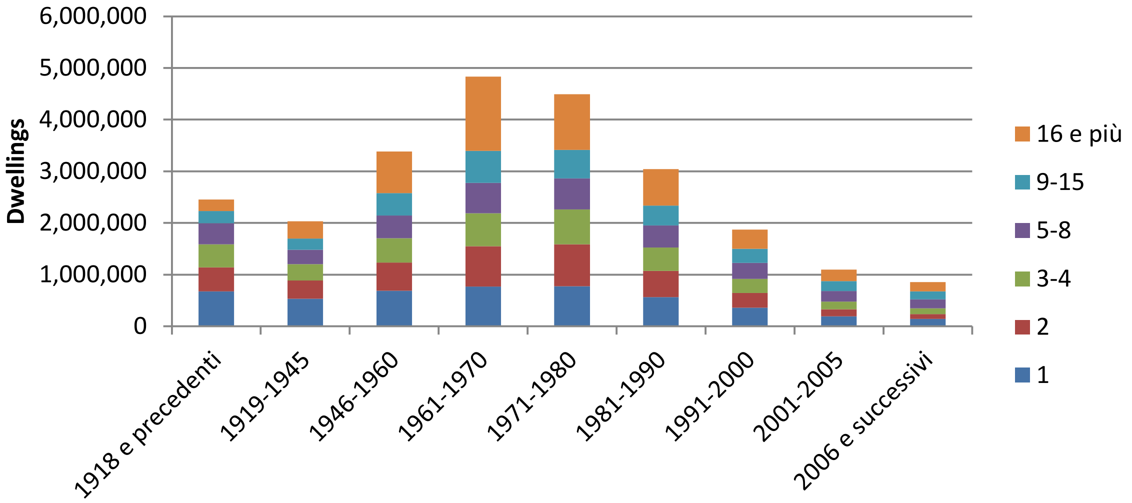
At the end of 2013 Italy had a population of 60 782 668; the number of households, which are taken in this study as the units making up the demand for heat, was 25 791 690.
As stated earlier, energy consumption for heating and cooling in households is made up mainly of consumption for winter heating (almost 84 %), which depends largely on climate conditions and building characteristics.
The national housing stock, divided by residential buildings, period of construction and number of dwellings in the building, is presented in the following table and chart.

Table 13 – Dwellings inhabited by residents divided by period of construction and number of dwellings in the building

	Building size class							
Building period	1 dwelling	2 dwellings	3-4 dwellings	5-8 dwellings	9-15 dwellings	16 or more dwellings	Total	
1918 and 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 and 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 %
	19 %	*17 %*	*15 %*	*14 %*	*13 %*	*22 %*	*100 %*	

Source: elaboration of ISTAT census, 2011

Figure 11 – Number of dwellings by period of construction and building size class (ISTAT census 2011)



Since for the purposes of this study it is crucial to have a sufficiently accurate description of the demand for heat, heating demand has been calculated for each Italian municipality, based on its climatic condition, area and the type of dwellings occupied by residents.
Consumption was broken down through two separate steps:

- **bottom-up calculation**: calculation of consumption for winter heating per building class, made using average specific consumption values by a reference building in each class [12](climate condition area – period of construction – number of dwellings in the building) (kWh/m^2), reconstructed with the rules set out in the technical standards on the energy certification of buildings. To perform the calculation, it was necessary to reconstruct the composition of the occupied housing stock in each municipality[13];
- **top-down calibration**: correction of the results obtained using the previous method to take into account the fact that the consumption calculated refers to standard climate conditions, relates to uniform demand over the day, and is expressed in terms of primary energy. The correction is made by reproportioning results to ensure consistency with the national consumption for heating, reconstructed as set out above.

The following table and chart set out the consumption thus calculated by type of building.

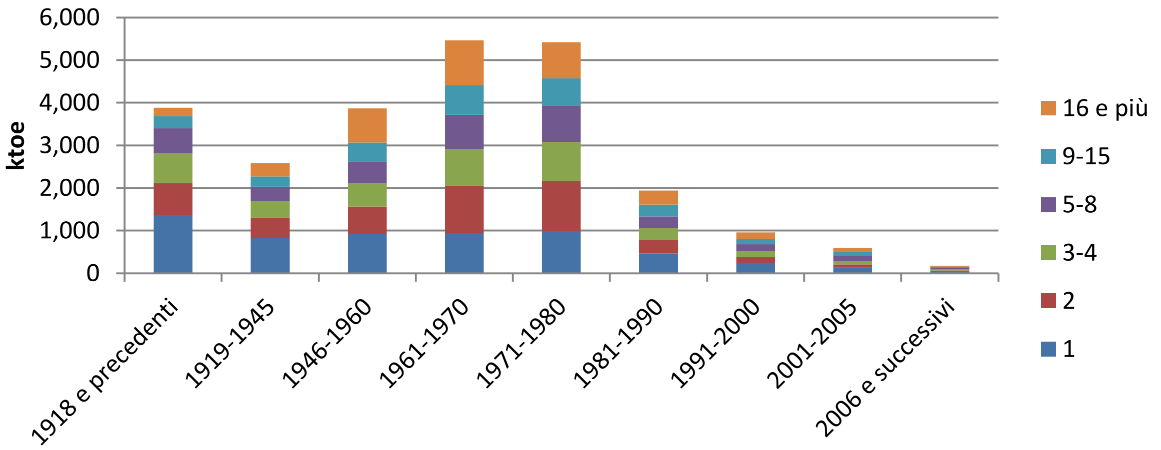
[12] Analisi tecnico-economica di interventi di riqualificazione energetica del parco edilizio residenziale italiano (Technical-economic analysis of energy efficiency projects in the housing sector in Italy), Ricerca Sistema Energetico, February 2014.

[13] The census of population and housing contains data on the built stock occupied by residents in the Provinces and the provincial capitals. These data are distributed among municipalities other than the provincial capital city on the basis of the number of dwellings in each municipality (occupied + non-occupied) for each class.

Table 14 – Consumption for winter heating of the residential sector (ktoe) broken down by period of construction and number of dwellings in the building

		Building size class						Total	
		1 dwelling	2 dwelling	3-4 dwellings	5-8 dwellings	9-15 dwellings	16 or more dwellings		
building period	1918 and earlier	1.367	742	697	595	285	199	3.885	16 %
	1919-1945	829	470	402	328	242	316	2.587	10 %
	1946-1960	917	651	539	505	451	802	3.864	16 %
	1961-1970	943	1.108	864	805	683	1.061	5.465	22 %
	1971-1980	988	1.175	918	851	642	848	5.422	22 %
	1981-1990	461	324	274	275	279	328	1.941	8 %
	1991-2000	235	146	138	164	125	148	956	4 %
	2001-2005	131	73	81	119	97	100	601	2 %
	2006 and later	48	19	23	36	29	25	180	1 %
Aggregate values		5.919	4.708	3.935	3.679	2.833	3.827	24.901	100 %
		24 %	19 %	16 %	15 %	11 %	15 %	100 %	

Figure 12 – Consumption for winter heating of the residential sector broken down by period of construction and number of dwellings in the building



After reconstructing the built stock of each Italian municipality, it is possible to distribute the consumption for winter heating and domestic hot water production among all the municipalities. The following table provides the data obtained aggregated by region. Greater detail is provided in the following maps.

Table 15 – Consumption (year 2013) for space heating and cooling and DHW production in the residential sector, by region

	Dwellings with residents (2011)	Winter heating consumption (ktoe)	Consumption for DHW (ktoe)	Total consumption (ktoe)
Piedmont	1 922 089	2 605	208	2 812
Valle d'Aosta	58 551	72	6	78
Lombardy	4 092 948	5 020	463	5 483
Trentino Alto Adige / Sudtirol	418 994	550	49	598
Veneto	1 947 814	2 882	231	3 113
Friuli-Venezia Giulia	536 551	762	58	820
Liguria	740 540	619	75	694
Emilia-Romagna	1 866 323	2 477	207	2 684
Tuscany	1 529 666	1 641	175	1 816
Umbria	357 167	453	42	495
Marche	612 242	717	74	791
Lazio	2 277 387	1 970	261	2 232
Abruzzo	513 762	562	62	624
Molise	125 411	158	15	173
Campania	2 026 156	1 227	276	1 503
Apulia	1 517 101	1 035	194	1 229
Basilicata	227 344	238	28	266
Calabria	760 907	551	94	645
Sicily	1 940 472	931	239	1 170
Sardinia	663 752	432	78	510
Italy	24 135 177	24 901	2 834	27 735

1.3.3 Map of municipalities and conurbations with a plot ratio of at least 0.3

The following map, as shown in Annex 3 to Legislative Decree No 102 of 4 July 2014, shows the density of usable floor area characterised by means of the plot ratio. This was calculated on the basis of the 2011 ISTAT census data, applying the following formula:

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

where:

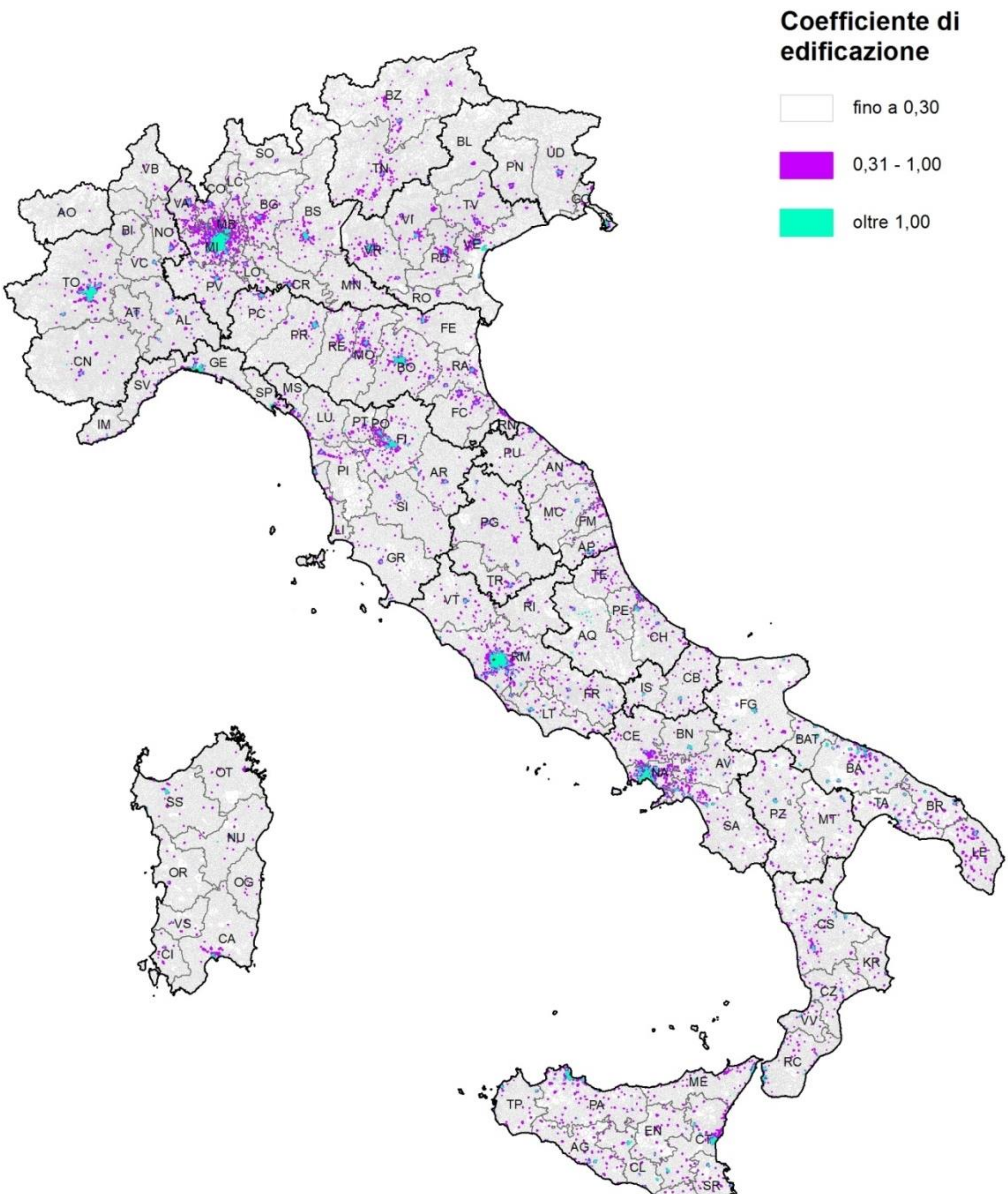
PR_i: Plot ratio of the i area surveyed [%]

Su_i: inhabited usable floor areas surveyed by the ISTAT Census 2011 [m2]

A_i: nth area of the ISTAT 2011 Census [m2]

The geographical resolution at which the plot ratio was calculated is very detailed, since the census zones (from which the aggregate value can be determinedSu_i) 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 a proxy of demand for heat; however, in Italy it should be assessed with care because it should be weighed against highly variable heat values found in the country according to latitude and terrain.

Figure 13 – Map of the plot ratio



Coefficiente di edificazione	Plot ratio
Fino a	Up to
Oltre	Above

Geographically, the areas with high plot ratio 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 on the Po Plain and along most of Italy's coast.

Overall, the areas with plot ratio >0.3 make up 0.5 % of the country's total surface area, and 35 % of its population. If out of these areas only those with the highest demand for heat are considered (climate condition areas E-F) the values drop respectively to 0.2 % and 12.6 %.

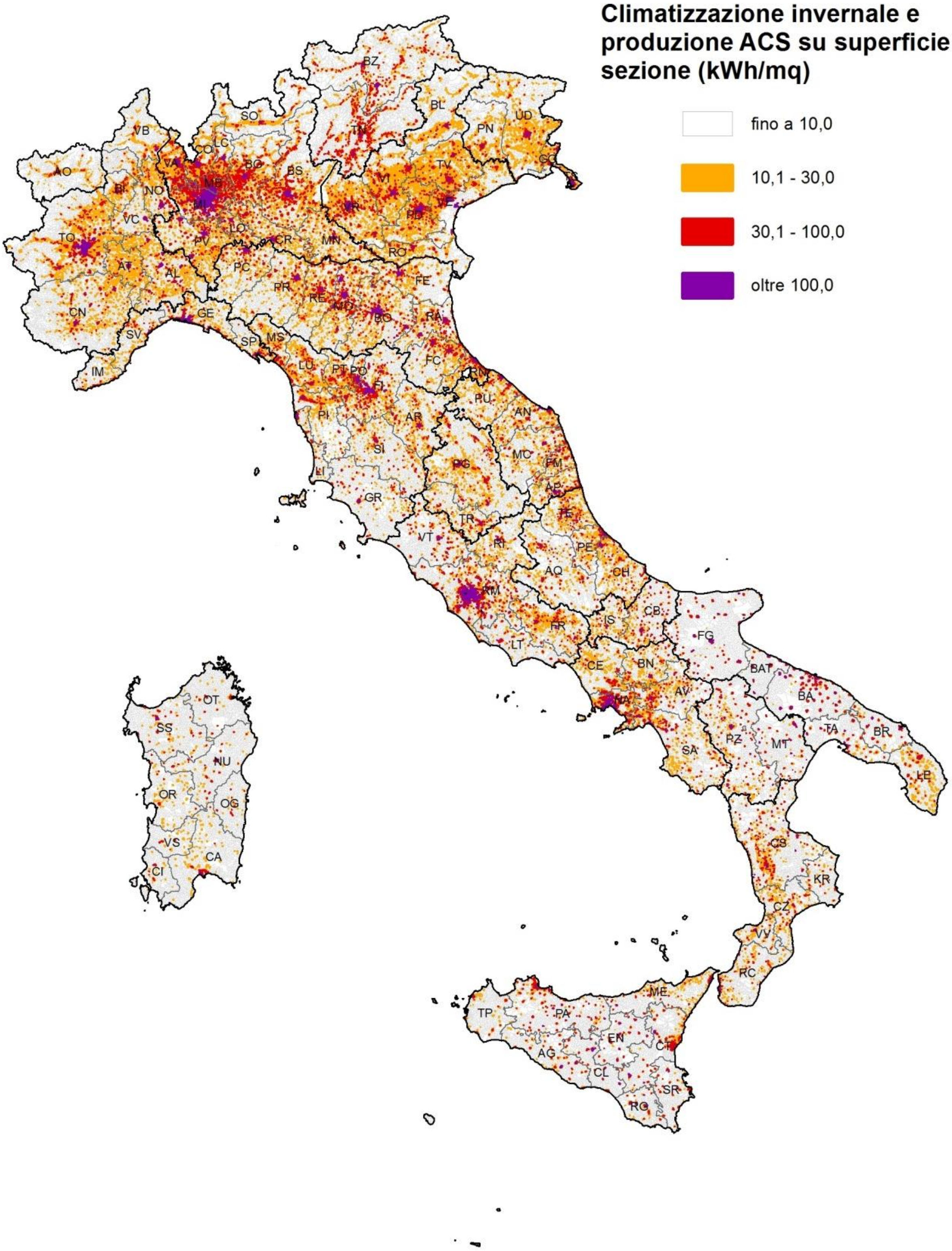
Table 16 – Characteristics of the areas with plot ratio > 0.3

Climatic zone	nr. municipalities	Average HD (PR>0,3)	Land Area km^2 (PR>0,3)	Population (PR>0,3)
A	2	574	1	10 361
B	104	785	108	1 706 679
C	542	1166	371	5 696 009
D	709	1734	420	6 147 753
E	1153	2470	561	7 333 900
F	97	3478	11	125 134
Total (PR>0,3)	**2607**	**1968**	**1 472**	**21 019 836**
% of total ITA	**32 %**		**0,5 %**	**35 %**

The following map describes the density of heating demand (kWh/m2) from the residential sector. The distribution in the country of consumption for winter heating and for domestic hot water production is shown, highlighting the centres with the highest demand concentration.

The consumption data calculated at municipal level by the procedure described earlier were divided between the census zones into which the municipal territory is divided on the basis of the residents in each zone (data from the 2011 general census of population and housing, ISTAT). The consumption for winter heating and domestic hot water production is then divided by the area of the census zone: this yields an indicator of heating demand by land area unit.

Figure 14 – Density of residential consumption for winter heating and domestic hot water production. Year 2013



Climitazzione invernale e produzione ACS su superficie sezione (kWh/mq)	Winter heating and domestic hot water (DHW) production in the census zone area (kWh/m²)
Fino a	Up to
Oltre	Above

As shown in the following table, taken from the database created to represent the maps described above, more than 60 % of the demand for winter heating and 46 % of the demand for domestic hot water come from climate condition area E, which by and large corresponds to northern Italy.

Almost 50 % of heat demand is concentrated in areas with densities in excess of 30 kWh/m^2.

Table 17 – Breakdown of relevant residential consumption and associated densities, by climate condition area

Climate condition area	consumption for winter heating (GWh)	consumption for domestic hot water production (GWh)	mean consumption density* kWh/m²	consumption in areas with densities* between 30 and 100 kWh/m² (GWh)	consumption in areas with densities* of more than 100 kWh/m² (GWh)
A	-	13	0.25	-	-
B	3 732	1 768	0.69	1 356	46
C	28 412	7 033	0.80	10 243	1 838
D	67 177	8 090	0.94	26 815	10 757
E	176 791	15 072	1.54	60 329	21 839
F	13 489	987	0.32	2 775	365
Total	289 601	32 963	1.07	101 518	34 845

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

1.4 Service sector

1.4.1 Breakdown of consumption by use

The total consumption recorded in Italy in the service sector, between 2003 and 2013, is shown in the following table, by energy source. The data include electricity consumption, while they do not take into account the consumption of renewable thermal energy[14] supplied by heat pumps.

Table 18 – End-user consumption in the service sector in Italy (data in ktoe)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Solid fuels	0	0	0	0	0	0	0	0	0	0	0
Lignite/Brown Coal	0	0	0	0	0	0	0	0	0	0	0
Total petroleum products	1.045	1.036	1.051	1.048	991	1.050	836	829	756	633	612
Liquified petroleum gas (LPG)	672	652	665	614	582	561	592	588	534	445	451
Gasoline (without bio components)	0	0	0	0	0	0	0	0	17	13	8
Gas/diesel oil (without bio components)	372	385	387	433	409	488	244	241	206	175	153
Total fuel oil	0	0	0	0	0	0	0	0	0	0	0
Gas	6.230	6.206	7.434	7.563	7.071	8.623	8.610	8.614	7.255	7.276	7.259
Natural gas	6.230	6.206	7.434	7.563	7.071	8.623	8.610	8.614	7.255	7.276	7.259
Derived heat	0	69	70	97	101	74	62	49	139	105	154
Renewable energies	145	143	146	149	151	155	163	125	128	154	171
Solar thermal	3	4	6	7	11	14	18	27	28	31	34
Solid biofuels (excluding charcoal)	7	8	8	10	8	8	13	21	21	21	36
Biogas	0	0	0	0	0	0	0	1	3	25	25
Geothermal Energy	135	132	132	132	132	132	132	76	76	77	77
Electrical energy	5.798	6.015	6.352	6.712	6.867	7.117	7.249	7.362	7.473	7.763	7.651
All products	**13.218**	**13.469**	**15.053**	**15.569**	**15.182**	**17.019**	**16.920**	**16.979**	**15.751**	**15.931**	**15.847**

Source: elaboration of Eurostat data

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

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[15].

Table 19 – End-user consumption in the service sector in Italy (data in ktoe) by type of use (2013)

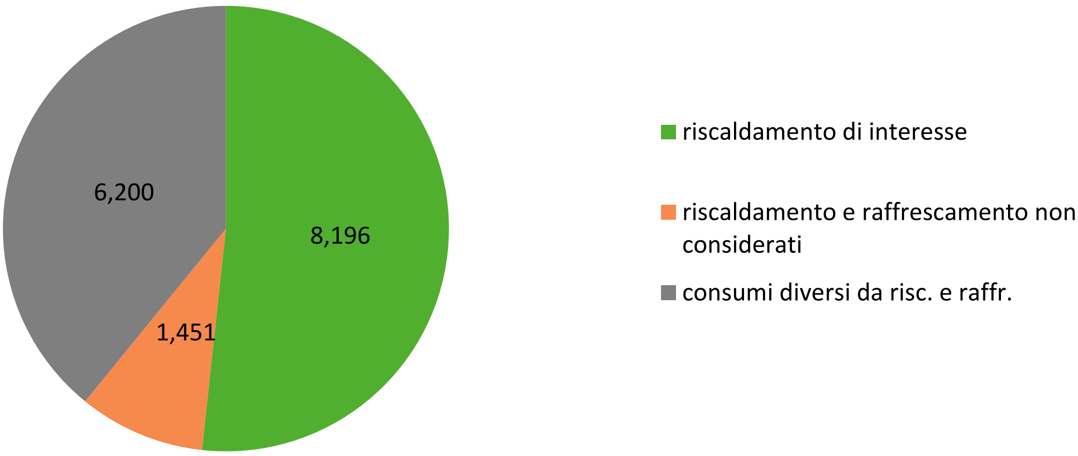
	Solid fuel solidi	Petroleum products	Gas	Derived heat derivato	Renewables rinnovabili	Electricity elettrica	Total
Heating and cooling	0,0	611,5	7.259,0	153,9	171,1	1.450,8	9.646,3
Winter heating, DHW and other uses	*0,0*	*611,5*	*7.259*	*153,9*	*171,1*	*1.025,6*	*9.221,1*
Summer cooling						*425,2*	*425,2*
other electrical uses						6.200,3	6.200,3
Total	0,0	611,5	7.259,0	153,9	171,1	7.651,1	15.846,6

Vis-à-vis the data provided in the preceding table, the following figures on the demand for heating and cooling are limited to the components most relevant to this study, i.e. the types of consumption felt to be more easily covered by cogeneration and district heating systems. Considering that electric heating and cooling systems in the service sector can be complex and are already highly integrated, for the purpose of moisture control and controlled ventilation, in general, we feel that this demand is not currently easily replaceable by district heating or cogeneration systems. Therefore, the consumption for heating and cooling assessed in the following chapter is 8.2 Mtoe.

[15] Electricity consumption for heat pumps has been reconstructed through the following steps:

- calculation of total installed capacity in Italy, in the non-residential sector, obtained as the difference between total installed capacity and total residential capacity, previously calculated;
- calculation of the equivalent hours of operation for the cooling of non-residential buildings, obtained mainly from analysis of the CENED databases of the Lombardy Region (selecting only non-residential buildings equipped with heat pumps as generators);
- application of standard performance data to the Italian cooling capacity installed in the non-residential sectors; for heating, the parameters set out in Commission Decision No 2013/114/EU are used.

Figure 15 – Consumption for heating and cooling selected out of the total in the service sector. Year 2013 (data in ktoe)



Riscaldamento di interesse	Relevant heating
Riscaldamento e raffrescamento non considerati	Heating and cooling not considered
Consumi diversi da risc. e raffr.	Consumption other than heating and cooling

1.4.2 Heating demand: sectoral and geographical distribution

The service sector is highly diverse in terms of structure and consumption profile. The following table shows consumption reconstructed by GSE on the basis of detailed assessments by RSE[16] for each subsector, relying on extensive literature[17].

[16] Perego O., Bazzocchi F. Benini M. "Rapporto RSE RdS 14009625".

[17] M. Aprile "Caratterizzazione energetica del settore alberghiero in Italia, ENEA, Report RSE/2009/162".

U. Curcio "Indagine sui consumi e sulla diffusione delle apparecchiature nel settore terziario in Italia", CESI Report A5053452, 2005.

Federalberghi "DATATUR Trend e statistiche sull'economia del turismo", 2014.

CNEL "La situazione degli impianti sportivi in Italia al 2003", Rome, January 2005.

S. Elia, E. Santini Analisi di consumo, elettrico e termico, del centro sportivo Giulio Onesti del CONI di Roma, ENEA Report RdS, September 2012.

ENEA "Determinazione dei fabbisogni e dei consumi energetici dei sistemi edificio-impianto, Caratterizzazione del parco immobiliare ad uso ufficio, Report RSE/2009/163".

ENEA "Determinazione dei fabbisogni e dei consumi energetici dei sistemi edificio-impianto, Caratterizzazione del parco immobiliare ad uso centro commerciale, Report RdS/2011/161".

Confcommercio Research Department, "Rapporto sulle Economie Territoriali e il terziario di Mercato", 2014.

FederDistribuzione "Mappa del Sistema Distributivo Italiano", 2013.

Politecnico di Milano "Energy Efficiency Report", December 2013.

F. Carrara "I consumi energetici della Pubblica Amministrazione Stima dei consumi e scenari di riqualificazione energetica, Rapporto RSE GSE", December 2014.

Table 20 – Consumption for heating by the service sector in Italy, divided by subsector (data in ktoe)

	national area (m^2)	consumption for heating (ktoe)
Public administration Public	72 308 533	964.0
Healthcare	56 908 138	1 289.4
Leisure activities	9 183 394	288.5
Education	83 370 933	997.0
Hotels		634.6
Sports facilities	44 755 776	1 197.7
Offices	56 674 733	828.4
Commerce - Supermarket chains	22 292 112	85.9
Other		1 909.9
Total		8 195.5

The national energy consumption for heating can be divided geographically by subsector, based on:

- specific consumption parameters, typical of each subsector, from the calculations made by RSE;
- provincial level data on the number and/or size (m^2 or m^3) of the buildings belonging to the main subsectors of services (commerce, education, offices, etc.) collected and published by the Real Estate Market Observatory (OIM) operated by the Land Registry Agency/Revenue Agency;
- the data from the ISTAT 2011 census of industry and services on the number of workers by subsector, which are useful to reproportion the provincial data supplied by OIM set out in the previous point among the individual municipalities of each Province of Italy.

Table 21 – Consumption for heating by the service sector in Italy, divided by subsector (data in ktoe)

	Government Pubblica	Healthcare	Leisure activities	Education	Hotels	Sports centres	Offices	Commerce - Supermarket chains	Other	Total
Piedmont	106	155	31	104	42	126	65	9	233	871
Valle d'Aosta	9	7	1	8	17	11	3	1	11	68
Lombardy	161	242	59	233	59	205	229	19	348	1 556
Trentino-Alto Adige	49	29	28	56	110	50	26	4	89	442
Veneto	91	115	46	126	78	130	106	10	207	910
Friuli-Venezia Giulia	38	48	12	38	16	33	23	2	74	284
Liguria	16	33	5	19	21	27	13	2	42	177
Emilia-Romagna	76	132	37	88	79	144	96	11	160	824
Tuscany	56	71	22	51	43	96	53	4	106	502
Umbria	16	25	8	15	19	43	15	1	41	183
Marche	25	29	10	26	18	40	20	3	53	224
Lazio	110	89	13	56	32	73	61	4	175	613
Abruzzo	25	30	3	22	15	38	13	3	45	194
Molise	10	8	0	5	4	8	3	1	9	47
Campania	39	90	3	32	20	51	28	5	98	367
Apulia	33	47	2	41	18	44	25	3	80	293
Basilicata	15	10	1	9	4	9	5	1	16	69
Calabria	19	45	2	19	12	20	12	1	28	158
Sicily	39	62	4	31	16	29	22	2	67	270
Sardinia	31	23	2	17	10	20	11	1	30	146
Italy	964	1 289	289	997	635	1 198	828	86	1 910	8 195

1.5 Industry

1.5.1 Breakdown of consumption by use

The trends in consumption recorded by Eurostat in the industrial sector in Italy for the past 10 years are shown in the following table. For the purposes of this study, the industrial sector includes consumption by the energy industry, which covers consumption by the auxiliaries of electricity and derived heat producing installations, consumption by pumping plants and consumption for energy purposes (net of the consumption of raw materials) by refineries, coke ovens and hydrocarbon plants. In 2013, total consumption by the industrial sector was slightly short of 34.5 Mtoe.

Table 22 – Consumption (ktoe) of the industrial sector, including the energy industry, in Italy by source

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Solid fuels	3 863	3 877	4 231	3 707	3 695	3 327	1 873	2 945	3 454	3 432	2 396
Other Bituminous Coal	1 268	1 292	1 412	1 262	1 237	1 308	714	994	1 196	1 494	762
Coke Oven Coke	2 550	2 538	2 559	2 402	2 413	1 974	1 117	1 911	2 212	1 900	1 598
Lignite/Brown Coal	2	2	2	2	1	1	2	2	1	1	1
Coking Coal	44	45	258	40	44	44	40	39	44	38	35
Total petroleum products	12 505	11 972	12 283	11 182	11 526	11 229	9 179	8 773	8 237	7 188	5 768
Refinery gas	2 569	2 527	2 790	2 704	3 046	2 735	2 501	2 796	2 748	2 022	2 075
Liquified petroleum gas (LPG)	509	468	489	476	430	357	316	357	333	289	247
Gasoline (without bio components)	306	334	325	296	395	247	244	175	25	482	312
Other kerosene	10	4	4	4	1	1	0	4	2	0	1
Kerosene type jet fuel (without bio components)	15	16	21	22	18	15	12	21	16	12	13
Naphtha	218	55	57	22	28	19	16	14	13	11	0
Gas/diesel oil (without bio components)	758	817	776	418	452	400	341	496	740	437	341
Total fuel oil	5 102	4 095	3 886	3 650	3 739	3 818	3 021	2 236	1 652	1 621	823
Petroleum coke	2 966	3 186	3 500	3 194	3 020	3 204	2 697	2 667	2 708	2 314	1 954
Other Petroleum Products	52	470	436	397	398	434	31	9	1	0	2
Gas	17 344	14 650	14 187	13 639	13 214	12 187	10 361	11 004	10 483	10 461	10 030
Natural gas	17 302	14 636	14 157	13 605	13 199	12 173	10 357	11 001	10 477	10 231	9 851
Coke Oven Gas	12	10	9	28	12	14	5	4	7	212	168
Blast Furnace Gas	31	4	21	6	2	0	0	0	0	18	10
Derived heat	0	4 302	4 381	4 747	4 645	4 593	4 162	4 702	4 466	4 074	4 008
Renewable energies	223	220	213	214	182	281	394	217	253	271	275
Solar thermal	0	0	0	0	0	0	0	7	7	8	8
Solid biofuels (excluding charcoal)	206	203	198	198	167	243	375	201	236	234	237
Biogas	0	0	0	0	0	0	0	0	0	20	20
Charcoal	18	17	15	15	15	38	19	7	7	7	7
Geothermal Energy	0	0	0	0	0	0	0	3	3	2	2
Electrical energy	14 556	14 547	14 553	14 732	14 650	14 226	12 342	12 977	13 051	12 295	11 732
Industrial wastes (non-renewable)	62	62	62	62	62	62	62	223	249	281	281
All products	**48 553**	**49 631**	**49 910**	**48 282**	**47 973**	**45 904**	**38 372**	**40 841**	**40 193**	**38 001**	**34 489**

Source: elaboration of Eurostat data

Unlike the consumption shown in the previous tables, here energy consumption for heating has been separated according to the 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). Electricity uses also include a share for heating (e.g. electrical ovens or heat pumps), although it was decided that this would not be calculated since its estimate would be unreliable due to the lack of precise data. Furthermore, these uses are not felt to be easily replaceable by district heating or cogeneration, since they are usually characterised by precise process needs. Therefore, analysis focuses on uses of fuels and derived heat (see the following table), which amount to about 22.7 Mtoe.

Table 23 – Consumption in industry (including energy industry) in Italy by use, 2013 (data in ktoe)

	electricity	gas	petroleum products	coal	derived heat	renewables and waste	Total
space heating and cooling, process uses		10 030	5 768	2 396	4 008	556	22 757
use for electricity	11 732						11 732
total use by industry	11 732	10 030	5 768	2 396	4 008	556	34 489

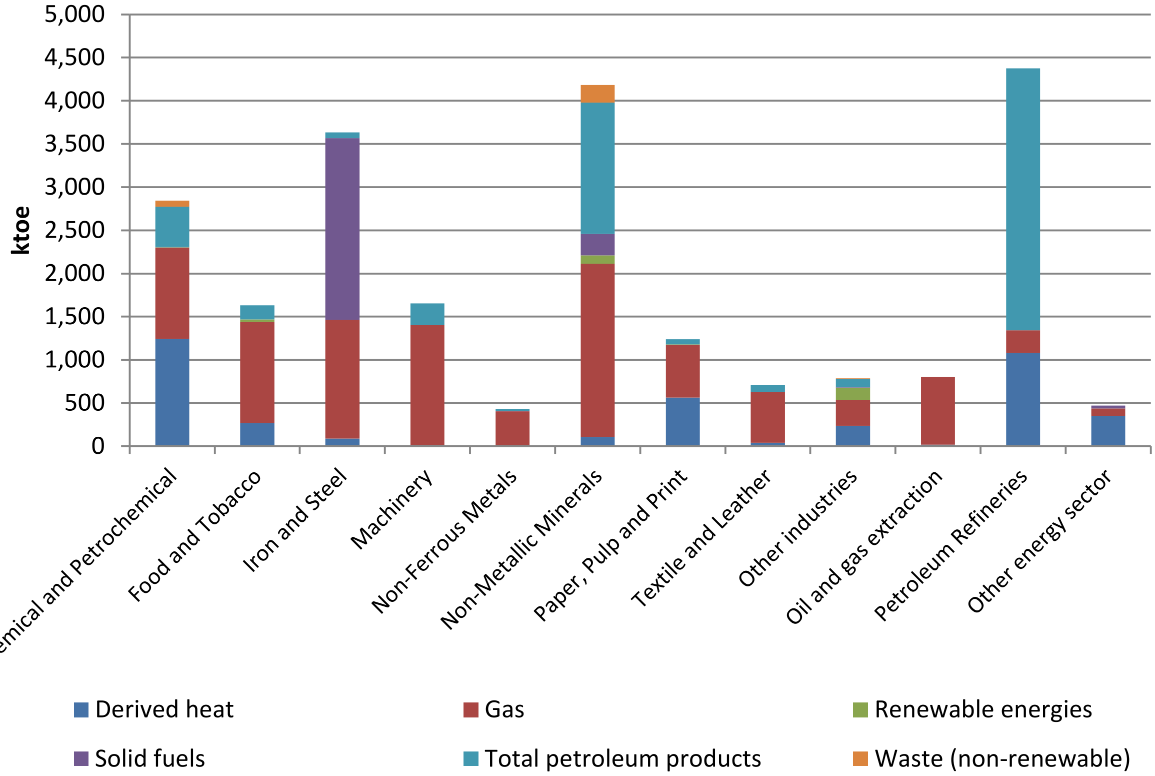
Heating consumption is broken down by sector, as shown in the table and chart below. The highest energy consumption in industry is by refineries, and ceramics and glass works, followed by iron and steel plants, and by the chemical and petrochemical industries.

Table 24 – Heating consumption in industry (including the energy industry) in Italy by subsector, 2013 (data in ktoe)

	Derived heat	Gas	Renewable energies	Solid fuels	Total petroleum products	Waste (non-renewable)	TOTAL
Chemical and Petrochemical	1243.2	1053.2	6.8	1.4	469.5	71.1	2845.2
Food and Tobacco	265.8	1173.9	29.7	0	160	0	1629.4
Iron and Steel	87.1	1375.2	0	2104.3	66.7	0	3633.3
Machinery	15.4	1386.6	0.6	0	252.2	0	1654.8
Non-Ferrous Metals	0.6	403.8	0	1.4	25.6	0	431.4
Non-Metallic Minerals	108.2	2004.3	95.7	251.2	1519.6	201.8	4180.8
Paper, Pulp and Print	563.6	613	0.4	0	62.5	0	1239.5
Textile and Leather	40.3	585.6	0.1	0	81.3	0	707.3
Other industries	236.2	300.8	141.3	2.7	98.2	8	787.2
Oil and gas extraction	17.6	786.1	0	0	0	0	803.7
Petroleum Refineries	1077.8	264	0	0	3032.9	0	4374.7
Other energy sector	352.3	83.4	0	34.8	0	0	470.5
TOTAL	4 008.1	10 029.9	274.6	2 395.8	5 768.5	280.9	22 757.8

Source: elaboration of Eurostat data

Figure 16 – Heating consumption in industry (including the energy industry) in Italy by subsector, year 2013 (data in ktoe)



1.5.2 Map of industrial areas with a total annual heating and cooling consumption in excess of 20 GWh

The following map, as shown in Annex 3 to Legislative Decree No 102 of 4 July 2014, shows the geographical and sectoral breakdown of the main energy uses by the different industrial sites in Italy and their size class. The consumption shown includes all the direct consumption on site, for both thermal and electricity generation purposes (in the case of self-production). The classification of industrial sectors used in this study matches that used by Eurostat in energy balances.

The industrial sites have been geolocated on the basis of their identification details obtained from the ETS database[18].

The mapped plants are all industrial sites with combustion plants with total rated thermal input in excess of 20 MWt, which in 2013 had consumption >20 GWh.

[18] http://ec.europa.eu/clima/policies/ets/registry/documentation_en.htm

The map includes only installations for the self-production of electricity and heat in industries and in the processing sector, excluding the electricity-heat generation plants operated by utilities[19]. Due to the non-availability of precise data, it was not possible to separate consumption for electricity self-production, which in Italy takes up a significant share in several sectors (the main being iron and steel, refineries, chemicals and paper). Consequently, the data by sector should be considered to be indicative as to industrial consumption for heat production.

Energy consumption at industrial sites has been derived using the following equation:

$$C_{ik}\ (\%) = \frac{CO2_{ik}}{EF_k}$$

Where:
C_{ik}: estimated consumption in 2013 at industrial site i of sector k [%]
$CO2_{ik}$: CO2 emissions measured in 2013 from industrial site i of sector k [%]
EF_k: average emission factor of industrial sector k

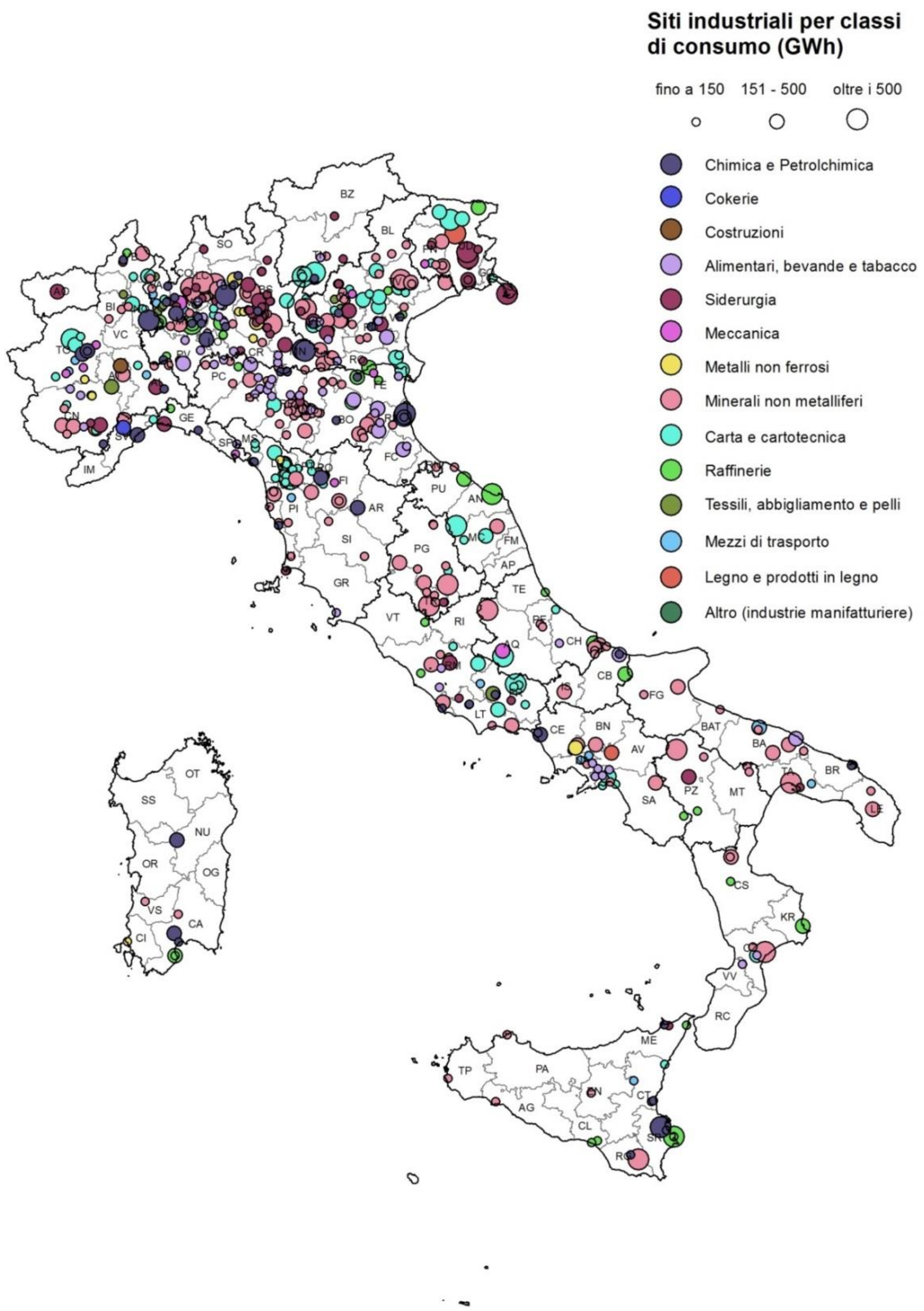
To calculate the average emission factors of the different 'i' average emission factors of the different industrial sectors the following data were used: the fossil fuel mixes by sector taken from the Eurostat energy balances and the specific emission factors of national fuels taken from ISPRA and IPCC. The average emission factors calculated for the various sectors are shown in the following table:

Table 25 – Average emission factors by industry sector

Sector	Subsector	$FE_k(tCO_2/TJin)$
Processing	Refineries	69.9
Processing	Coke ovens	78.7
Industrial	Iron and Steel	84.3
Industrial	Non-Ferrous Metals	56.8
Industrial	Chemical and Petrochemical	64.4
Industrial	Non-metallic Minerals	78.4
Industrial	Mining and Quarrying	62.9
Industrial	Food, Drink and Tobacco	57.9
Industrial	Textile, Clothing and Leather	57.9
Industrial	Paper, Pulp and Print	57.5
Industrial	Transport Equipment	55.8
Industrial	Mechanical Engineering	58.3
Industrial	Wood and wood products	55.8
Industrial	Construction	58.1
Industrial	Other (manufacturing industries)	78.3

[19] Ad hoc maps on these data are provided in the following sections.

Figure 17 – Industrial sites with total annual consumption of primary energy in excess of 20 GWh



Siti industriali per classi di consume (GWh)	Industrial sites by consumption class (GWh)
Raffinerie	Refineries
Cokerie	Coke ovens
Siderurgia	Iron and Steel
Metalli non ferrosi	Non-Ferrous Metals
Chimica e petrolchimica	Chemical and Petrochemical
Minerali non metalliferi	Non-metallic Minerals
Miniere e cave	Mining and Quarrying
Alimentari, bevande e tabacco	Food, Drink and Tobacco

Tessili, abbigliamento e pelli	Textile, Clothing and Leather
Carta e cartotecnica	Paper, Pulp and Print
Mezzi di trasporto	Transport Equipment
Meccanica	Mechanical Engineering
Legno e prodotti in legno	Wood and wood products
Costruzioni	Construction
Altro (industrie manifatturiere)	Other (manufacturing industries)

Consumption by industrial sites is more concentrated in northern Italy, where industry is historically more widespread. There are however some major industrial areas with high unit energy consumption in southern Italy. The industrial sites with the highest unit consumption are refineries, chemical industry and the petrochemical industry, iron and steel, ceramics and the paper industry.

1.6 Agriculture and fishery

1.6.1 Breakdown of consumption by use

Statistical data show for the agricultural sector steady decline in consumption over the past ten years. The decline is mainly due to diesel, while use of the other sources remained stable.

Table 26 – Consumption by agriculture in Italy, by source (data in ktoe)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total petroleum products	2 626.7	2 609.7	2 610.8	2 584.2	2 450.7	2 380.3	2 401.4	2 266.3	2 228.4	2 129.2	2 106.7
Liquified petroleum gas (LPG)	*73.6*	*72.5*	*73.6*	*73.6*	*70.3*	*68.1*	*65.9*	*68.1*	*65.9*	*59.3*	*57.1*
Gasoline (without bio components)	*8.4*	*20.0*	*19.0*	*15.8*	*13.7*	*13.7*	*11.6*	*11.6*	*9.5*	*9.5*	*9.5*
Gas/diesel oil (without bio components)	*2 544.7*	*2 517.3*	*2 518.3*	*2 494.8*	*2 366.7*	*2 298.5*	*2 323.9*	*2 186.5*	*2 153.0*	*2 060.4*	*2 040.0*
Gas	132.7	138.3	168.8	148.3	156.2	136.8	141.7	142.2	130.2	128.6	128.3
Natural gas	*132.7*	*138.3*	*168.8*	*148.3*	*156.2*	*136.8*	*141.7*	*142.2*	*130.2*	*128.6*	*128.3*
Derived heat	0.0	1.2	1.2	2.1	3.4	0.9	12.7	1.3	9.4	15.5	20.3
Renewable energies	80.8	79.4	79.5	79.7	79.8	79.9	80.5	48.2	48.5	41.0	41.6
Solar thermal	*0.2*	*0.2*	*0.3*	*0.4*	*0.5*	*0.7*	*0.9*	*1.3*	*1.4*	*1.6*	*1.7*
Solid biofuels (excluding charcoal)	*0.5*	*0.5*	*0.6*	*0.7*	*0.6*	*0.6*	*1.0*	*1.6*	*1.6*	*1.6*	*1.8*
Geothermal Energy	*80.1*	*78.6*	*78.6*	*78.6*	*78.6*	*78.6*	*78.6*	*45.3*	*45.3*	*37.8*	*38.2*
Electrical energy	443.9	445.8	461.2	473.2	486.6	487.5	485.8	482.3	507.9	509.4	488.1
All products	**3 284.2**	**3 274.4**	**3 321.5**	**3 287.6**	**3 176.7**	**3 085.4**	**3 122.1**	**2 940.3**	**2 924.3**	**2 823.6**	**2 785.0**

Source: elaboration of Eurostat data

Consumption data by the sector are broken down by flow to separate the share for heating only.

Table 27 – Consumption by the agricultural sector in Italy in 2013 by use (data in ktoe)

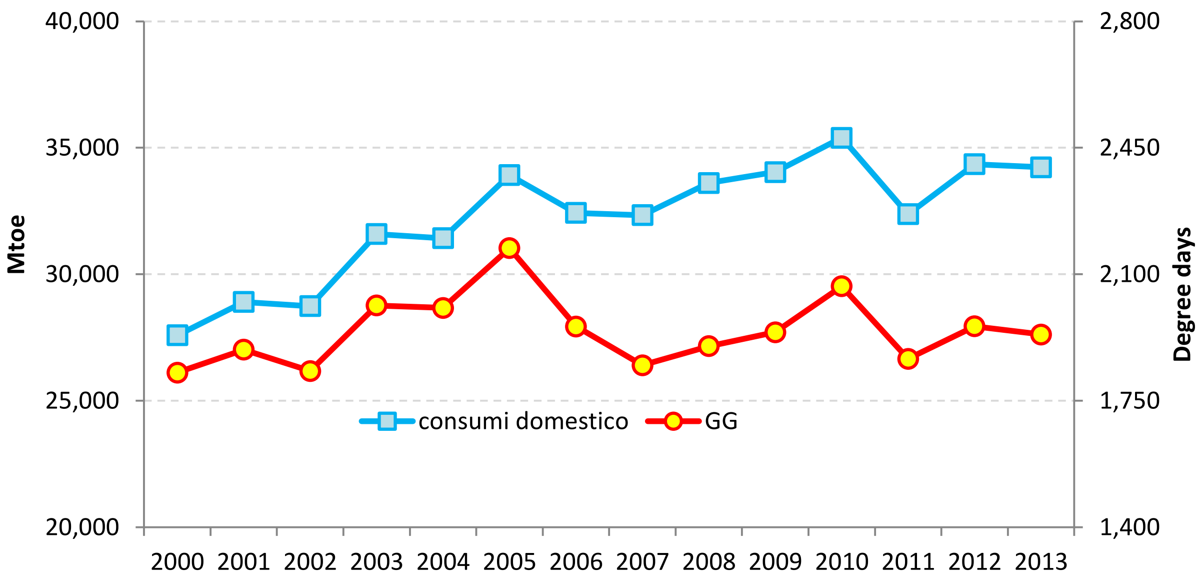
	oil products	gas	derived heat	renewables	electricity	Total
Heating and cooling	146.2	128.3	20.3	41.6	0.0	336.4
Space heating and cooling, drying, other uses	*146.2*	*128.3*	*20.3*	*41.6*		*336.4*
electrical uses					488.1	488.1
operation of agricultural machinery	1 960.5					1 960.5
Total agriculture	2 106.7	128.3	20.3	41.6	488.1	2 785.0

Heating consumption by agriculture is not broken down geographically, because we lack sufficiently reliable data for identifying the consumption centres of energy products (mainly greenhouses, dryers, livestock farms). Furthermore, pinpointing distribution of consumption in the territory 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 share of agriculture in the customer mix of district heating networks). Note, moreover, that energy consumption for heating by agriculture makes up a tiny fraction (0.5 %) of total heating consumption

1.7 Change in baseline climatic conditions

As already stated, the heating consumption presented in previous chapters relates to 2013. To develop scenarios to 2023, it might be worth introducing assessment criteria for this consumption that factor in variables such as annual climate variations – a factor that, as shown in the following graph (consumption in the residential sector), significantly affects consumption for space heating and cooling.

Figure 18 – Consumption trends in the residential sector and average national degree days



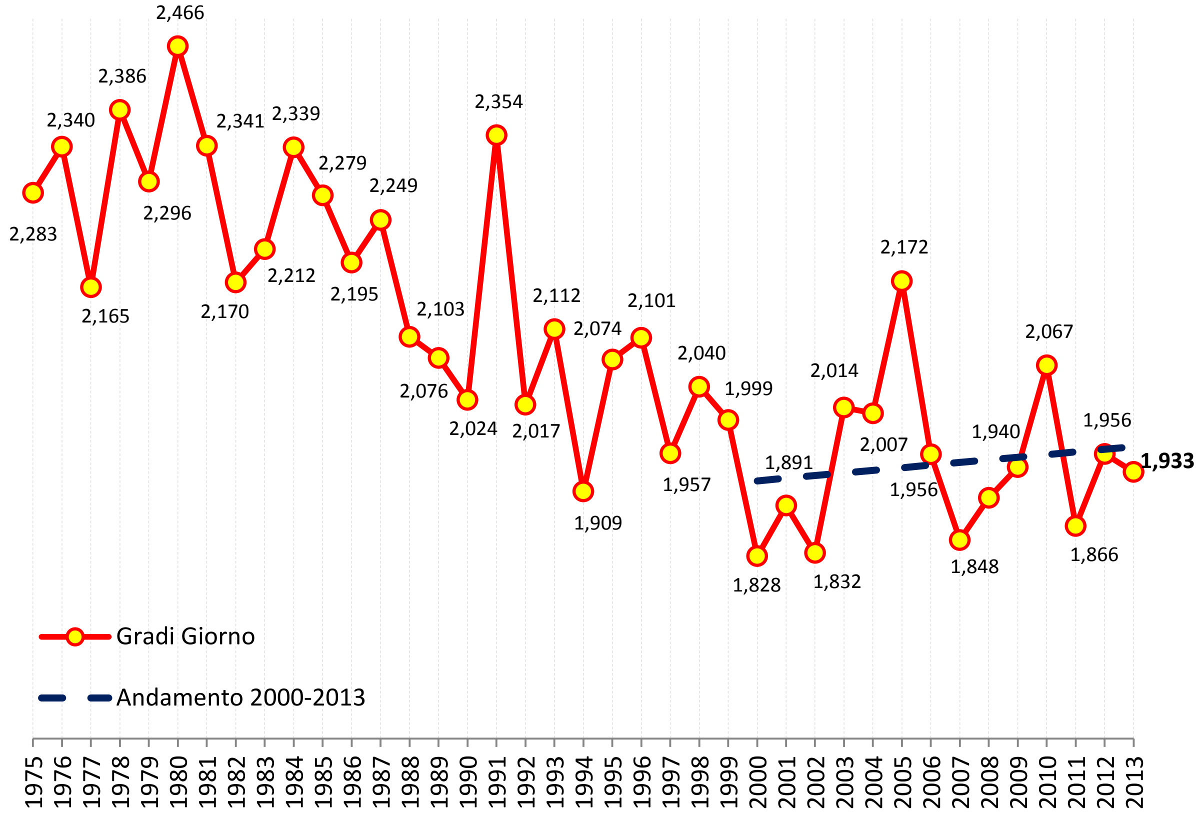
Consumi domestico	Domestic consumption
GG	Degree days

Documented and validated scenarios for annual variations in winter temperatures in Italy to 2023, with particular reference to the expected severity of winters in the long term, are not currently available in the literature.

To make up for the lack of information, the option of stripping out the climate variable from consumption for both 2013 and 2023 was initially considered, restating all values at standard temperature conditions, such as those laid down by the aforementioned Presidential Decree No 412/1993.

However, this approach would only produce meaningful results if the trend in medium to long-term winter severity (expressed in degree days) showed no clear temperature trends, thereby justifying the 'neutralisation'. However, this is not the case for Italy's winter climate: taking the period 1975-2013, for example (see graph below), a downward trend in national average degree days emerges, whereas restricting the scope of the analysis to the years 2000-2013 (next chart) reveals the opposite trend, i.e. an upward trend in degree days. The haphazard trends observed and the resulting subjectivity of any initial choice militates against the elaboration of climate scenarios to 2023. It is therefore deemed more prudent and appropriate to take the consumption figure for 2013 as a baseline, according to the actual weather conditions for the year, which can then be used as a benchmark for subsequent years. In any case, 2013 was fairly average compared with recent years (the degree days in 2013 in fact equalled the average degree days for the past eight years).

Figure 19 – Trend for national average degree days from 1975 to 2013



Gradi Giorno	Degree days
Andamento 2000-2013	Trend 2000-2013

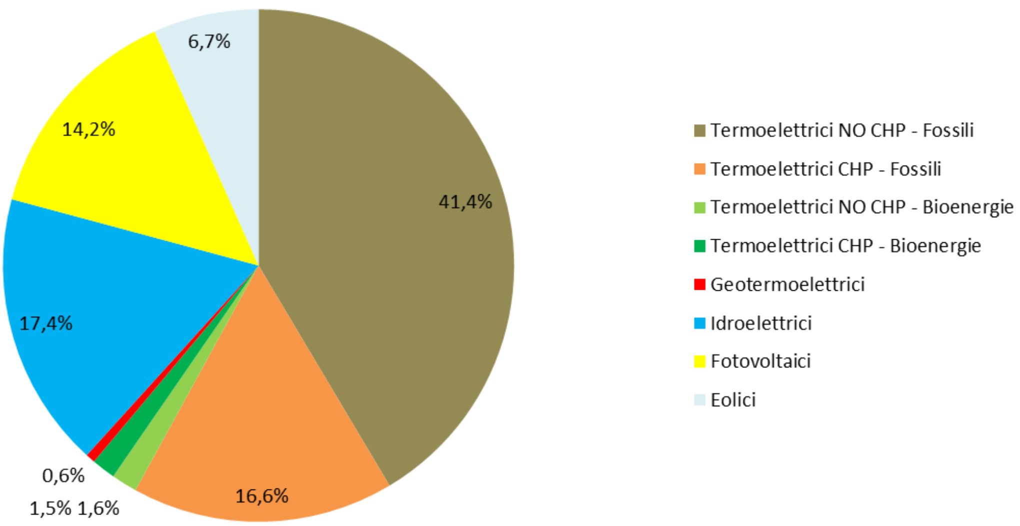
2 Cogeneration in the national stock of power plants

2.1 Thermal power stations

At the end of 2013, Italy had total installed electrical capacity of 128.4 GW, including 79.2 GW (62 %) consisting of thermal power stations[20]. The rest is divided as follows: 17 % hydropower plants and 21 % other renewable sources such as solar and wind. Looking at the composition of thermal power stations, 29 % of their capacity (and 18 % of total electrical capacity), amounting to 23.2 GW, is from CHP plants[21].

On the basis of Terna's statistical data, the gross output of electricity by the total stock of Italian power stations in 2013 amounted to 290 TWh, of which 192 TWh from the stock of thermal power stations. CHP plants produce in total 91 TWh of electricity.

Figure 20 – Breakdown of gross output of electrical power stations in 2013 – Total 128.4 GW



Termoelettrici NO CHP - Fossili	Non-CHP thermal power plants – Fossil fuels
Termoelettrici CHP - Fossili	CHP thermal power plants – Fossil fuels
Termoelettrici NO CHP - Bioenergie	Non-CHP thermal power plants – Bioenergy
Termoelettrici CHP - Bioenergie	CHP thermal power plants – Bioenergy
Geotermoelettrici	Geothermal
Idroelettrici	Hydroelectric

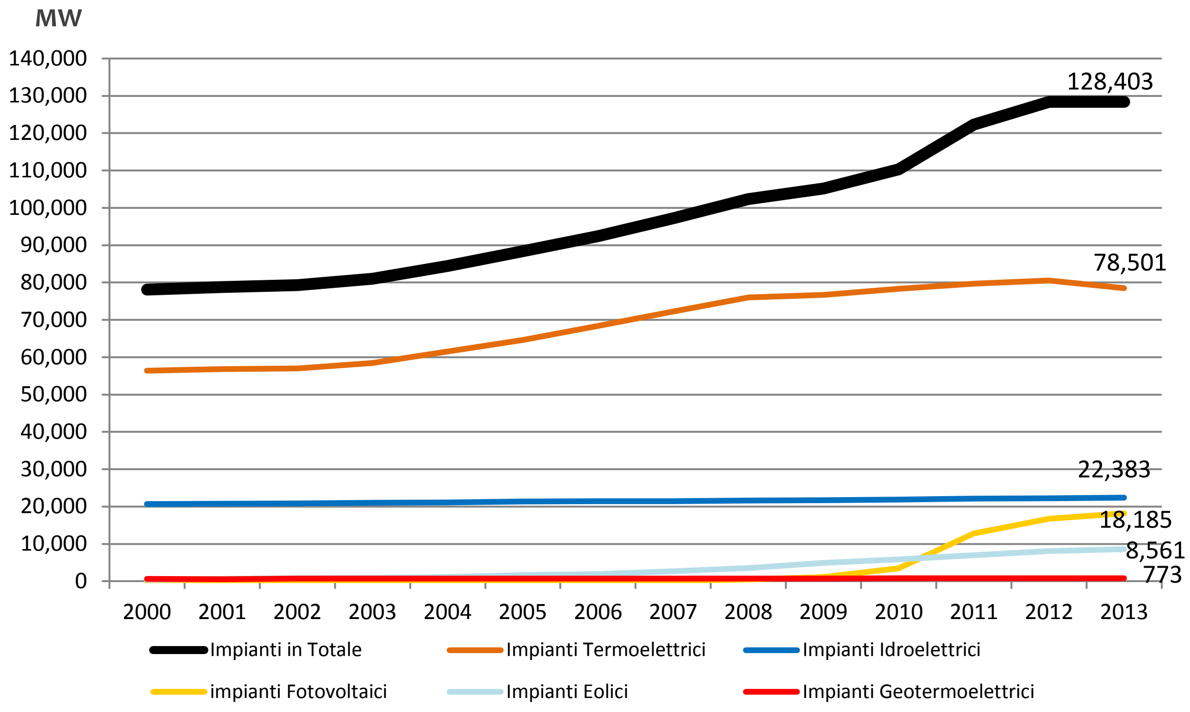
[20] This group includes plants using the following sources: fossil fuels, geothermal energy, bioenergy and waste.

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

Fotovoltaici	Photovoltaic
Eolici	Wind

An analysis of the time series of installed capacity shows significant, steady growth in recent years. The greatest contributors have been renewable sources such as solar and wind power. On the other hand, thermal power stations declined in 2013 after peaking in 2012.

Figure 21 – Time series of gross output of electric power plants



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

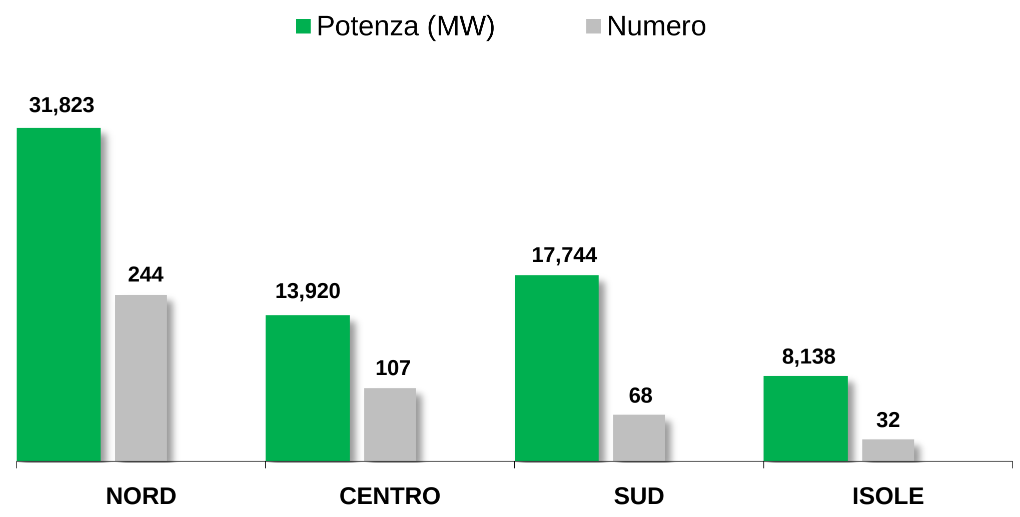
The national peak loads of around 55 GW, usually reached in summer, and the thermoelectric power output which last year (2014) dropped below 200 TWh[22], indicate a significant thermoelectric over-capacity, with several stations used mainly for reserve purposes, while others are largely inactive and close to decommissioning.

[22] This corresponds on average to fewer than 3000 equivalent hours of use of thermoelectric capacity. This reduction in the number of hours of thermoelectric power production is driven by several factors including: stagnation of electricity demand, development of renewable power production and, in recent years, an increase in hydropower generation too.

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 5MWe. The installed capacity of this size class is 71.6 GW (90 % of thermoelectric and 56 % 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 31.8 GW. Central Italy has 23 % of these plants, and the south and Islands have 22 %. Looking at plant density per km^2, this is greater in the north of the country (1 plant every 453 km^2), while in southern Italy and on the islands their density is about three times lower (1 plant every 1 237 km^2).

Figure 22 – Geographical distribution of thermal power stations with a power output of more than 5 MW. Output and number



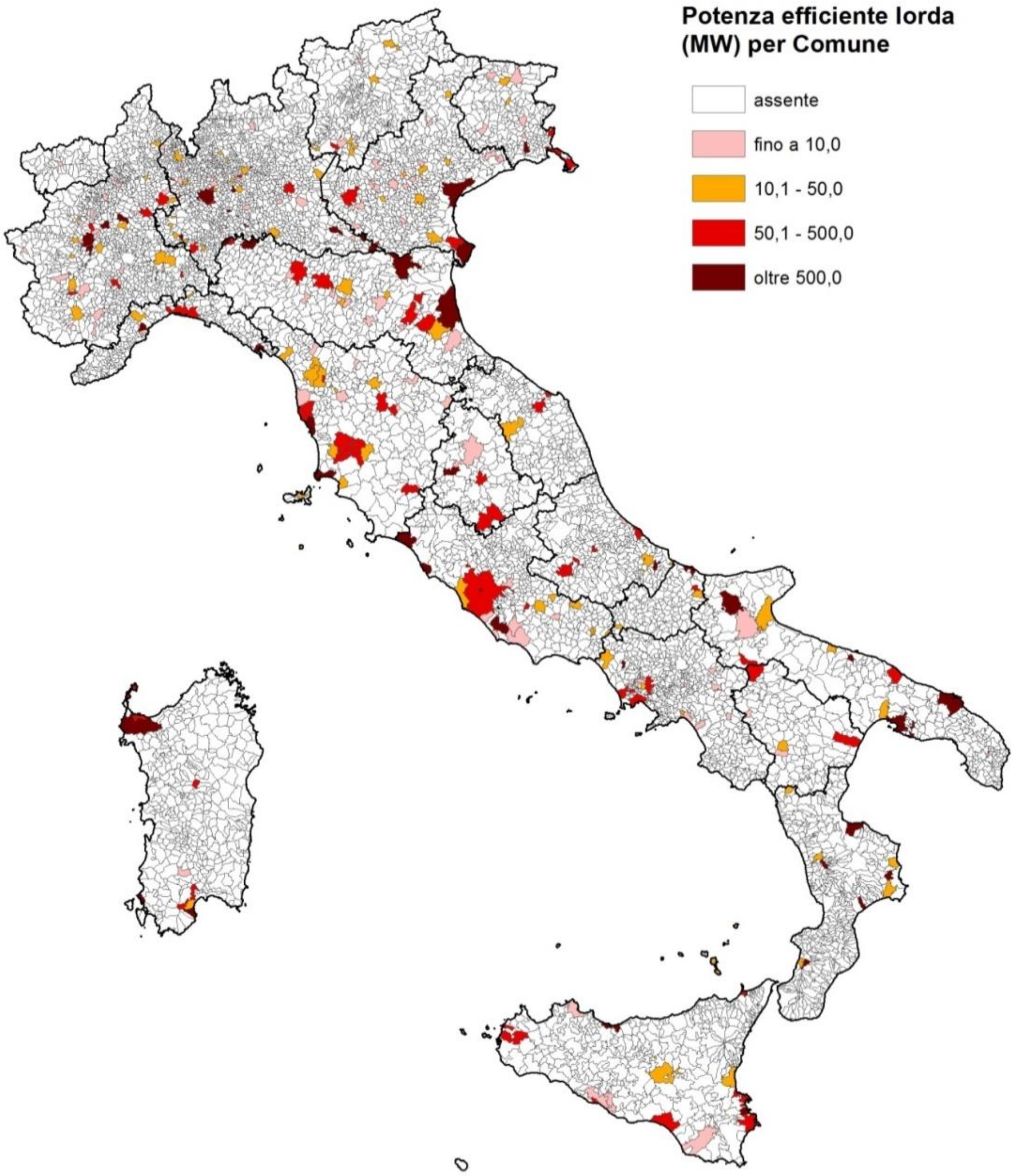
Potenza (MW)	Power output (MW)
Numero	Number
NORD	Northern Italy
CENTRO	Central Italy
SUD	Southern Italy
ISOLE	Islands

The following map shows the geographical distribution of medium-large thermoelectric power installed 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 RES (photovoltaic, wind, hydroelectric) and all electricity generation plants below 5 MWe, which on initial assessment are considered to be less interesting 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 23 – Geographical distribution of thermoelectric capacity by plants exceeding 5 MW



Potenza efficiente lorda (MW) per Comune	Gross electric output (MW) by municipality
Assente	Absent
Fino a	Up to
Oltre	Above

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[23] in northern Italy and the presence of more evenly spread industrial plants in that area, compared with the south where industries are located in fewer large industrial sites. The map also shows some correspondence between the country's large industrial centres and some of the areas with the greatest thermoelectric potential (to give some examples: Porto Marghera (Venice) in the north; Piombino (Livorno) in the centre; Taranto in the south; Priolo Gargallo (Syracuse), Augusta (Syracuse) and Porto Torres (Sassari) on the islands). Many of these sites have both thermal power stations owned by the utilities that feed electricity into the national grid and sizeable self-production plants mostly supplying energy to industries on site.

For the purpose of the assessments made in this study, the plants have been characterised in terms of types and fuels by using and cross-checking 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 energy from renewable sources).

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

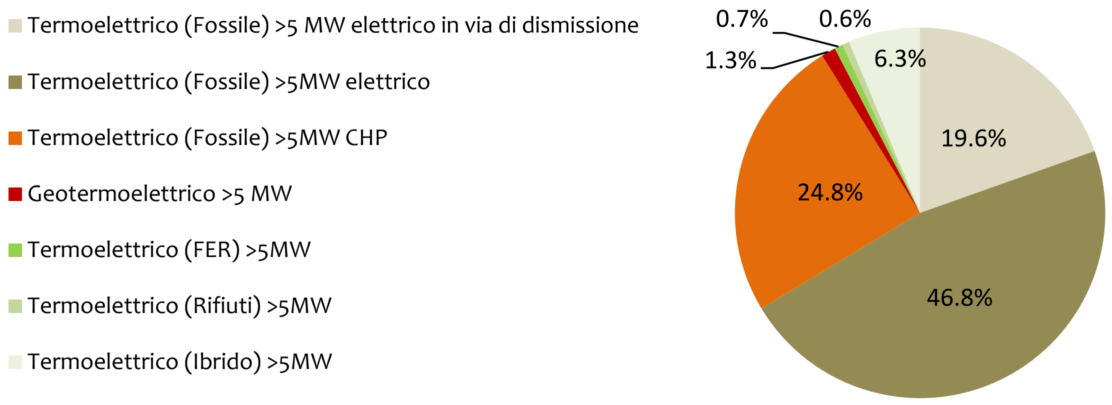
The plants have been classified according to type of fuel as follows:

- thermoelectric (fossil): plants using fossil fuels such as coal, petroleum products, natural gas, other derived gases;
- thermoelectric (RES): 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 2013 was 128.4 GW but, as stated earlier, this study only considers the share of thermal power stations with a capacity of more than 5 MWe to assess its heat recovery potential. The installed capacity of these plants can be measured as 71.6 GW, minus about 20 % of plants currently being decommissioned.

[23] Electricity consumption in Northern Italy is double that of southern Italy and the islands

Figure 24 – Mix of thermoelectric generation > 5 MW – Total 71.6 GW



Termoelettrico (Fossile) >5MW eletricco in via dismissione	Thermoelectric (fossil fuels) > 5 MW electrical capacity, currently being decommissioned
Termoelettrico (Fossile) >5MW eletricco	Thermoelectric (fossil fuels) > 5 MW electrical capacity
Termoelettrico (Fossile) >5MW CHP	Thermoelectric (fossil fuels) > CHP capacity 5 MW
Geooelettrico >5MW	Geoelectric > 5 MW
Termoelettrico(FER) >5MW	Thermoelectric (RES) > 5 MW
Termoelettrico(Rifiuti) >5MW	Thermoelectric (waste) > 5 MW
Termoelettrico(Ibrido) >5MW	Thermoelectric (hybrid) > 5 MW

Looking at the energy sources of thermal power stations having a capacity exceeding 5 MW, we can see that the vast majority (about 90 %) uses fossil fuels; a share (25 % of total installed capacity) of those plants is used for cogeneration. Just 1.3 % of the thermoelectric capacity mix is made up of geothermal electrical plants, while only 0.7 % is made up of plants powered by bioenergy[24]; waste-to-energy plants and hybrid plants account for around 7 %.

2.1.1 Map of electricity generation installations with total annual production of more than 20 GWh

The following map, in accordance with Annex 3 to Legislative Decree No 102 of 4 July 2014, shows the geographical distribution of thermal power stations with annual electricity output of more than 20 GWh, with an indication of the type of plants and power sources.

The analysis focuses on thermal power stations, both CHP and non CHP, having a capacity of more than 5 MW, enabling them to achieve the above-mentioned minimum annual electricity production of 20 GWh.

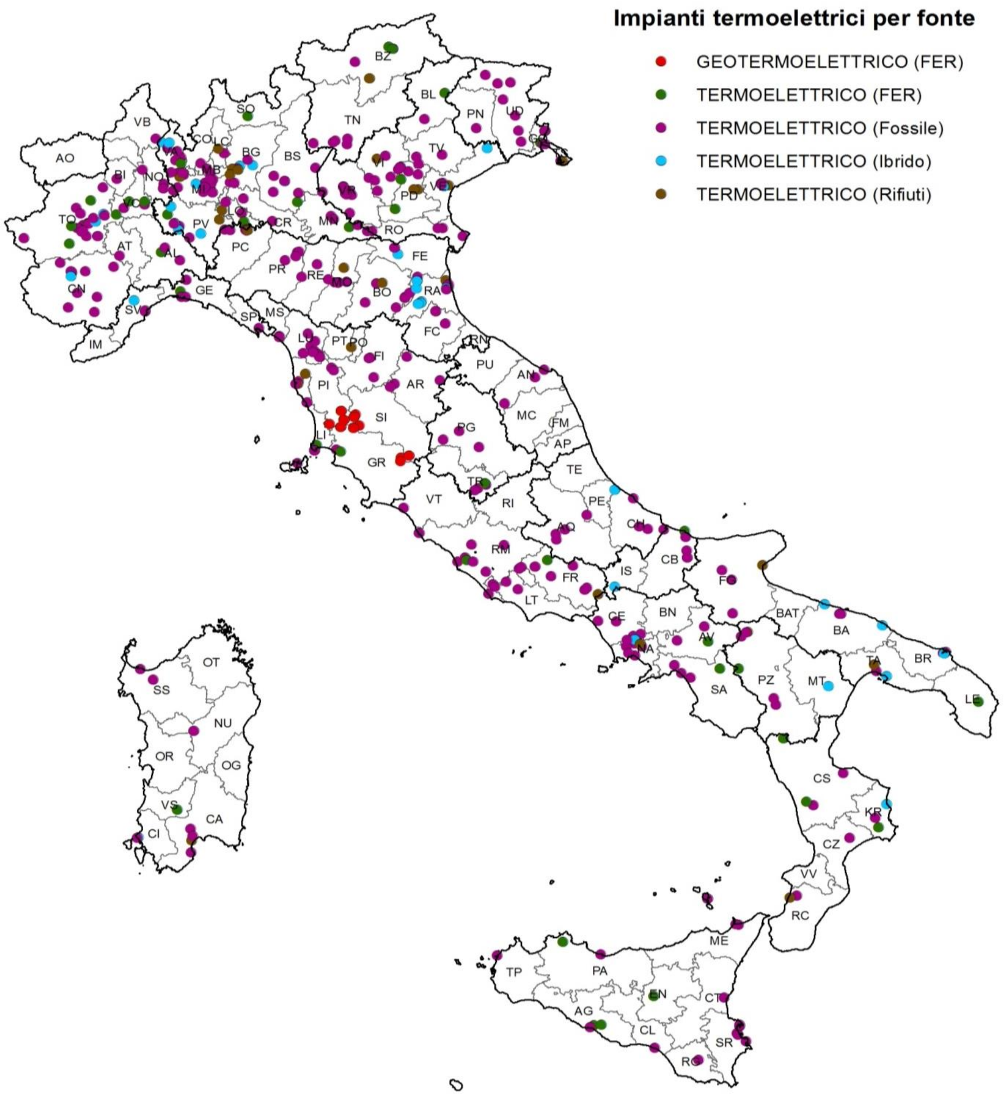
The plants have been characterised by collating and harmonising the data from several databases managed by different energy sector players (Terna, GSE, AIRU, Utilities).

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

The thermal power stations have been characterised in terms of:

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

Figure 25 – Geographical distribution of thermal power stations with a capacity of more than 5 MW



Impianti termoelettrrici per fonte	Thermal power stations by source
GEOOTERMOELETTRICO (FER)	Geothermal power (RES)
TERMOELETTRICO (FER)	Thermoelectric (RES)
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 (10) and waste-fuelled plants (8). Piedmont has a higher than average share of plants using renewable energy sources (20 % of its plants are RES), while Tuscany stands out as the only region with geothermal electricity plants. In the centre and south, the thermal power stations using renewable sources are fewer but more evenly spread.

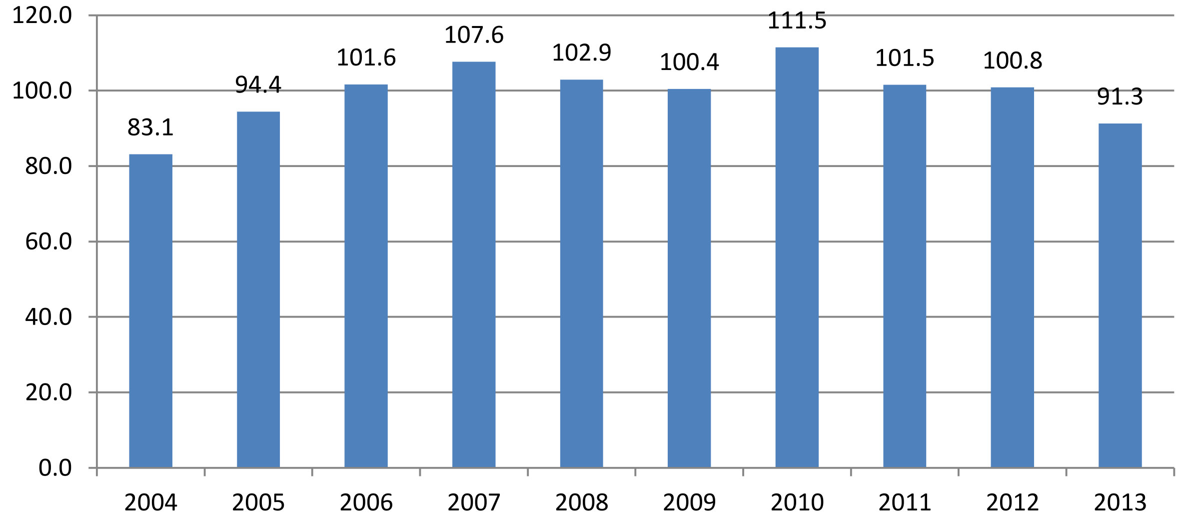
2.2 Cogeneration (CHP) plants

As at 2013, 18 % of the national electricity generation capacity, or 23 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 fluctuating, peaking in 2010 and then dropping in 2013 back to 2005 levels.

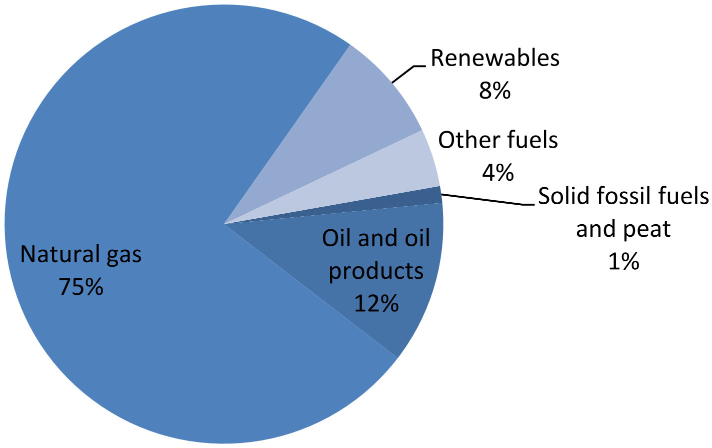
In 2013, electricity generation in CHP plants amounted to 91.3 TWh, based on installed capacity of 23 GW.

Figure 26 – Time series of electricity generation by CHP plants (TWhe)



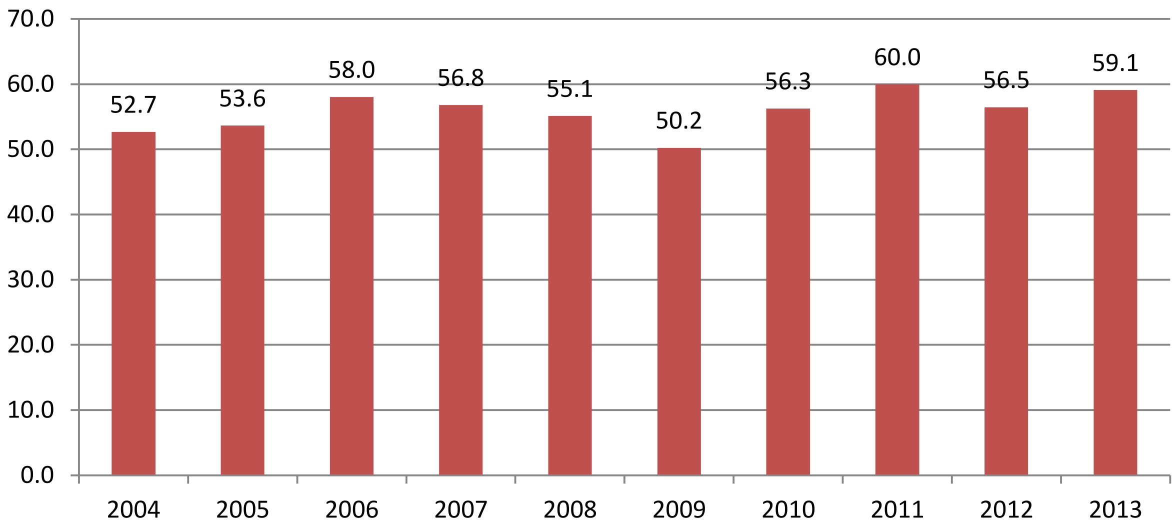
Focusing on 2013, we can note that the fuel most used in these plants is natural gas, which alone accounts for 75 % of gross power generation from CHP.

Figure 27 – Electricity output from CHP plants in 2013 by source – Total 91.3 TWhe



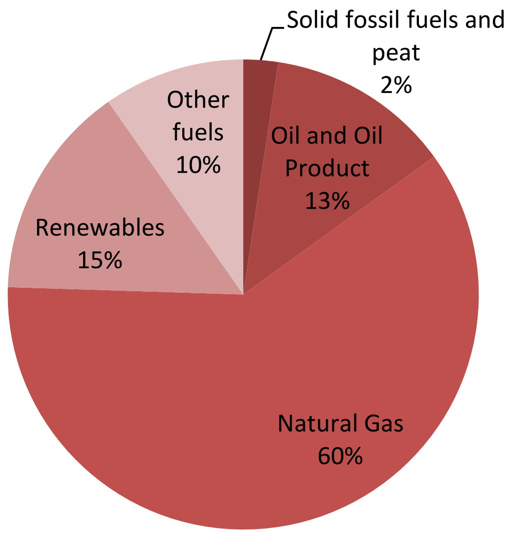
The useful heat from CHP plants in 2013 stood at 59.1 TWht, up from the previous years. The trend observed in individual years is slightly different from that of electricity, but it mirrors the same fluctuations.

Figure 28 – Time series of the useful heat produced by CHP plants (TWht)



More than 60 % of the useful heat comes from natural gas.

Figure 29 – Useful heat produced by CHP plants in 2013 by source – Total 59.1 TWht



It should be noted that the electricity highlighted earlier concerns all the energy produced in plants that operated in cogeneration mode but does not refer to the value of cogenerated electricity.

For this purpose, Directive 2012/27/EU (Annex I) has laid down a method for calculating 'electricity from cogeneration', which is defined as the electricity generated in a process linked to the production of useful heat. The values used for the calculation of electricity from cogeneration are determined on the basis of the expected or actual operation of the unit under normal conditions of use.

The production of electricity from cogeneration is considered equal to the annual total production of electricity by cogeneration units having 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 the 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 electricity divided by the heat produced, using the method set out in Annex I to Directive 2012/27/EU.

Applying this method, the electricity cogenerated in 2013 is 36.7 TWh (Eurostat), well below the 91.2 TWh which includes all the electricity from cogeneration installations. Natural gas contributes 67 % of the total.

Figure 30 – Time series of 'electricity from cogeneration' as defined in Annex 1 to Directive 2012/27/EU (TWh)

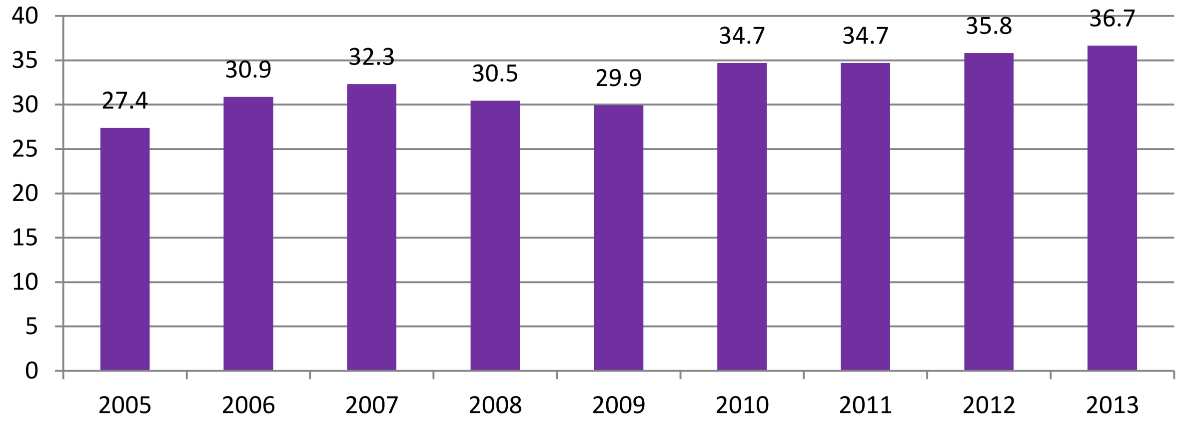
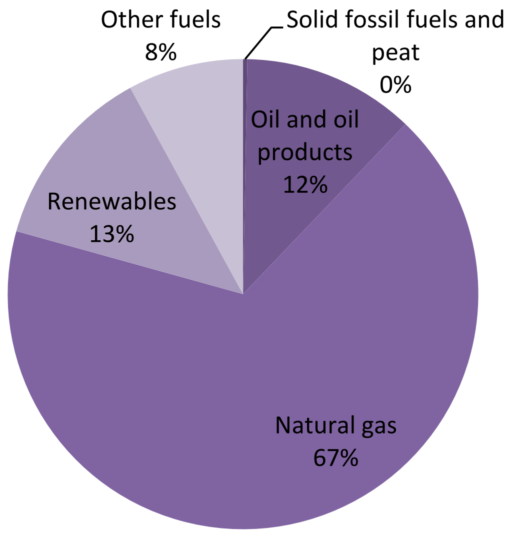


Figure 31 – Production of electricity from cogeneration in 2013 by source – Total 36.7 TWhe



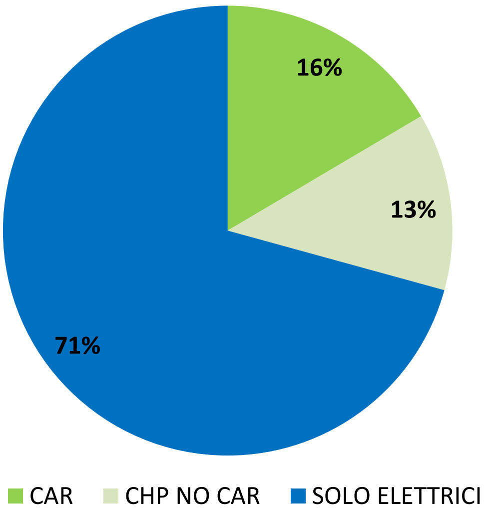
2.3 High-efficiency cogeneration (CHP) plants

The analyses in this section derive partly from calculations produced from data contained in applications submitted to GSE for output in 2013. The 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 for calculation of efficiency of cogeneration and primary energy savings are determined on the basis of the operation of the unit under normal conditions of use. In accordance with Annex 2 to the Ministerial Decree of 4 August 2011, cogeneration is classed as high-efficiency if the output from the cogeneration units provides primary energy savings (PES) of at least 10 % compared with the reference values for separate production of electricity and heat. 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 2013, 29 % of installed thermoelectric capacity was categorised as cogeneration, and more than half of this satisfied the definition of high-efficiency cogeneration.

Figure 32 – Breakdown of thermoelectric [25]output by level of cogeneration



CAR	HIGH-EFFICIENCY CHP
CHP NO CAR	NON-HIGH-EFFICIENCY CHP
SOLO ELETTRICI	ELECTRICITY ONLY

Considering the approximately 14 GW of thermal power stations producing electricity only which are being shut down, the share of cogeneration plants could well rise in the coming years to close to 40 % of the national thermoelectric capacity.

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

The thermal power stations producing electricity only are spread quite evenly across the country. Conversely, 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[26]. The operating data for assessing their compliance with high-efficiency cogeneration requirements relate to the year 2013.

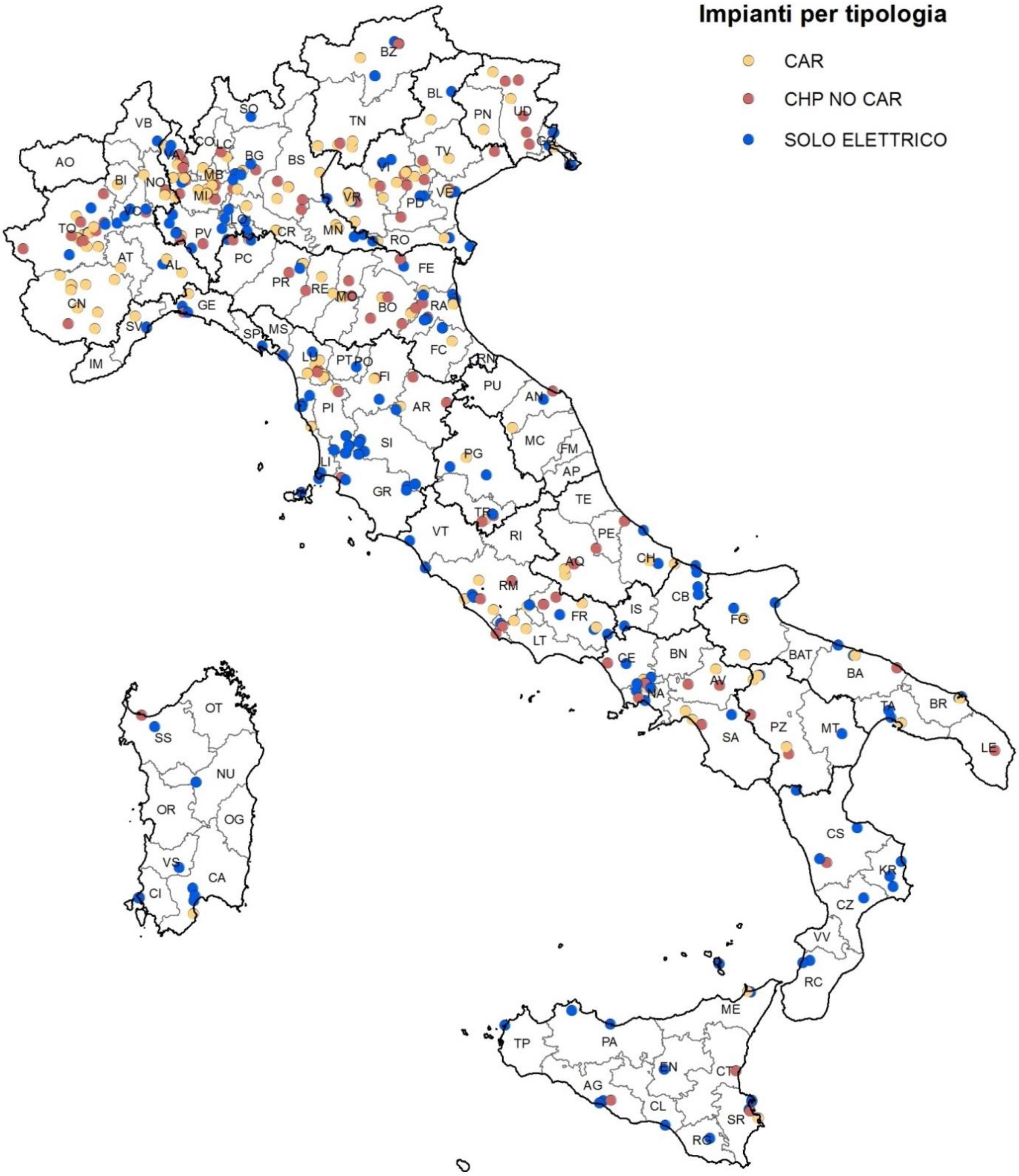
Plants have been classed with regard to cogeneration as follows:

- electricity only: producing only electricity
- Non-HE CHP: plants producing both electricity and heat but which in 2013 did not meet the requirements for classification as high-efficiency CHP[27]
- High-efficiency CHP: plants which in 2013 produced electricity and heat in accordance with high-efficiency requirements.

[26] Thus the map does not include about 5% of total high-efficiency CHP capacity in 2013. Among high-efficiency CHP plants, more than half of the 1024 total units are smaller than 5 MW and have total rated capacity of just above 500 MWe.

[27] They include plants not classed as high-efficiency CHP by reason of their design and of their operating mode in 2013. Plants currently classed as Non-high-efficiency CHP, might well be reclassified as high-efficiency CHP in subsequent years.

Figure 33 – Map of thermal power stations with a capacity of more than 5 MWe, classed according to cogeneration type



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

2.3.1 HE CHP: plant technologies

As stated at the start of this chapter, the assessments made in this section of the study are based largely on the applications for recognition of high-efficiency CHP received by GSE for the year 2013. More precisely, here below, the number of units, total generation capacity and gross electricity output refer to the total number of units that applied to GSE for recognition as high-efficiency units. 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 refers to 1 025 cogeneration units, with total generation capacity exceeding 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, 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 more than 85 % of the total. Combined-cycle gas turbines with heat recovery (CC) and gas turbines with heat recovery (GT) make up 11.8 % of the total.

Figure 34 – Number of units (100 % = 1 025 units)

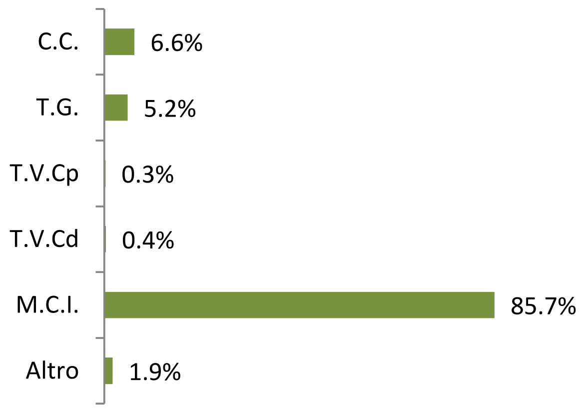
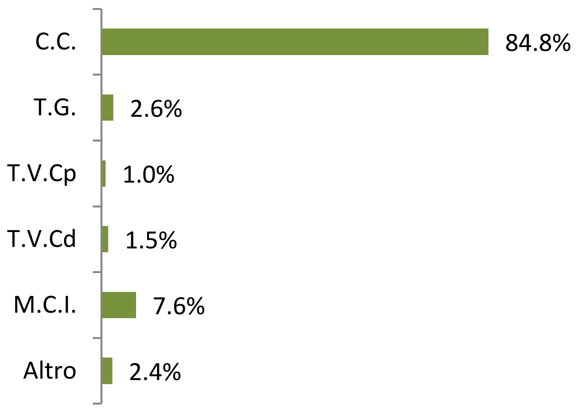


Figure 35 – Generation capacity (100 % = 13 087 MW)



Out of the 13 GW of capacity, 7.6 % 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 (85 %) 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 also 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 high-efficiency electricity produced in 2013 amounts to 26 142 GWh, while the useful heat amounts to 31 331 GWh.

Figure 36 – 'Gross' electricity (100 % = 55 019 GWhe)

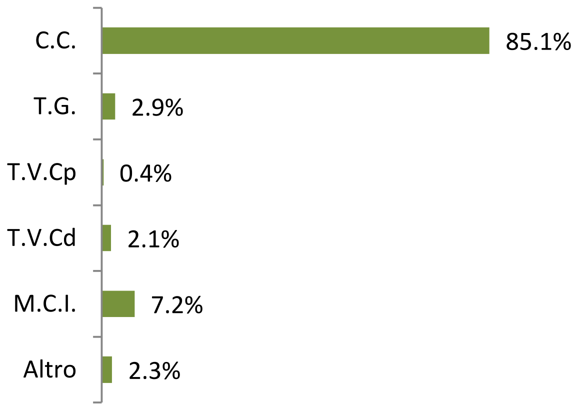
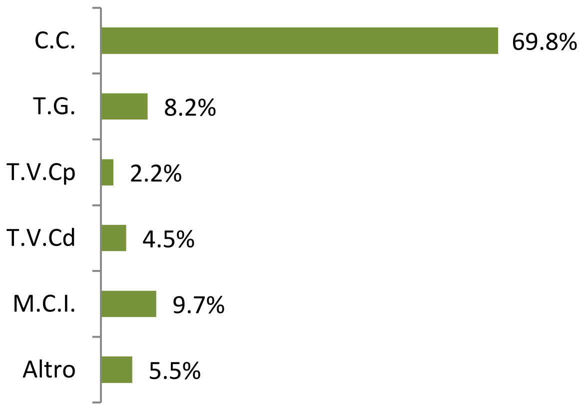


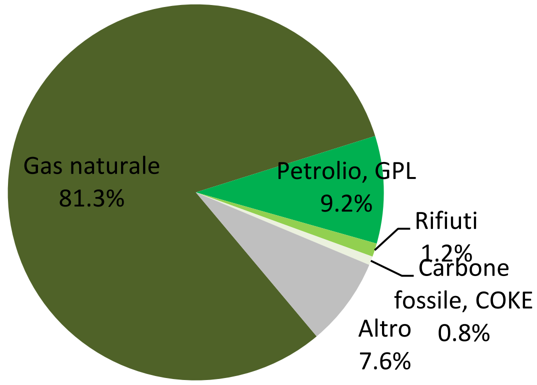
Figure 37 – Useful heat (100 % = 31 331 GWht)



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

Waste is used only by units with steam-condensing extraction turbine, while hard coal/coke is used only by units consisting of steam back-pressure turbine.

Figure 38 – Fuels used by the plants that applied for classification as high-efficiency CHP in 2013

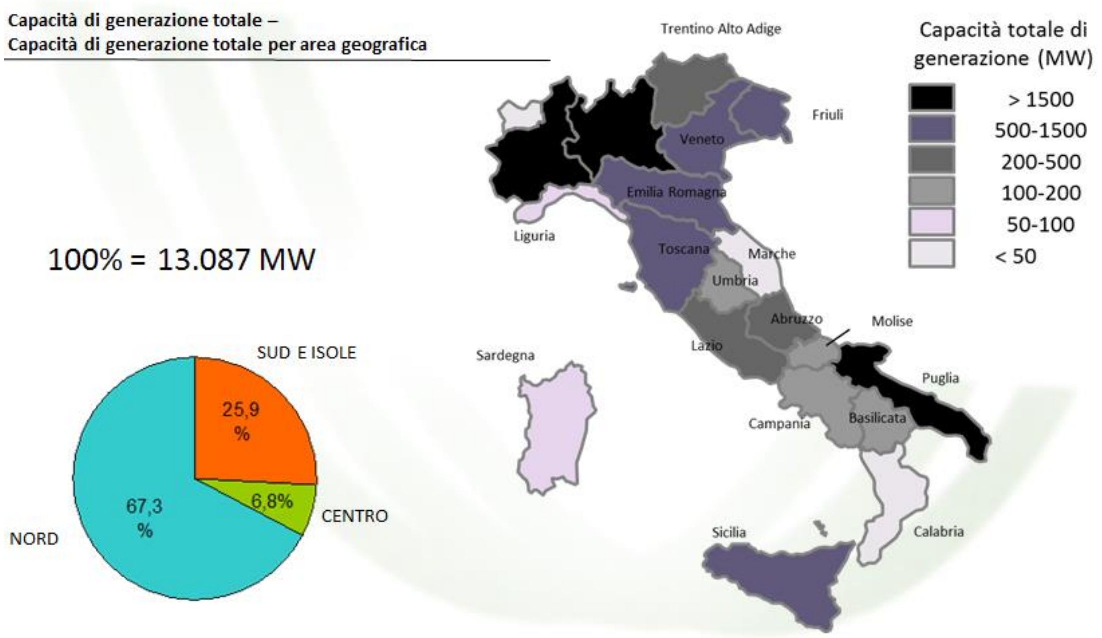


2.3.2 HE CHP: geographic distribution

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

About 67 % of generation capacity is located in the north, especially in Lombardy and Piedmont. In the south and on the islands, only Puglia and Sicily have sizeable values. The share of central Italy is low; significant values are found only in Tuscany and Emilia Romagna.

Figure 39 – Geographical distribution of the plants that applied for recognition of high-efficiency CHP in 2013



Capacità di generazione totale -	Total generation capacity –
Capacità di generazione totale per area geografica	Total generation capacity by geographical area

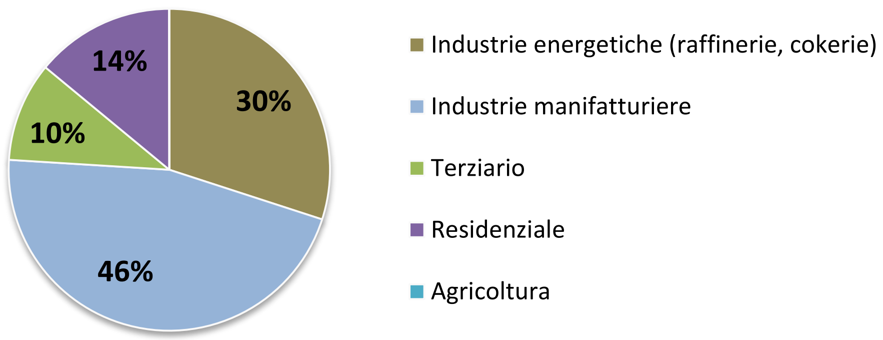
Capacità totale di generazione (MW)	Total generation capacity (MW)
SUD E ISOLE	SOUTH AND ISLANDS
CENTRO	Central Italy
NORD	Northern Italy

2.3.3 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 made of the sectors that in 2013 used the heat and electricity from high-efficiency CHP units. This was done by identifying, for each CHP plant the sector of the company owning it. If the owner was an ESCO or a utility, the sector of the final users of the thermal energy produced by the high-efficiency CHP plant was also considered.

In 2013, the heat produced by high-efficiency CHP was used as follows: 76 % by the industrial sector (30 % refineries and 46 % other manufacturing industries); and 24 % by the residential and service sectors, mostly via district heating infrastructure[28].

Figure 40 – Breakdown of the final uses of the heat produced by high-efficiency CHP by sector

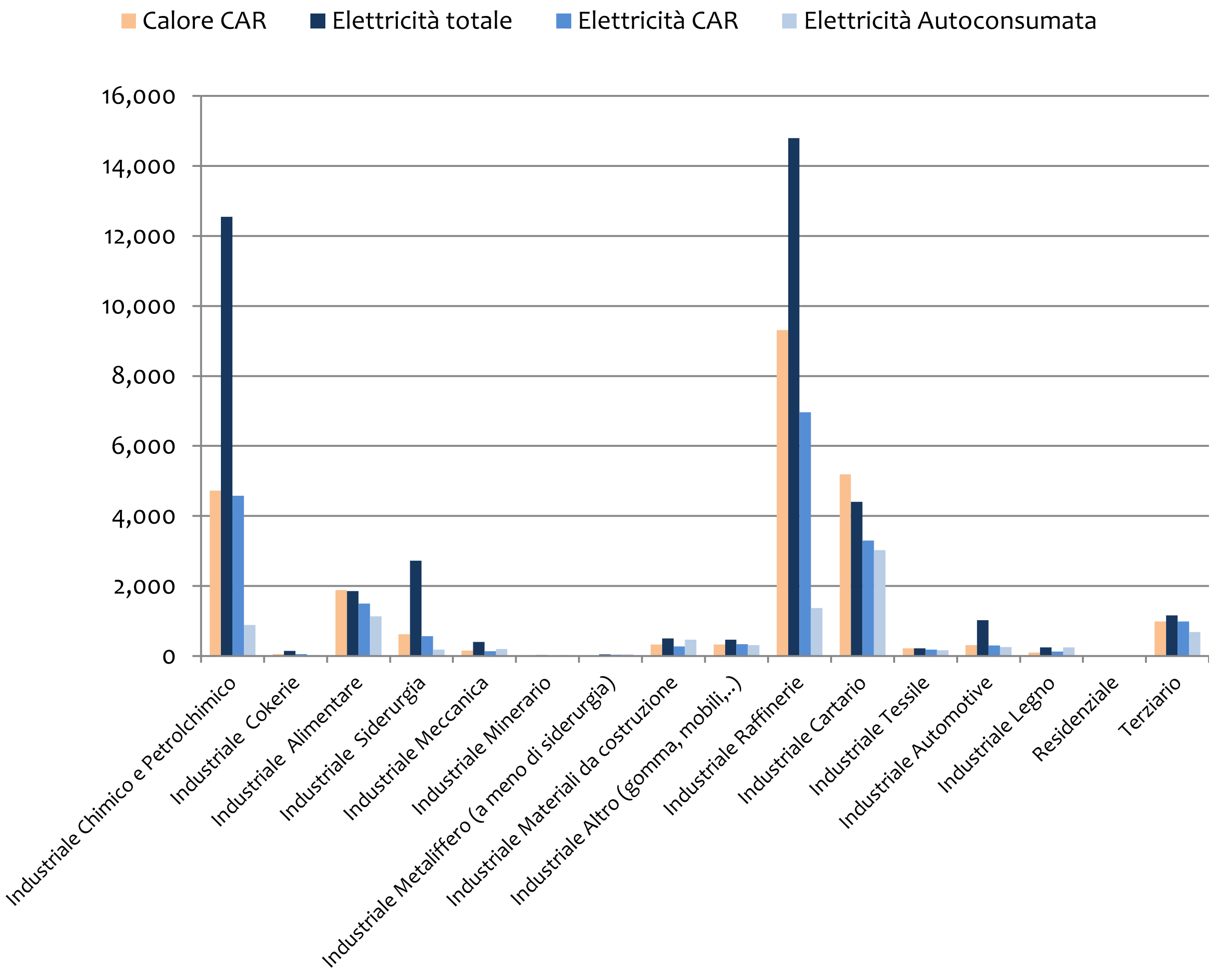


Industrie energetiche (raffinerie, cokerie)	Energy industries (refineries, coke ovens)
Industrie manifatturiere	Manufacturing industries
Terziario	Services
Residenziale	Residential
Agricoltura	Agriculture

The industrial sector is the main end-use sector for heat from high-efficiency CHP. Within industry, the greatest end-users are in order: refineries, chemical and petrochemical industries and the paper industry.

[28] The heat produced by high-efficiency CHP units and conveyed via district heating networks was associated with end-use sectors by analysing national statistics on district heating shown in Chapter 3.

Figure 41 – Electricity (total produced, produced by high-efficiency CHP, self-consumed) and useful heat from individual high-efficiency CHP units[29] by sector



Calore CAR	HE CHP heat
Elettricità totale	Total electricity
Elettricità CAR	HE CHP electricity
Elettricità Autoconsumata	Self-consumed electricity
Industriale Chimico e petrolchimico	Industrial Chemical and petrochemical
Industriale Cokerie	Industrial Coking plants
Industriale Alimentare	Industrial Food sector
Industriale Siderurgia	Industrial Iron and steel
Industriale Meccanica	Industrial Mechanics

[29] This dataset does not include high-efficiency CHP units in district heating systems.

Industriale Minerario	Industrial Mining
Industriale Metaliffero (a meno di siderurgia)	Industrial Metals (excluding iron and steel)
Industriale Materiali da costruzione	Industrial Building Materials
Industriale Altro (gomma, mobil,…)	Industrial Other (rubber, furniture, etc.)
Industriale Raffinerie	Industrial Refineries
Industriale Cartario	Industrial Paper
Industriale Tessile	Industrial Textiles
Industriale Automotive	Industrial Automotive
Industriale Legno	Industrial Timber
Residenziale	Residential
Terziario	Services

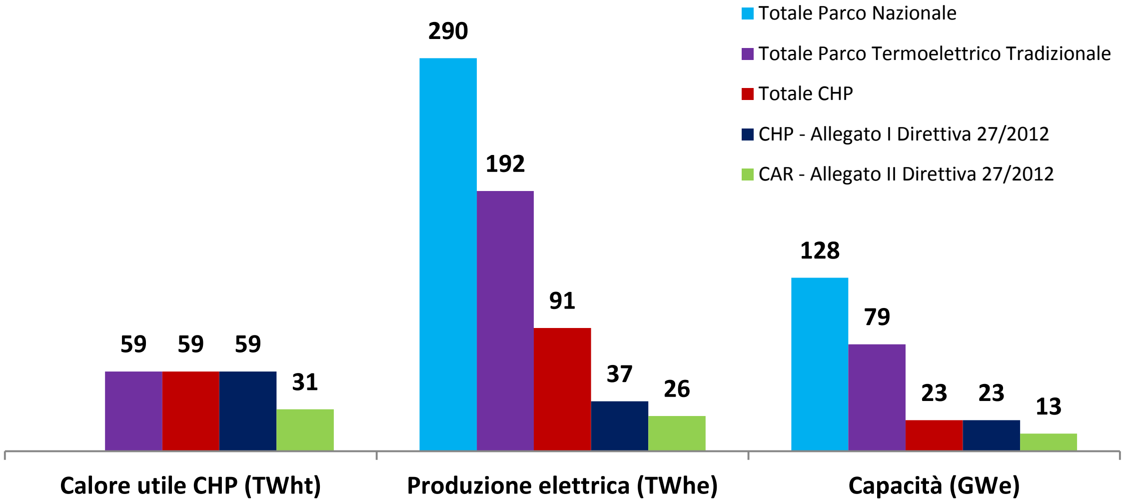
2.4 Overview of the national stock of power plants

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 in the various meanings of cogeneration set out in the legislation.

As at 2013, the national stock of electrical power plants had a capacity of 128 GW. The amount of electricity produced was 290 TWhe.

- A subset of the national stock of power plants consists of the stock of thermal power stations. This has a capacity of 79 GW and an output of 192 TWhe.
- The Italian stock of thermal power stations includes a share of plants operating in cogeneration mode: this further subset has a capacity of 23 GW and produces 91 TWhe of electricity and 59 TWht of useful heat.
- According to Directive 2012/27/EU, it is important to identify in cogeneration installations the share of electricity that is truly cogenerated. 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 is 37 TWhe. The value of the useful heat produced remains 59 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 submitted applications is 13 GW, the useful heat produced is 31 TWht and the electricity produced in high-efficiency cogeneration mode is 26 TWhe.

Figure 42 – Summary diagram of the national stock of thermal power stations, specifying capacity [30](GWe), electricity production (TWhe) and useful heat (TWht)



Totale Parco Nazionale	Total national stock
Totale Parco Termoelettrico Tradizionale	Total conventional thermal power plants
Totale CHP	Total CHP
CHP – Allegato I Direttiva 27/2012	CHP – Annex I, Directive 27/2012/EU
CAR – Allegato II Direttiva 27/2012	HE CHP – Annex II, Directive 27/2012/EU
Calore utile CHP (TWht)	Useful heat CHP (TWht)
Produzione elettrica (TWhe)	Electrical production (TWhe)
Capacità (GWe)	Capacity (GWe)

[30] The capacity refers to the overall capacity of plants, including units which in 2013 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 the high-efficiency CHP classification (however, the high-efficiency CHP production is that of actual approved high-efficiency CHP plants).

3 District heating

District heating means the distribution of thermal energy from one or more central sources of production through a network to multiple buildings or sites, for the use of space heating, manufacturing processes and domestic hot water supply.[31]

This chapter describes the current stage in the spread of district heating systems in Italy. The main sources of information used are:

- AIRU, Associazione Italiana Riscaldamento Urbano (Italian Urban Heating Association), which collects and publishes in its yearbook detailed information on the main district heating systems in operation in Italy;
- GSE, which every year carries out a direct survey on the plants using renewable sources that produce only thermal energy intended at least partly for sale to third parties; this survey includes many district heating systems using biomass, which are generally small in size.

The data shown were obtained by collating them from the two above sources.

In 2013, the thermal energy fed into the grid by plants serving district heating networks amounted to 11 375 GWh, while the thermal energy supplied to customers amounted to 9 600 GWh. Losses during heat distribution came to 1 774 GWh (16 % of the feed-in energy).

The cooling energy supplied to users on the contrary was very low, at just 102 GWh.

[31] Article 2(1)(g) of Legislative Decree No 28/2011.

Table 28 – Overview of the district heating networks in Italy in 2013

Municipalities with district heating	**No**	**213**		
Total heated space	**Mm^3**	**316**		
Length of distribution networks	**km**	**4 088**		
Thermal energy supplied	**MWht**	**9 600 340**		
Residential	"	6 171 754	*% of total*	64 %
Services	"	2 752 995	"	29 %
Industrial	"	675 591	"	7 %
Losses	**MWht**	**1 774 276**	**% of feed-in energy**	**16 %**
Feed-in thermal energy	**MWht**	**11 374 616**		
FOSSIL FUEL – NON CHP	"	2 625 056	*% of total*	23 %
FOSSIL FUEL – CHP	"	5 774 034	"	51 %
RES – NON CHP	"	1 114 681	"	10 %
RES – CHP	"	385 262	"	3 %
WASTE – NON CHP*	"	5 006	"	0 %
WASTE – CHP*	"	1 470 577	"	13 %
Cooling supplied	**MWht**	**101 608**		
Services	"	99 832	*% of total*	98 %
Residential	"	1 337	"	1 %
Industrial	"	439	"	0 %
Losses	**MWht**	**3 568**	**% of feed-in energy**	**3 %**
Cooling supplied	**MWht**	**105 176**		
Efficient plants (feed-in thermal energy)	**Number**	**162**	**MWht**	**8 021 720**
RES ≥ 50 %	"	121	"	1 439 293
CHP ≥ 75 %	"	18	"	4 991 225
BOTH CHP ≥ 75 % AND RES ≥ 50 %	"	12	"	142 113
COMBINED ≥ 50 %	"	11	"	1 449 089
Non-efficient plants	**Number**	**51**	**MWht**	**3 352 896**

* The biodegradable fraction of waste is considered equal to 50 %

The existing district heating networks are found almost exclusively in northern parts of the country. Of these, 68 % are located in three Regions (Piedmont, Lombardy and Trentino Alto-Adige), where 81 % of the thermal energy from district heating is located. In central Italy, a significant exception is Tuscany where district heating networks distribute geothermal heat, which abounds in parts of the Region. Other district heating networks in central Italy can be found in Osimo (Ancona Province) and Rome.

3.1 Sectors of use

A total of 95 % of the energy delivered through district heating networks is used for space heating and domestic hot water (DHW) production; only 5 % is delivered for the production of process heat in the industrial sector.

The distribution of energy supplied by sector is shown below. A few district heating networks differ from the rest in that they supply thermal energy to more than one sector at once. As the figure below shows, heat is supplied primarily to the residential sector, and to a lesser extent the industrial sector.

Figure 43 – Heat supplied by sector in 2013

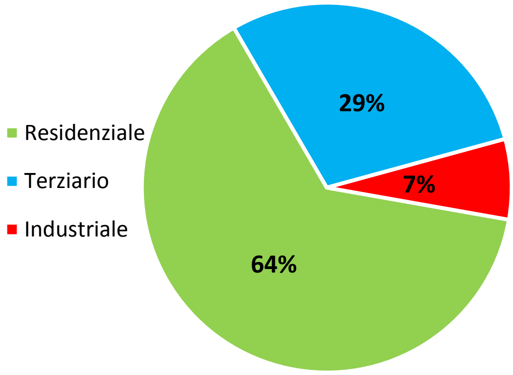
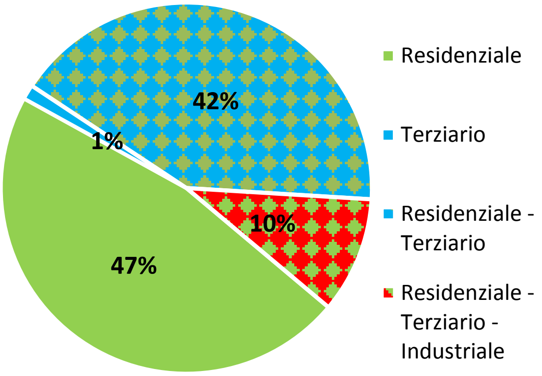


Figure 44 – Heat supplied by main sectors or groups of sectors in 2013



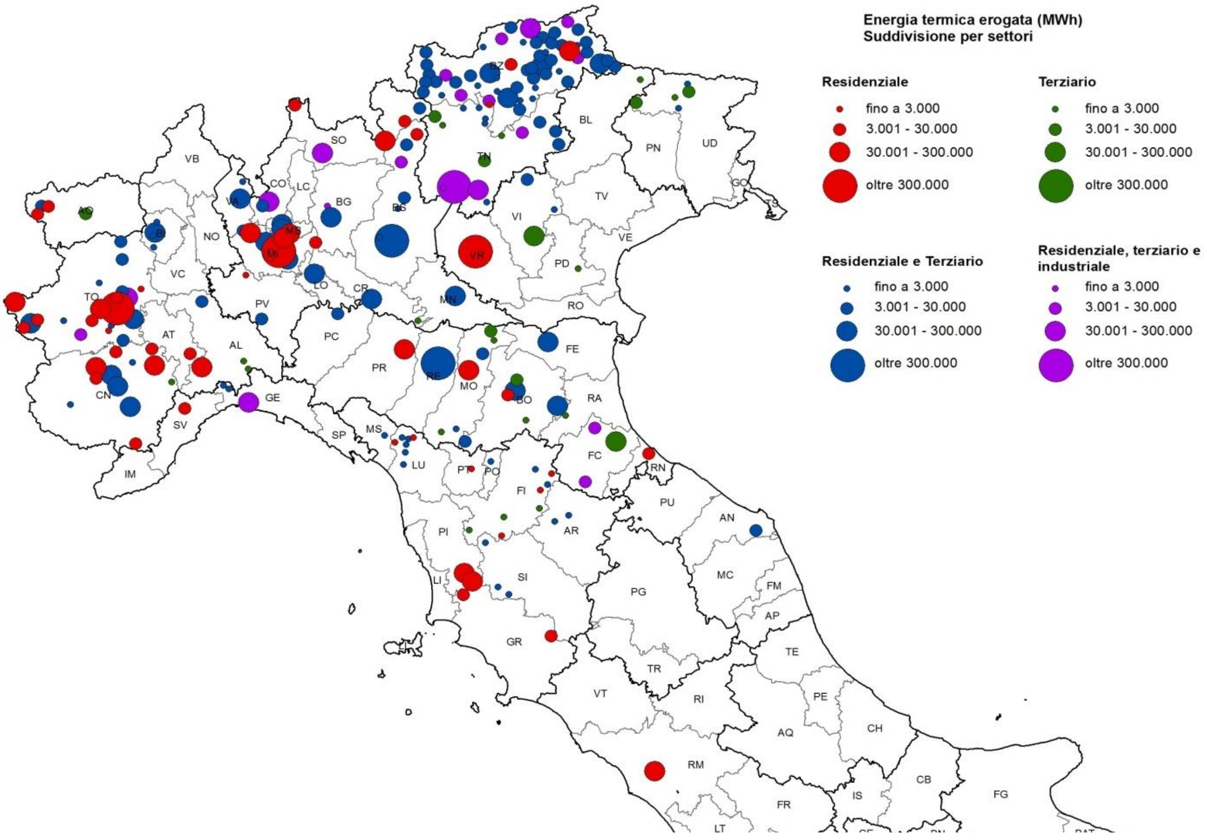
Residenziale	Residential
Terziario	Services
Industriale	Industrial

In the national district heating market, the share of the service sector is sizeable: just under 30 % 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 this sector. In any case, 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 (around 1 % of cases).

The following map shows the geographical distribution of the thermal energy delivered by district heating networks, in the different sectors of use. To identify the sectors of use served by the networks the following rules were applied:

- Residential sector network: the energy delivered to the residential sector is ≥ 70 % of the total energy delivered by the network
- Service sector network: the energy delivered to the service sector is ≥ 70 % of the total energy delivered by the network
- Residential-Service sector network: the energy delivered to each of the two sectors is ≤ 70 % while the sum of the energy delivered to the residential and service sectors is ≥ 90 %
- Residential-Service Industrial sector network: the energy delivered to the industrial sector is ≥ 10 %, while the residential and service sectors each receive < 70 % of the total energy delivered by the network

Figure 45 – Geographical distribution of the thermal energy delivered by district heat networks – Breakdown by main sector (2013)

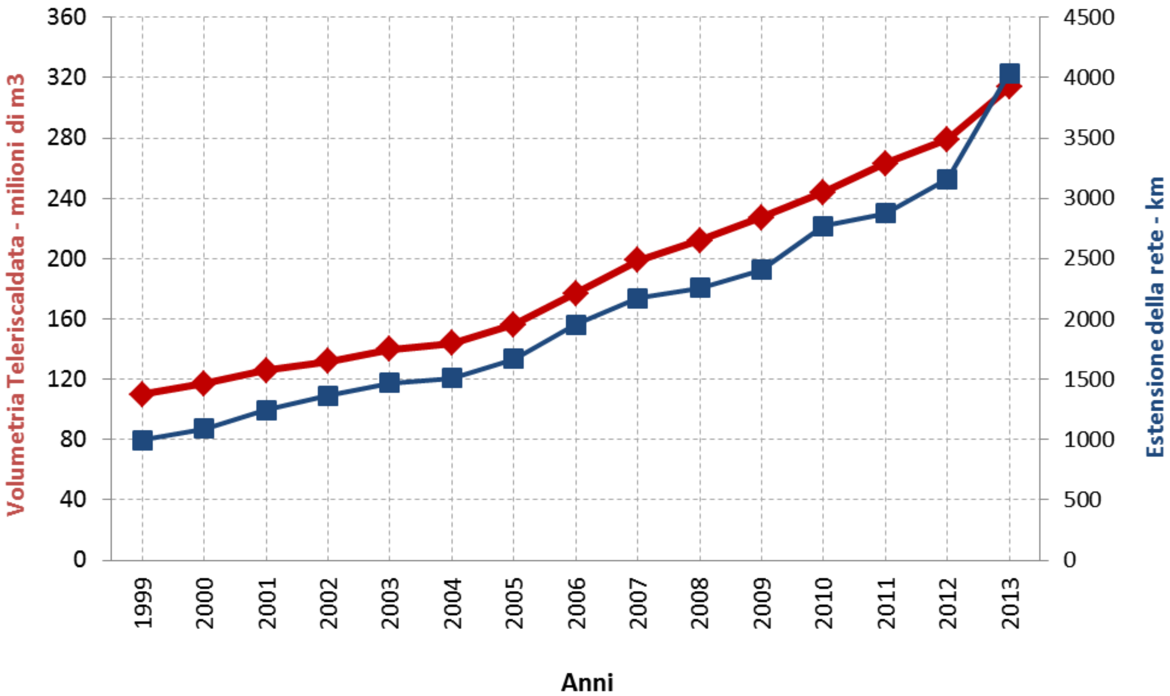


Energia termica erogata (MWh)	Heat supplied [MWh]
Suddivisione per settori	Breakdown by sector
Residenziale	Residential
Terziario	Services
Residenziale e terziario	Residential and services
Residenziale, terziario e industriale	Residential, services and industrial
Fino a	Up to
Oltre	Above

3.2 Growth of district heating in Italy

Over the past 15 years, district heating has advanced steadily in Italy. As shown in the chart below, between 1999 and 2013 the space heated has increased by 185 % overall, while the length of the networks has increased by 305 %. According to the data published in the AIRU yearbook, accompanied by information held by GSE, at the end of 2013, around 316 million m^3 of demand points were served by district heating networks, with a total length of more than 4 000 km.

Figure 46 – Trends in volume and size of the district heating network



Volumetria Teleriscaldata – milioni di m3	Heated space – million m^3
Extensione della rete – km	Length of networks – km
Anni	Years

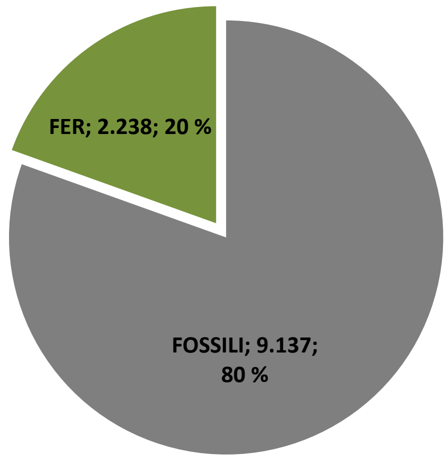
The development of district heating in Italy started later than in other European countries. The causes of this initial delay are mainly the national climate, on average less cold than that of countries where DH developed earlier, and the methane supply programme, launched in the 1950s in northern Italy (the part of the country most suitable for district heating) through exploitation of the deposits in the Po Valley.

The first networks date back to the 1970s, with the networks of Modena (Quartiere Giardino, 1971), Brescia (1972), Mantua (1972), Verona (Forte Procolo, 1973) and 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 the volume heated by DH in Italy at the time. In the 1980s and 1990s, many Italian cities built 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). From the 1990s onward, a number of small mountain towns have developed district heating networks using biomass-fuelled systems.

3.3 Supply systems for district heating networks

The plants serving district heating networks in Italy (surveyed by AIRU and GSE) supplied around 11 375 GWht of thermal energy in 2013. Of this, 80 % came from fossil fuels and the remaining 20 % from RES (including in both cases the respective share of waste, at 50 %).

Figure 47 – Thermal energy supplied by plants serving district heating networks (GWht and %)



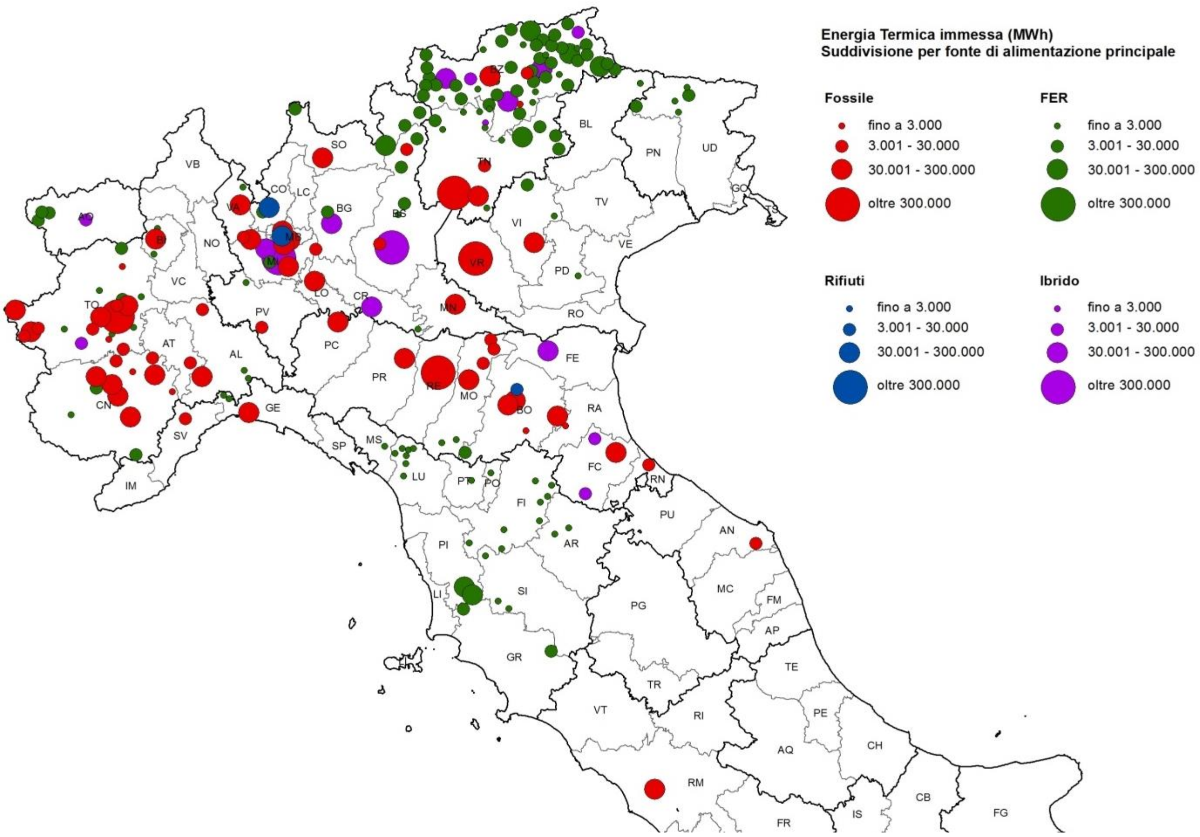
In 2013, 128 networks were supplied by renewable energy; although small, they represent around 60 % of existing networks.

As shown by the following map, most of the networks using RES are located in mountain areas (especially Trentino-Alto Adige), where methane-based networks are less developed and the availability of biomass is greater. District heating networks using RES are also found in Tuscany, where the main source used is geothermal. The use of waste is rather limited; the main waste-burning plants serving district heating networks are located in Lombardy.

The following map shows the geographical distribution of the thermal energy supplied by district heating networks, by source of energy. To identify the main energy sources serving the networks the following rules were applied:

- RES network: the energy produced from RES is ≥ 70 %;
- Fossil fuel network: the energy produced from fossil fuels is ≥ 70 %;
- Waste-burning network: the energy produced from the burning of waste is ≥ 70 %;
- Hybrid network: the energy is produced from a mix of the above sources, none of which exceeds 70 %.

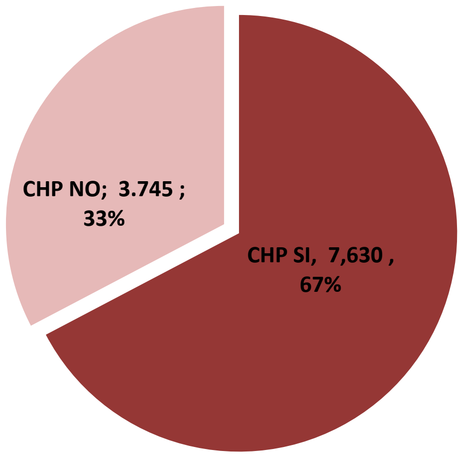
Figure 48 – Geographical distribution of the thermal energy produced by plants serving district heating networks – Breakdown by main fuel source (2013)



Energia termica immesa (MWh)	Heat supplied (MWh)
Suddivisione per fonte di alimentazione principale	Breakdown by main fuel source
Fossile	Fossil
FER	RES
Rifiuti	Waste
Ibrido	Hybrid
Fino a	Up to
Oltre	Above

As for the technologies used, 67 % of the energy (7 630 GWht) was produced in cogeneration plants.

Figure 49 – Thermal energy (GWht) produced by plants serving district heating networks – CHP/NON-CHP Breakdown (2013)



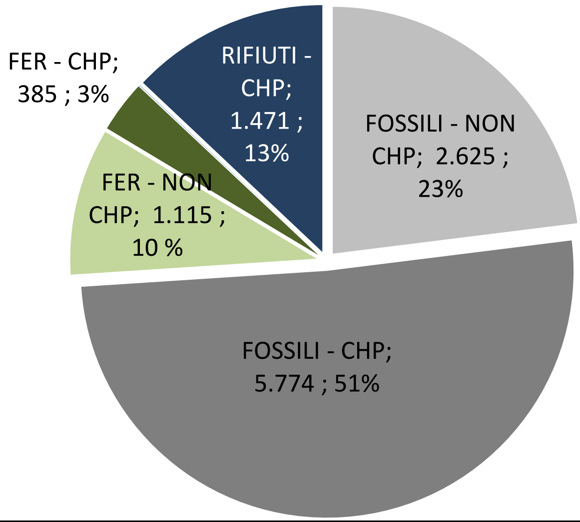
CHP NO	NON-CHP
CHP SI	CHP

A total of 50 % of the thermal energy distributed through district heating networks is produced in cogeneration installations using fossil fuels. The backup energy produced by means of simple fossil-fuel boilers makes up 23 %. Clearly, most of the energy from fossil fuels comes from cogeneration installations (69 % of total fossil fuels). If we also considered the contribution from non-biodegradable waste, the amount of energy produced from fossil fuels would total 80 %, 71 % in CHP plants and 29 % in simple boilers.

Only 3 % of the thermal energy distributed via district heating networks is produced in cogeneration plants powered by renewables. The proportion of energy generated in non-CHP plants powered by renewables is more significant (10 %). For biodegradable waste, the proportion of energy produced from renewables would be exactly 20 %, divided between CHP plants and simple boilers.

The energy produced by the plants serving district heating networks is summarised in the following chart, which shows the energy sources and types of technology used.

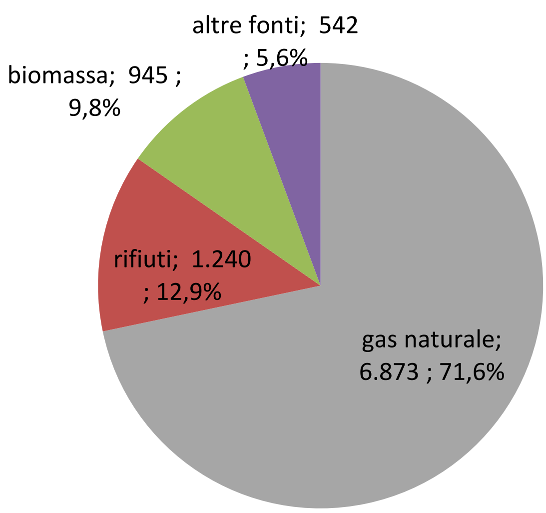
Figure 50 – Thermal energy produced (GWht) by source and type of CHP and non-CHP plant (2013)



FER – CHP	CHP (RES)
FER – NON CHP	NON-CHP (RES)
RIFIUTI – CHP	CHP (WASTE)
FOSSILI – NON CHP	NON-CHP (FOSSIL FUELS)
FOSSILI – CHP	CHP (FOSSIL FUELS)

In terms of the most used energy sources, the production mix breaks down as shown in the figure below.

Figure 51 – Thermal energy delivered (GWht) by source (2013)

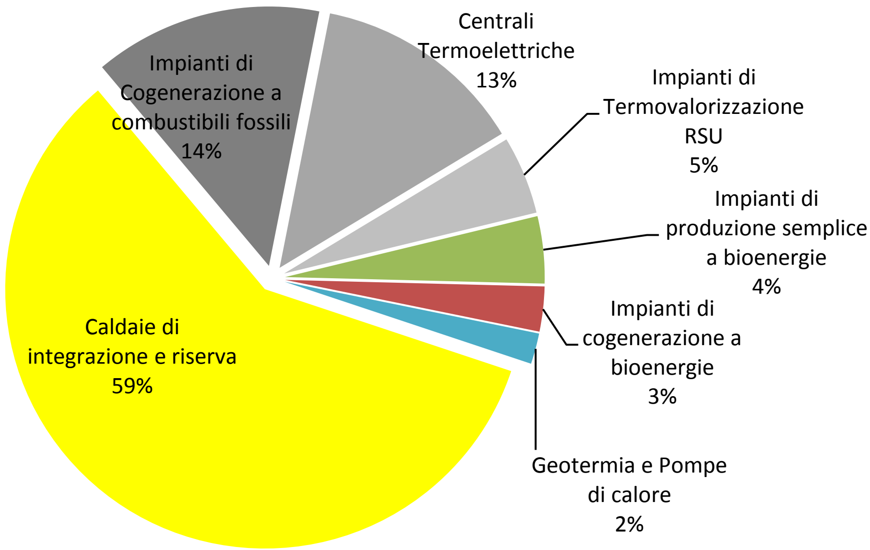


Biomassa	Biomass
Altre fonti	Other sources
Rifiuti	Waste
Gas natural	Natural gas

As to the thermal capacity of the plants installed in Italy and serving district heating networks, this amounts to 8 056 MW (thermal), according to the AIRU yearbook[32].

The main type of plant is backup boilers, which cover more than half of the installed capacity (59 %). Cogeneration plants using fossil fuels play a major role (2 601 MWt). Of these, 1 144 MWt (14 %) are installed in dedicated cogeneration plants and 1 065 MWt (13 %) in thermal power stations constructed with the main aim of generating electricity for the national grid. Almost all the plants burning municipal solid waste are CHP plants, and account in total for 392 MWt (5 %). Bioenergies also play a significant role, supplying 561 MWt, divided into simple production plants (boilers using bioenergies, landfill gas and sludge) producing 336 MWt (4 %) and cogeneration plants producing 225 MWt (3 %). Geothermal source plants (117 MWt) and heat pump (37 MWt) systems play a smaller role; together they make up 2 % of installed capacity.

Figure 52 – Thermal capacity serving district heating – Distribution of plants by type (2013, source: AIRU)

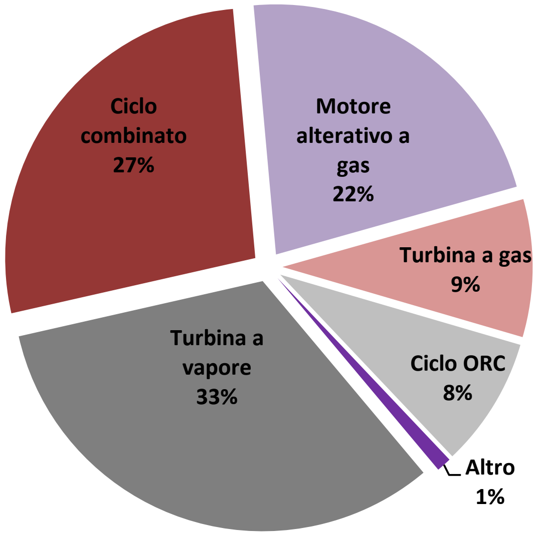


Caldaie di integrazione e riserva 59%	Backup boilers 59%
Impianti di Cogenerazione a combustibili fossili 14%	Fossil-fuel CHP plants 14%
Centrali Termoelettriche 13%	Thermoelectric power plants 13%
Impianti di Termovalorizzazione RSU 5%	Waste-to-energy plants (municipal solid waste) 5%
Impianti di produzione semplice a bioenergy 4%	Simple bioenergy production plants 4%
Impianti di cogenerazione a bioenergy 3%	Bioenergy CHP plants 3%
Geotermia e Pompe di calore 2%	Geothermal and heat pump 2%

[32] Data applying to the group of plants surveyed by AIRU. Plants surveyed by GSE are not included since the data are not yet available.

The installed capacity of dedicated cogeneration units, using either fossil fuels or bioenergies, in 2013 amounted to 1 368 MWt.

Figure 53 – Breakdown by type of system of the thermal capacity installed in dedicated cogeneration units (year 2013, source: AIRU)



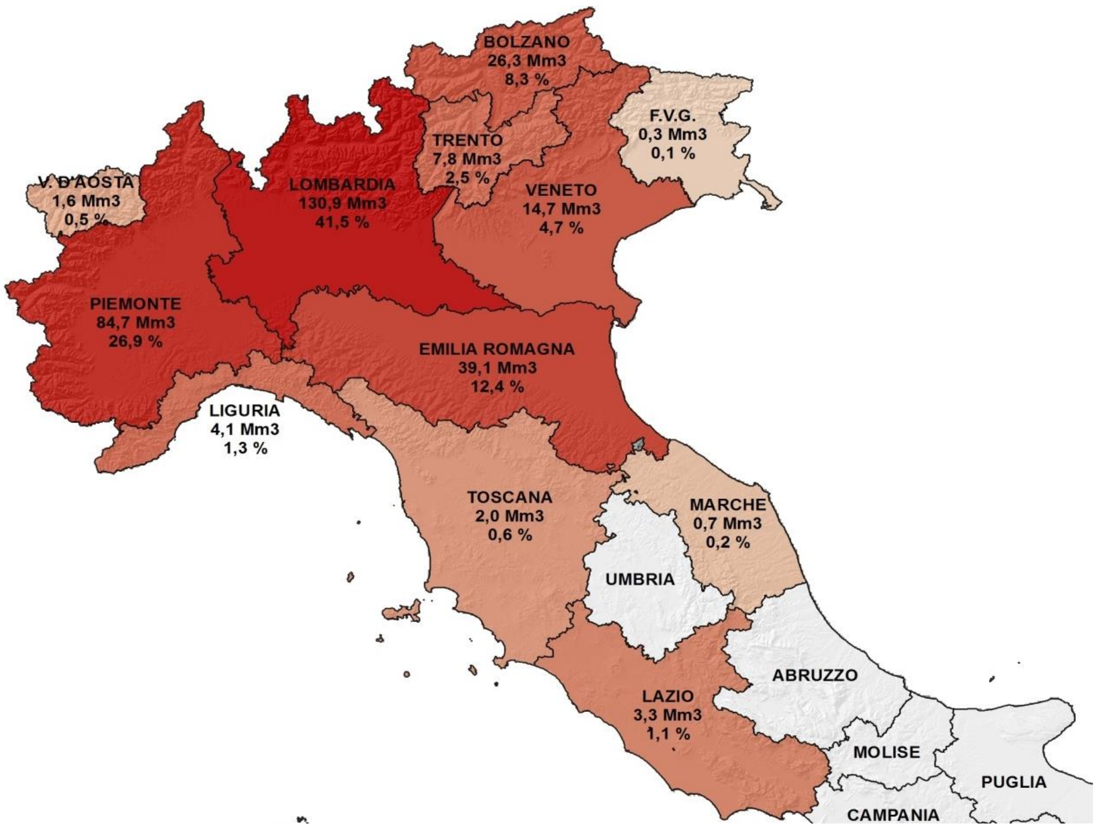
Turbina a vapore 33%	Steam turbine
Ciclo combinato 27%	Combined cycle
Motore alterativo a gas 22%	Alternating gas engine
Turbina a gas 9%	Gas turbine
Ciclo ORC 8%	ORC unit
Altro 1%	Other

The most commonly used type of plant is the Rankine cycle steam turbine, which in terms of capacity makes up 33 % (446 MWt) of installed cogeneration capacity. The combined-gas steam cycle and alternating gas engines cover respectively 26 % (371 MWt) and 23 % (302 MWt) of installed capacity. Gas turbines make up just 8.9 % while ORC units are starting to make up a sizeable share, covering currently 8.4 % of installed capacity (115 MWt).

3.4 Regional distribution of district heating units

The built stock served by district heating networks in Italy in 2013 amounted to about 316 million m^3 in 213 cities. This stock is almost entirely concentrated in five northern regions (300 million m^3, or 96 %). Lombardy is the dominant region with 131 million m^3 (41 % of the total), followed by Piedmont, Emilia Romagna, Trentino-Alto Adige (mainly Bolzano) and Veneto. As concerns the regions of central Italy small district heating networks are located in Lazio, Tuscany and in the Marche.

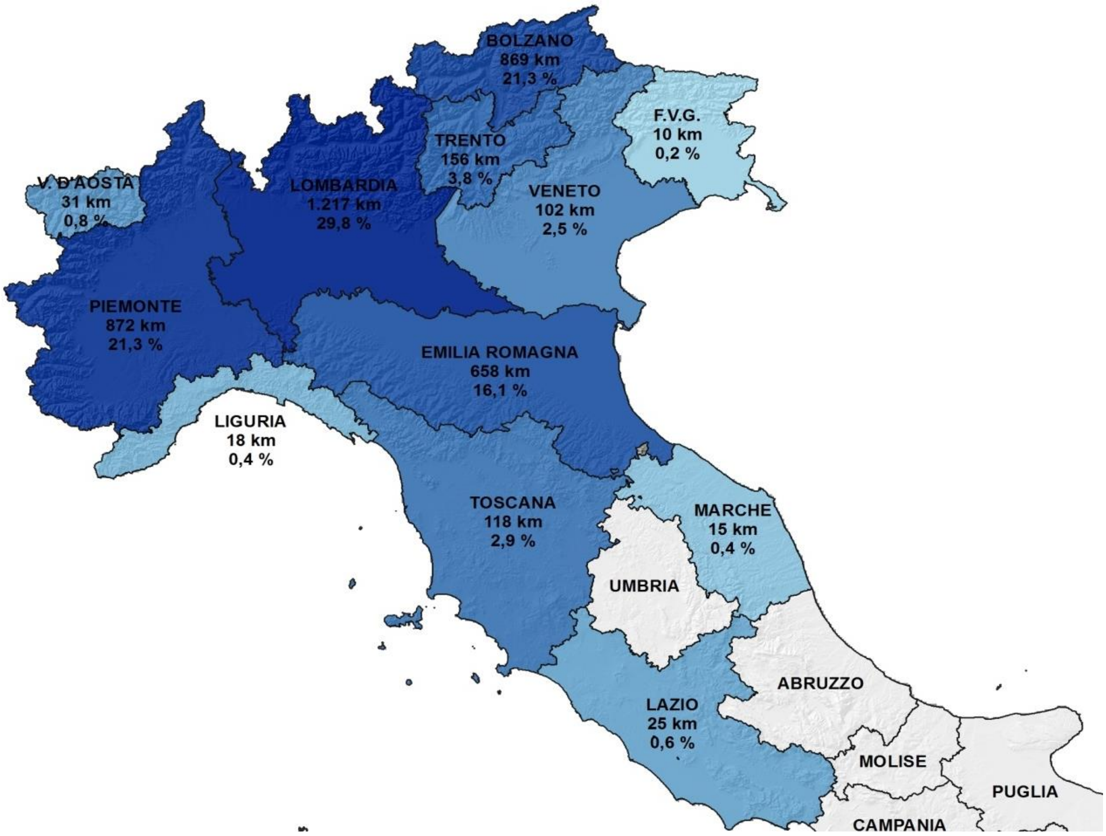
Figure 54 – Geographical distribution of built stock volumes served by district heating in Italy (2013)



Looking at the ratio of volumes served by district heating units to the resident population at 1 January 2014, a marked disparity emerges between Trentino Alto Adige, with a value of about 32 m^3 per inhabitant (more than 50 m^3/inhabitant for Bolzano) and the other regions. Trentino Alto Adige is followed by Piedmont (18.9 m^3/inhabitant), Lombardy (13.1 m^3/inhabitant), Valle d'Aosta (12.2 m^3/inhabitant) and Emilia Romagna (8.8 m^3/inhabitant). Next come Veneto (3 m^3/inhabitant) and Liguria (2.5 m^3/inhabitant), followed by all the others.

Urban district heating comprises a network of 4 088 km. Once again northern regions lead the field: Lombardy has 30 % of Italy's total district heating networks, followed by Trentino-Alto Adige (25 %), Piedmont (21 %) and Emilia Romagna (16 %).

Figure 55 – Geographical distribution of district heating networks (year 2013)



In terms of the energy delivered, this is concentrated mainly in Lombardy, Piedmont and Emilia Romagna, where overall more than 75 % of the total heat was supplied by district heating networks in 2013. The mix of energy sources also varies:

- solid biomass tends to be used more in alpine regions or provinces, such as Bolzano (62 % of the total) and Lombardy (15 %).
- Heat recovery from waste incineration is virtually confined to the Lombardy region (89 %) and Emilia Romagna (9 %).
- Natural gas is the predominant source in most regions, except for Friuli Venezia Giulia, Tuscany and Valle d'Aosta, where renewables (biomass or geothermal energy) are the dominant energy source.

Table 29 – Thermal energy delivered to demand points of district heating systems in 2013, broken down by the main sources and by region (ktoe)

Region	Energy delivered (GWh/year)				
	natural gas	waste	biomass	other sources	Total
Abruzzo	-	-	-	-	-
Basilicata	-	-	-	-	-
Calabria	-	-	-	-	-
Campania	-	-	-	-	-
Emilia-Romagna	916	110	5	66	1 098
Friuli Venezia Giulia	1	-	9	0	9
Lazio	77	-	-	-	77
Liguria	82	-	2	-	83
Lombardy	1 837	1 111	143	326	3 416
Marche	15	-	-	-	15
Molise	-	-	-	-	-
Piedmont	2 803	-	47	6	2 856
Apulia	-	-	-	-	-
Sardinia	-	-	-	-	-
Sicily	-	-	-	-	-
Tuscany	-	-	15	112	126
Aut. Prov. Aut. Bolzano	253	20	586	22	881
Aut. Prov. Aut. Trento	548	-	83	5	636
Umbria	-	-	-	-	-
Valle d'Aosta	0	-	43	3	46
Veneto	343	-	13	2	358
Total ITALY	**6 873**	**1 240**	**945**	**542**	**9 600**

3.4.1 Map of the existing district heating infrastructure and assessment of its efficiency

Article 2(2)(tt) of Legislative Decree No 102 of 4 July 2014 defines as efficient those district heating and district cooling networks that use at least one of the following:

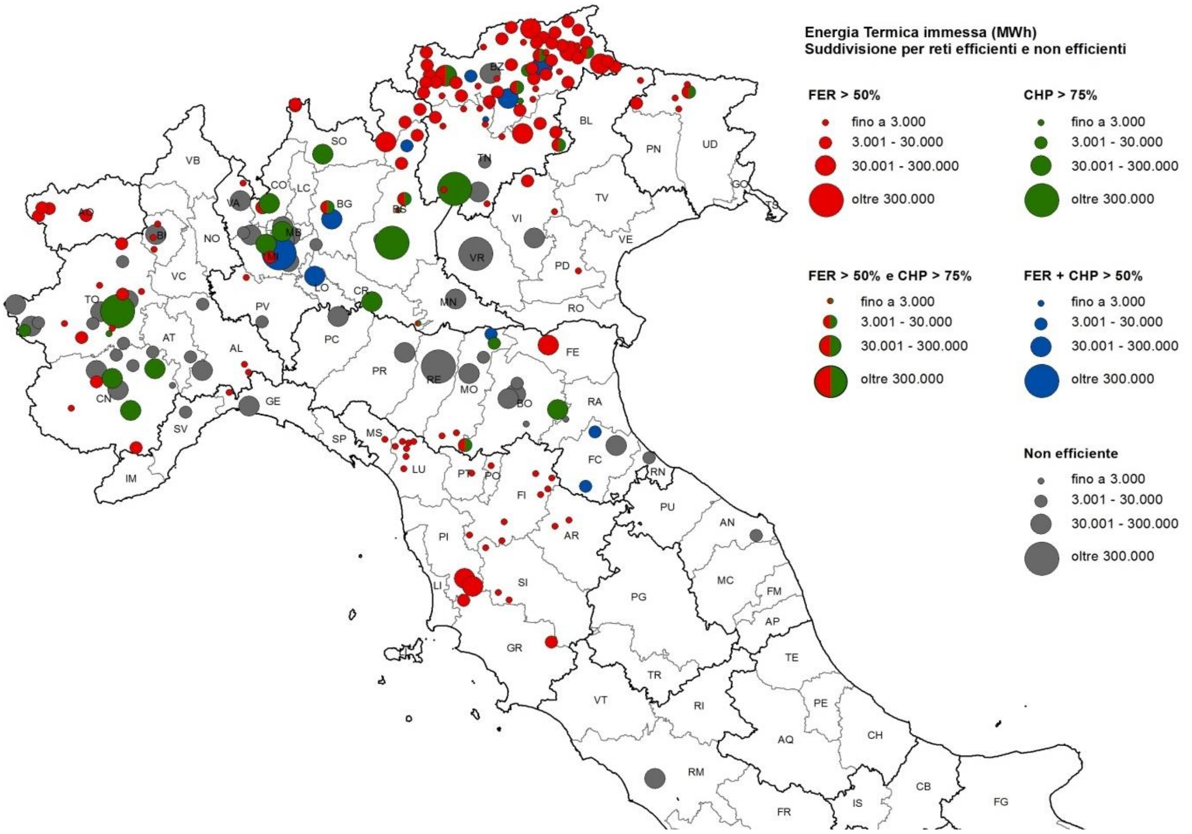
a. 50 percent of energy from renewable sources;
b. 50 percent of waste heat;
c. 75 percent of cogenerated heat;
d. 50 percent of a combination of the above.

The following map, as provided for by Annex 3 to Legislative Decree No 102 of 4 July 2014, provides an overview of the district heating networks existing in Italy at the end of 2013. To prepare this map, the following types of efficient networks were included:

- RES ≥ 50 %: district heating systems that in 2013 used at least 50 % of renewable energy
- CHP ≥ 75 %: district heating systems that in 2013 used at least 75 % of cogenerated heat
- RES ≥ 50 % and CHP ≥ 75 %: district heating systems that in 2013 met both of the above requirements
- RES + CHP ≥ 50 %: district heating systems that in 2013 used a combination of RES and CHP heat of 50 % or more.

The type of plant using more than 50 % of waste heat is not included in the above list since no such plants exist in Italy.

Figure 56 – Geographical distribution of district heating networks (efficient and non-efficient) with an indication of the thermal energy they use (year 2013)



Energia termica immesa (MWh)	Heat supplied (MWh)
Suddivisione per reti efficienti e non efficienti	By efficient and inefficient networks
FER	RES
CHP	CHP
Non efficiente	Non-efficient
Fino a	Up to
Oltre	Above

The map shows that most of the district heating systems existing in the national territory already comply with the efficiency requirements set out in the legislation. Only 24 % of networks, producing about 29 % of the energy supplied to district heating networks, is not currently in line with the requirements.

The efficiency requirements are frequently met, especially on account of the high share of energy from renewable sources, in particular in mountain areas, which in some cases are not served by methane networks and conversely have a large supply of biomass. This is the case for the networks in Trentino Alto-Adige, or where geothermal energy is present, as in Tuscany and Ferrara.

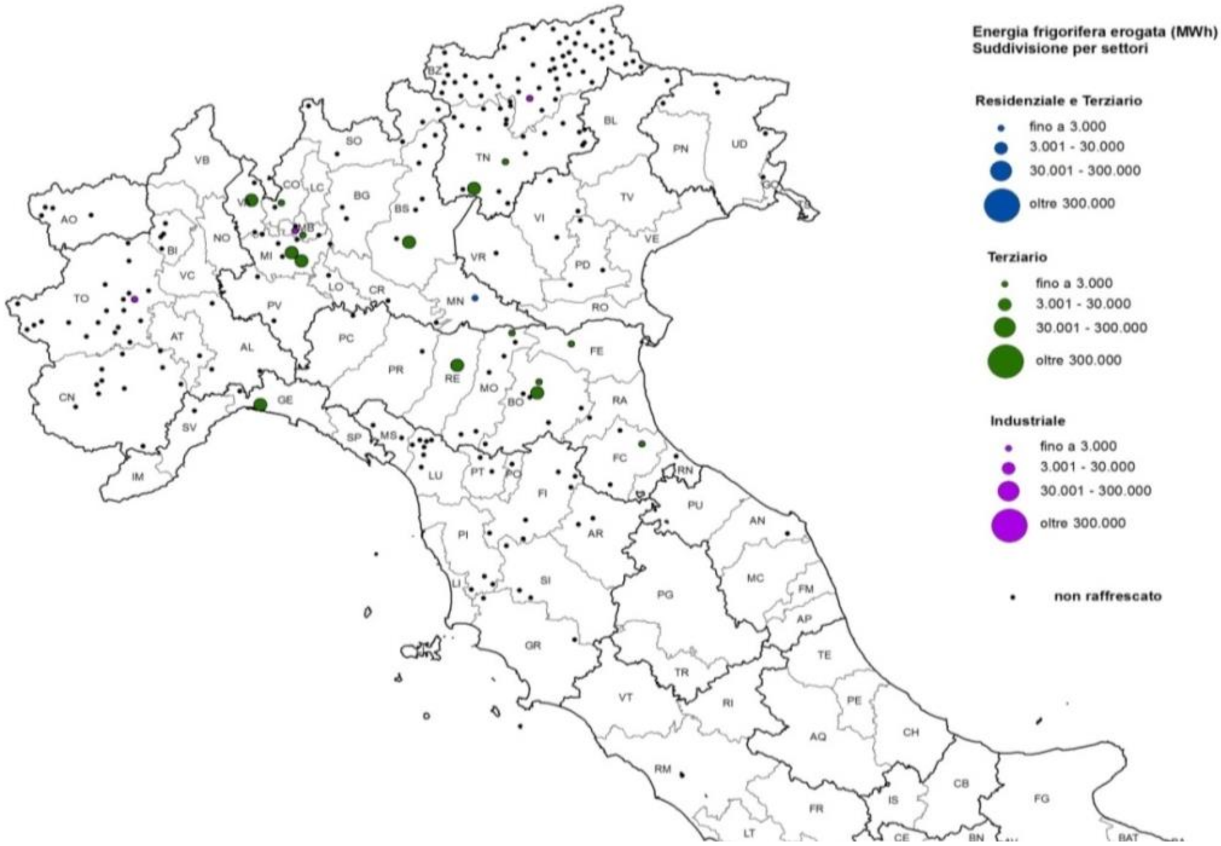
There are also major district heating systems using cogeneration installations (Turin, Brescia, Riva del Garda) which meet the second efficiency condition listed. Other, small plants are able to meet both the requirement of over 50 % RES and a cogeneration share of over 75 % (these are found mostly in Trentino Alto Adige).

Efficiency through a combination of production from CHP and production from RES is achieved by the district heating systems in the municipalities of Milan, Bergamo and Bolzano.

3.5 Existing district cooling networks

The following map provides details on the siting of district cooling networks, their size in terms of cooling energy delivered and the sectors served.

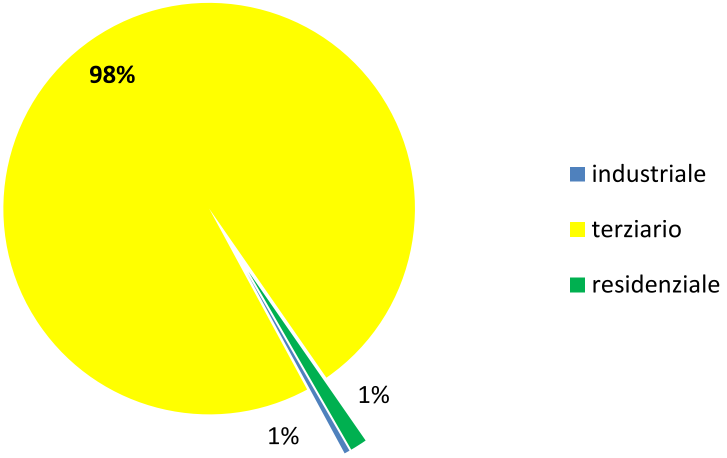
Figure 57 – Geographical distribution of the cooling energy delivered by district heating and cooling networks – Breakdown by sector (year 2013)



Energia frigorifera erogata (MWh)	Cooling supplied (MWh)
Suddivisione per settori	Breakdown by sector
Residenziale e terziario	Residential and services
Terziario	Services
Industriale	Industrial
Fino a	Up to
Oltre	Above

There are very few district cooling networks in Italy: those few are located only in municipalities which already had district heating networks. District cooling infrastructure delivers a small amount of cooling energy, just above 100 GWh, mostly to the service sector.

Figure 58 – Cooling energy delivered by sector by district cooling networks (year 2013)



Residenziale	Residential
Terziario	Services
Industriale	Industrial

Fifty-two percent of the energy supplied for district cooling (about 53 GWh) is produced at the installation and subsequently transferred to demand points, while the remainder (48 %) is cooled locally at the demand point sites.

As to the technology used to produce cooling energy, 56 % uses absorption technology, the rest (44 %) uses electricity.

4 Supply of thermal energy for direct uses

Following the in-depth analysis of cogeneration and district heating, this chapter provides[33] an overview of the direct uses of thermal energy sources by households and businesses. Taken together, direct uses are the third way of meeting the national demand for heating and cooling – the most significant and widespread[34]. The level of detail and granularity of the information varies according to the different user sectors. However, for each one, the manner and degree of use of the different sources has been reconstructed. For the residential sector, additional details are provided on the types of heating and cooling systems.

This chapter also provides an estimate of the theoretical annual availability of biomass, referring to the contribution from the sectors considered: civil (waste), agricultural, forestry and industrial. Finally, the theoretical availability of waste heat from industrial processes is considered.

4.1 Direct uses for heating and cooling by the different sectors

In 2013 the **residential sector** directly consumed almost 29 Mtoe for thermal uses (space heating and DHW production, cooking and cooling). Of these, about 6.8 Mtoe were from renewable sources (23.5 %). The types and respective shares of the different energy sources are listed in the following table.

[33] See in particular sections 4.1 and 4.2.

[34] Thus, this chapter addresses the overall supply of energy for heating and cooling from different energy sources, excluding derived heat (which in turn includes cogenerated heat).

Table 30 – Direct uses for heating and cooling in the residential sector in 2013 (ktoe)

Energy sources		Main technologies	Reference data	ktoe	%
Renewable sources	Solar thermal	Solar collectors	Thermal energy produced by solar collectors	124	0.4 %
	Solid biomass	Fireplaces. stoves. boilers	Energy contained in the biomass	6 633	23.1 %
	Geothermal	Systems for the collection and direct use of geothermal fluids	Thermal energy obtained by collecting water or steam from the underground	1	0.0 %
Petroleum products		Boilers	Energy contained in petroleum products	2 709	9.4 %
Gas		Boilers	Energy contained in gas	18 073	62.9 %
Electricity		Heat pumps, water heaters, electric heaters, mobile heating units, etc.	Electricity consumption	1 209	4.2 %
TOTAL SOURCES				**28 750**	**100 %**

Source: elaboration of Eurostat data

The main energy source for space heating and domestic hot water production is natural gas. In 2013 about 18 Mtoe of this fuel were used, covering 62.9 % of total energy consumption by the residential sector. The gas boiler, single-household or centralised, is therefore the most common system in Italy for household heating.

Other fossil energy sources include petroleum products (mainly diesel and LPG, in this case too mainly used to fire boilers), whose consumption is just above 2.7 Mtoe (9.4 % of the total). The electricity used by households for heating (winter) and cooling (summer) amounts to about 1.2 Mtoe (4.2 %), while the consumption of coal has become negligible.

As stated earlier, renewable sources have come to play a significant and still growing role: today they cover almost one fourth of domestic heating consumption.

The largest share (98 %) among renewables for domestic heating is represented by *solid biomass*, on account of the large number of appliances, stoves and boilers using wood or pellets, representing about 6.6 Mtoe of the total heat supplied.

The data collected by the recent sample-based survey on energy consumption by households, carried out by ISTAT for 2013, provides useful information on the direct uses of thermal energy. The main findings are:

- in 2013, 21.4 Italian households out of 100 used firewood in open fireplaces, closed fireplaces, boilers, stoves, etc., to produce heat;
- the overall consumption of firewood in households exceeds 17.7 million tonnes (the average annual consumption per household is about 3.2 tonnes). Only 45 % of households purchase all the wood they use: the rest gathers at least some of the wood informally;
- in the same year, 4.1 Italian households out of 100 used pellets in boilers, stoves, etc., to produce heat;
- the overall consumption of pellets in households is slightly less than 1.5 million tonnes (the average annual consumption per household is about 1.4 tonnes). The pellets are nearly all purchased.

Solar energy is harnessed through the use of thermal solar collectors/panels (flat/uncovered or tubes/in vacuum, with natural or forced circulation), able to convert radiant solar energy into thermal energy, mainly for the production of domestic hot water only and secondarily for space heating too. In 2013, around 2.5 million m^2 of solar panels had been installed in Italian homes, with a total energy output of 124 ktoe, or 0.4 % of total heating consumption.

Geothermal energy consists of the portion of ground heat, in the form of water or steam, extracted from the ground to produce heat by specially designed systems; in the residential sector, direct uses of the geothermal resource for heating (thus excluding district heating and uses of the geothermal resource by means of heat pumps) are almost negligible (1 ktoe).

The following tables provide instead a breakdown and incidence of the various energy sources used to supply heat to the industrial, service and agricultural sectors.

Table 31 – Direct uses for heating and cooling in the industrial sector in 2013 (ktoe)

Energy sources		**Main technologies**	**Reference data**	**ktoe**	**%**
Renewable sources	Solar thermal	Solar collectors	Thermal energy produced by solar collectors	8	0,0 %
	Solid biomass	Boilers	Thermal energy contained in biomass	244	1,3 %
	Geothermal	Systems for the collection and direct use of geothermal fluids	Thermal energy obtained by collecting water or steam from the underground	2	0,0 %
	Biogas	Boilers	Thermal energy contained in biogas	20	0,1 %
Non-renewable waste		Boilers	Thermal energy contained in waste	281	1,5 %
Petroleum products		Boilers	Energy contained in petroleum products	5.769	30,8 %
Gas		Boilers	Energy contained in gas	10.030	53,5 %
Coal		Boilers	Energy contained in coal and coal products	2.396	12,8 %
TOTAL SOURCES				**18.750**	**100 %**

Source: elaboration of Eurostat data

In 2013, in the **industrial sector**, 18.7 Mtoe of energy sources were used to produce heat for space heating and for DHW heating; of these, about 300 ktoe were renewable (mostly solid biomass), making up 1.5 % of total sources.

The most used source was natural gas (10 Mtoe, or 53.5 % of the total), followed by petroleum products, which make up a significant share in the industrial sector (5.8 Mtoe, or 30.8 %), and coal, with 2.4 Mtoe. The burning of waste to produce energy, albeit minor (less than 300 ktoe), is significant (1.5 % of the total).

The **service sector** in 2013 consumed almost 9.5 Mtoe of energy sources to produce thermal energy; in this sector the share of renewable sources is also very low (171 ktoe, or 1.8 % of the total). Natural gas tends to be the main source (7.3 Mtoe, or 77 % of the total); the use of electricity for space heating and cooling is also significant (1.4 Mtoe, or 15 % of the total), while the consumption of petroleum products is limited to just over 600 ktoe (6.5 %).

Table 32 – Direct uses for heating and cooling in the service sector in 2013 (ktoe)

Energy sources		Main technologies	Reference data	ktoe	%
Renewable sources	Solar thermal	Solar collectors	Thermal energy produced by solar collectors	34	0,4 %
	Solid biomass	Fireplaces. stoves. boilers	Thermal energy contained in biomass	36	0,4 %
	Geothermal	Systems for the collection and direct use of geothermal fluids	Thermal energy obtained by collecting water or steam from the underground	77	0,8 %
	Biogas	Boilers	Thermal energy contained in biogas	25	0,3 %
Petroleum products		Boilers	Energy contained in petroleum products	612	6,5 %
Gas		Boilers	Energy contained in gas	7.259	76,7 %
Electricity		Heat pumps, water heaters, electric heaters, mobile heating units, etc.	Electricity consumption	1.427	15,1 %
TOTAL SOURCES				**9.469**	**100 %**

Source: elaboration of Eurostat data

Lastly, compared to other sectors, in **agriculture** the production of thermal energy is minor, with overall consumption of energy sources coming to just over 300 ktoe. In this case, petroleum products play the leading role, accounting for 46.2 % of total consumption, followed by gas with 40.6 %. Renewable sources are mainly used to heat agricultural greenhouses, aquafarming and fish farming facilities, with an overall contribution of 13.2 %.

Table 33 – Direct uses for heating and cooling in the agricultural sector in 2013 (ktoe)

Energy sources		Main technologies	Reference data	ktoe	%
Renewable sources	Solar thermal	Solar collectors	Thermal energy produced by solar collectors	2	0,5 %
	Solid biomass	Fireplaces. stoves. boilers	Thermal energy contained in biomass	2	0,6 %
	Geothermal	Systems for the collection and direct use of geothermal fluids	Thermal energy obtained by collecting water or steam from the underground	38	12,1 %
Petroleum products		Boilers, portable generators	Energy contained in petroleum products	146	46,2 %
Gas		Boilers	Energy contained in gas	128	40,6 %
TOTAL SOURCES				**316**	**100 %**

Source: elaboration of Eurostat data

Note: for strictly statistical reasons, Eurostat does not as yet include in renewable sources the consumption of renewable thermal energy supplied by heat pumps.

4.2 Units and equipment in the residential sector

The available information and statistical data do not allow an accurate and detailed analysis of the equipment used by agricultural, industrial and service enterprises for the production of thermal energy. In the residential sector, on the other hand, vital information on the availability of heating and cooling systems and equipment is supplied by the sample-based survey of energy consumption by Italian households performed by ISTAT for 2013, which reflects – with some significant differences – the results of the national Census of population and housing carried out by ISTAT in 2011.

As concerns *space heating*, the following table provides data on the share of households in the various Italian regions that have a system in their home, by type of system.

Table 34 – Households divided by presence/lack and type of the only or main home heating system

Regions	Household heating system					
	Present				No system *(per 100 households)*	Total
	Central system	Independent system	Fixed or portable equipment	Total *(per 100 households)*		
Piedmont	34.4	53.3	12.3	100.0		100.0
Valle d'Aosta	31.6	47.0	21.4	100.0		100.0
Lombardy	29.4	61.6	8.9	99.8	..	100.0
Trentino-Alto Adige	31.7	48.7	19.7	100.0		100.0
Bolzano	*44.5*	*41.0*	*14.4*	*100.0*		*100.0*
Trento	*19.8*	*55.7*	*24.5*	*100.0*		*100.0*
Veneto	6.7	73.8	19.5	100.0	..	100.0
Friuli Venezia Giulia	15.4	64.7	19.9	99.0	..	100.0
Liguria	28.3	60.7	11.1	99.8	..	100.0
Emilia Romagna	12.8	79.7	7.4	99.7	..	100.0
Tuscany	7.9	79.9	12.2	99.5	..	100.0
Umbria	7.5	66.7	25.8	99.3	..	100.0
Marche	4.5	81.9	13.6	99.0	..	100.0
Lazio	22.5	62.9	14.7	98.6	1.4	100.0
Abruzzo	3.4	76.2	20.4	99.7	..	100.0
Molise	4.3	73.4	22.3	99.7	..	100.0
Campania	5.6	63.0	31.4	96.3	3.7	100.0
Apulia	3.0	82.9	14.1	97.2	2.8	100.0
Basilicata	4.7	73.0	22.2	99.1	..	100.0
Calabria	3.7	64.4	31.9	95.5	4.5	100.0
Sicily	3.8	55.6	40.7	88.4	11.6	100.0
Sardinia	8.9	32.2	58.9	95.4	4.6	100.0
Italy	**15.7**	**65.8**	**18.5**	**98.0**	**2.0**	**100.0**

Source: ISTAT
Two dots are used (..) where the values are so low as to be non-significant

Almost all Italian homes have at least one space heating unit: only 2 % do not, mostly in southern Italy (especially Sicily). An independent heating system is found in almost two thirds of homes (65.8 %); 15.7 % have a central heating system, while 18.5 % have single units, fixed or mobile (heat pumps, stoves, etc.) which supply heat to only part of the home (one or two rooms).

The data in the table show significant differences among the regions. Apart from Veneto, in northern Italy households tend to have a much higher percentage of central heating systems than the national average (double the national figure in the north-west, three times in the province of Bolzano). By contrast, in central and southern Italy the share of homes with central systems – excluding Lazio – is no more than 10 %.

Individual units are more widespread in the southern regions (mainly Campania, Calabria and the islands), and rarer in the centre and north of the country (in Lombardy and in Emilia Romagna they serve less than 10 % of households). Lastly, the presence of independent units is not significantly correlated with climate/geographical characteristics: they are found in 59 % of households in the north-west, 73 % of those in the north-east, 71 % of those in central Italy, and 64 % of those in the south.

Sardinia differs from the other regions in that it is not connected to the natural gas distribution network: consequently, the share of households with either independent or central units is 50 % lower than the national percentage, and most households (58.9 %) obtain heating through individual, fixed or portable units, using electricity or other fuels (biomass, diesel, LPG).

The following table shows the sources of the main heating unit used by households in the various regions.

Table 35 – Households by energy source of the only or main home heating unit

Regions	**Home heating**					
	Methane	Electricity	Biomass	LPG	Diesel	**Total**
Piedmont	74.5	1.1	15.9	3.4	5.1	100.0
Valle d'Aosta	30.5	2.2	23.4	10.9	33.0	100.0
Lombardy	87.0	1.0	7.2	1.5	3.3	100.0
Trentino-Alto Adige	51.9	2.0	28.7	2.3	15.1	100.0
Bolzano	*45.4*	*2.1*	*32.2*	*1.9*	*18.4*	*100.0*
Trento	*57.6*	*1.9*	*25.5*	*2.9*	*12.1*	*100.0*
Veneto	72.3	1.5	18.1	3.9	4.2	100.0
Friuli-Venezia Giulia	70.8	0.5	19.5	3.6	5.6	100.0
Liguria	77.0	4.1	9.6	3.0	6.3	100.0
Emilia-Romagna	87.4	0.6	7.2	4.0	0.8	100.0
Tuscany	78.3	1.6	12.7	3.2	4.2	100.0
Umbria	56.5	1.1	32.8	6.9	2.7	100.0
Marche	76.3	2.3	15.0	4.6	1.8	100.0
Lazio	74.6	6.1	10.7	5.3	3.3	100.0
Abruzzo	70.7	2.9	23.4	2.2	..	100.0
Molise	68.4	1.4	27.7	1.6	..	100.0
Campania	53.7	10.6	18.7	15.2	1.8	100.0
Apulia	78.7	3.6	11.5	3.4	2.8	100.0
Basilicata	64.6	2.3	30.2	2.0	..	100.0
Calabria	47.0	7.9	33.3	10.7	1.1	100.0
Sicily	52.2	24.1	7.9	14.7	..	100.0
Sardinia		19.7	40.2	21.2	18.9	100.0
Italy	**70.9**	**5.1**	**14.5**	**5.8**	**3.7**	**100.0**

Source: ISTAT

In line with the data on the consumption of energy sources supplied in the previous pages, analysis of the data published by the Ministry of Economic Development on the status of methane distribution in Italy shows that natural gas, mainly used by single-home or central boiler systems, remains the main fuel for residential use in Italy. Indeed, gas supplies heat to 70.9 % of households, with peaks of 87 % in Lombardy and Emilia Romagna, followed by four other regions with values above 75 %. In particular, gas is distributed in 6 594 Italian municipalities, as shown in the table below.

Table 36 – Gas distribution in Italy

Region	Municipalities with mains gas	Regional gas distribution ('000 scm)	Number of customers
Abruzzo	296	710 934	601 658
Basilicata	127	194 471	183 367
Calabria	280	270 460	355 634
Campania	430	983 987	1 242 964
Emilia Romagna	339	4 347 001	2 116 732
Friuli Venezia Giulia	184	861 492	507 590
Lazio	312	2 105 973	2 143 953
Liguria	150	893 230	840 235
Lombardy	1 443	8 963 037	4 560 955
Marche	222	826 935	627 263
Molise	133	128 429	120 994
Piedmont	1 031	3 784 455	1 938 537
Apulia	250	1 056 089	1 233 562
Sicily	322	638 022	935 360
Tuscany	240	2 205 039	1 467 352
Trentino-Alto Adige	184	652 864	256 847
Umbria	86	519 700	329 480
Valle d'Aosta	24	46 643	19 976
Veneto	541	4 075 288	1 953 492
Italy	**6 594**	**33 364 049**	**21 435 951**

Source: Ministry of Economic Development data processed by GSE

Almost one third of the gas is distributed in Lombardy, which has 4.5 million customers and a share of almost 2 000 Nm3 of gas per customer. In Piedmont, the number of customers is the same but the amount of gas supplied is lower. In the south, the region with the largest number of municipalities served by the methane network is Campania (430 municipalities), followed by Sicily and Calabria. In the South the average value of gas distributed by customer is 0.87 thousand of Nm3 of gas, markedly less than the average value in the north of the country (1.95 Nm3).

The Italian municipalities not supplied with methane are 1 498, making up 19 % of the total (8 092). About half of the municipalities not served by the methane network (48 %) are located in Southern Italy, 42 % in the North and only 10 % in central Italy. The largest area not supplied with methane is the whole of Sardinia, which has 377 municipalities. In Piedmont 175 municipalities are not served by the gas network, followed by Calabria and Campania, respectively with 129 and 121 municipalities.

Table 37 – Regional distribution of Italian municipalities without mains gas

Region	Total municipalities	Municipalities without methane	Population of municipalities without mains gas (%)
Abruzzo	305	9	1
Basilicata	131	4	1
Calabria	409	129	15
Campania	551	121	9
Emilia Romagna	348	9	0
Friuli Venezia Giulia	218	34	2
Lazio	378	66	1
Liguria	235	85	3
Lombardy	1 544	101	1
Marche	239	17	1
Molise	136	3	0
Piedmont	1 206	175	1
Apulia	258	8	0
Sardinia	377	377	100
Sicily	390	68	5
Tuscany	287	47	3
Trentino-Alto Adige	333	149	25
Umbria	92	6	1
Valle d'Aosta	74	50	29
Veneto	581	40	1
Italy	**8 092**	**1 498**	**6**

Source: Ministry of Economic Development data processed by GSE

With reference to the population, 29 % of the inhabitants of Valle d'Aosta live in municipalities without methane supply, while in Trentino Alto Adige the value is 25 %. At national level, 6 % of the population lives in municipalities not served by the gas network.

In general, those areas in which natural gas is used less obviously make greater use of other energy sources, in particular solid biomass (firewood and pellets) which are used in fireplaces, stoves and boilers. In central and southern regions, domestic heating systems using electricity (especially with heat pumps) are more common; in Umbria, Basilicata, Calabria and especially in Sardinia, the percentage of homes with these systems exceeds 30 % (40.2 % in Sardinia, for the reasons stated above).

The following table shows the distribution of units using wood and pellets among Italian households and their breakdown by region.

Table 38 – Households by type of systems using wood and pellets and breakdown by region, per 100 households using respectively wood and pellets

Regions	Wood			Wood pellets	
	Traditional fireplaces or stoves (a)	Innovative fireplaces or stoves (b)	Other systems (c)	Traditional fireplaces or stoves (a)	Other equipment (d)
Piedmont	86.9	7.2	12.8	97.8	..
Valle d'Aosta	89.0	6.3	14	88.8	12.7
Lombardy	97.1	..	3.4	93.9	..
Trentino-Alto Adige	90.9	5.1	25.3	79.9	30.8
Bolzano	*90.0*	6.6	*36.9*	*69.3*	*50.7*
Trento	*91.8*	3.8	13.6	*91.7*	..
Veneto	94.9	4.2	8.2	94.8	..
Friuli-Venezia Giulia	94.2	5.4	7.6	94.5	..
Liguria	84.8	14.5	8.4	79.0	..
Emilia-Romagna	93.8	4.7	4.9	97.6	..
Tuscany	88.3	10.6	7.5	81.4	19
Umbria	87.6	15.1	8.7	77.7	24.8
Marche	87.5	11.6	..	72.8	32.7
Lazio	74.6	25.0	6.5	55.3	49.3
Abruzzo	81.0	23.0	9.9	85.6	31
Molise	77.4	19.5	11.8	78.9	22.5
Campania	70.9	28.3	7.4	57.8	42.2
Apulia	81.9	16.0	5.5	69.6	..
Basilicata	69.6	29.6	13.1	74.2	..
Calabria	65.5	33.6	8	62.8	45.6
Sicily	79.0	10.6	14.3	64.7	..
Sardinia	91.2	10.7	4.7	92.2	8.5
Italy	**85.2**	**13.4**	**8.1**	**84.2**	**18.5**

Source: ISTAT

(a) Stoves and fireplaces heating individual rooms (including direct vent fireplaces and stoves)

(b) Stoves and fireplaces connected to radiators that distribute the heat to other rooms in the home

(c) Includes water heaters, boilers linked to radiators and cooking equipment

(d) Includes innovative stoves and fireplaces, water heaters, boilers linked to radiators and cooking equipment.

For both firewood and pellets the most common systems are 'traditional' ones, only able to heat up the room in which they are located; systems linked to radiators conveying the heat to other rooms in the home account for 13.4 % of the total for wood and 18.5 % for pellets.

For *water heating*, the following table shows the percentage of DHW production systems by region.

Table 39 – Households divided by presence/lack and type of the only or main water heating system

Regions	Present						Absent (per 100 households)	Total
	Central system	Independent system	Hot water boiler			Total (per 100 households)		
			Electric	Methane	Other sources			
Piedmont	11.5	67.3	10.0	9.6	1.6	99.6	0.4	100.0
Valle d'Aosta	16.3	60.4	21.4	0.9	1.0	98.9	1.1	100.0
Lombardy	8.6	70.4	6.3	13.9	0.8	99.9	0.1	100.0
Trentino-Alto Adige	26.4	64.2	5.7	1.1	2.6	99.8	0.2	100.0
Bolzano	*36.5*	*50.8*	*7.7*	*1.3*	*3.7*	*99.8*	*0.2*	*100.0*
Trento	*17.2*	*76.4*	*3.9*	*1.0*	*1.6*	*99.8*	*0.2*	*100.0*
Veneto	3.4	90.6	2.9	2.1	0.9	98.8	1.2	100.0
Friuli Venezia Giulia	10.0	79.2	8.5	1.3	1.0	99.0	1.0	100.0
Liguria	13.3	68.3	9.9	7.6	0.9	99.5	0.5	100.0
Emilia Romagna	8.4	85.3	3.3	2.6	0.3	99.5	0.5	100.0
Tuscany	2.9	85.8	8.7	2.2	0.5	99.7	0.3	100.0
Umbria	4.2	82.3	10.3	0.9	2.3	98.5	1.5	100.0
Marche	2.0	91.4	4.3	0.6	1.7	99.6	0.4	100.0
Lazio	4.3	67.7	23.4	3.9	0.7	99.5	0.5	100.0
Abruzzo	2.3	88.6	4.3	3.0	1.8	99.2	0.8	100.0
Molise	3.1	84.6	8.6	1.8	1.8	98.7	1.3	100.0
Campania	1.6	74.2	17.1	4.4	2.7	98.7	1.3	100.0
Apulia	2.1	83.0	13.2	1.2	0.5	99.6	0.4	100.0
Basilicata	2.6	84.5	9.5	0.7	2.7	98.2	1.8	100.0
Calabria	2.8	65.3	27.1	2.0	2.9	98.4	1.6	100.0
Sicily	2.1	54.7	36.8	4.6	1.8	99.1	0.9	100.0
Sardinia	0.6	42.9	46.4	0.0	10.1	97.7	2.3	100.0
Italy	**5.8**	**73.9**	**13.6**	**5.3**	**1.5**	**99.3**	**0.7**	**100.0**

Source: ISTAT

In Italy, 99.3 % of households have a domestic hot water production system. Here too, the most common are single-home systems: at national level, they are found in 73.9 % of homes, with the highest values in Veneto, Marche and Abruzzo and lowest values in the province of Bolzano, Calabria, Sicily and Sardinia. Except for Trentino, central water heating systems are not common: they serve about 10 % of homes in the north, about 4 % in the centre and 2-3 % in the south. About 20 % of households use water heaters, mostly using electricity. In 65 % of cases, the same unit that supplies hot water is also used for space heating.

The distribution of water heating systems by energy source is similar to that described for space heating: at national level, natural gas represents by far the greatest share (72 % of homes), followed in this case by electricity (14.4 %), LPG (7.6 %), diesel (2.9 %) and biomass (2.4 %).

Lastly, 43 % of households have a subsidiary space heating system; compared with the main system, the subsidiary system is usually a single unit, either fixed (61 % of subsidiary units) or portable (33 %).

The following table shows the percentage of residential space ***cooling*** systems (air conditioning) by region.

Table 40 – Households divided by presence/lack and type of the only or main air conditioning system

Regions	**Present**				**Absent** *(per 100 households)*	**Total**
	Central or separate air conditioning system	Fixed or portable air conditioning units (cooling only)	Fixed or portable air conditioning units with heat pump	**Total** *(per 100 households)*		
Piedmont	5.3	27.0	67.7	13.3	86.7	100.0
Valle d'Aosta	..	..	..	1.5	98.5	100.0
Lombardy	4.7	33.6	61.7	29.7	70.3	100.0
Trentino-Alto Adige	0.9	28.8	70.4	6.2	93.8	100.0
Bolzano	1.3	21.9	76.8	6.1	93.9	*100.0*
Trento	0.5	34.9	64.6	6.3	93.7	*100.0*
Veneto	6.1	34.1	59.8	45.3	54.7	100.0
Friuli Venezia Giulia	5.0	30.0	65.0	29.3	70.7	100.0
Liguria	7.0	14.9	78.1	16.1	83.9	100.0
Emilia Romagna	7.4	36.6	56.0	42.8	57.2	100.0
Tuscany	2.5	40.7	56.8	21.9	78.1	100.0
Umbria	3.0	16.2	80.8	13.3	86.7	100.0
Marche	..	20.2	78.2	20.1	79.9	100.0
Lazio	1.7	26.4	71.9	27.8	72.2	100.0
Abruzzo	..	24.0	71.0	13.4	86.6	100.0
Molise	..	23.5	75.6	11.5	88.5	100.0
Campania	2.2	17.7	80.1	28.2	71.8	100.0
Apulia	1.7	29.5	68.8	35.9	64.1	100.0
Basilicata	..	21.8	78.0	18.4	81.6	100.0
Calabria	7.4	21.7	70.9	28.8	71.2	100.0
Sicily	0.5	17.1	82.4	37.6	62.4	100.0
Sardinia	3.9	13.2	82.9	47.5	52.5	100.0
Italy	**3.9**	**28**	**68.1**	**29.4**	**70.6**	**100.0**

Source: ISTAT

In Italy, 29.4 % of households have a space cooling system. The most common systems are reversible HVAC systems (which can be used for both winter heating and summer cooling), found in 68.1 % of homes with air conditioning, and much more widespread in the Centre-South of Italy, which has a warmer climate (77.6 % of households in the South, 68.6 % in the Centre and about 60 % in the North). Next come cooling-only systems (28 %), which are mostly found in the Centre-North, and central or single-home systems (3.9 %).

4.3 Availability of thermal energy from biomass and waste

The purpose of this section is to analyse the theoretical availability of renewable energy sources for the production of thermal energy, with a focus on biomass. To assess the available quantities, the contributions from four sectors have been considered:

- Civil (waste)
- Agricultural
- Forestry
- Industrial

The table below summarises the estimate of annual availability of biomass for the types considered.

Table 41 – Estimate of the current availability of biomass (Mton/year)

	Sector	Availability by weight (Mton)
Civil	Waste	5
Agriculture	Dedicated energy crops	5
	Residual biomass	22.4
Forestry		34
Industry	Agrifood waste	1.32
	Processing waste (mainly from the wood and paper industries)	1.6
Total		**69.3**

The estimated annual theoretical availability of biomass is 69.3 million tonnes.

4.3.1 Civil sector (waste)

The civil sector contributes to energy generation through the use of municipal solid waste as fuel. In 2013 the production of waste amounted to about 29.6 million tonnes (source: Eurostat/ISPRA). The main types of waste management are broken down in percentage terms in the following table:

Table 42 – Percentage distribution of municipal waste management in Italy (2012)

Landfill	Waste-to-energy	Separate waste collection (recycling and composting)
41 %	18 %	41 %

Source: ISPRA

The data shows that landfill disposal is still widespread, covering 41 % of total municipal waste produced, i.e. about 12 Mton, down from the previous year. This reduction stems from greater recourse to other waste management methods.

Based on the Prime Ministerial Decree of 10 August 2016 and the ISPRA 2014 report on municipal waste, specific data has been obtained on waste-to-energy plants in operation and to be built in Italy[35] (location, authorised treatment capacity, waste treated, etc.). In 2013, 5.6 million tonnes of waste was sent to 40 waste-to-energy plants, with an estimated input energy content of 15.8 TWh. Of this, 6.8 TWh was used in 11 waste-to-energy plants connected to district heating networks, where 1.5 TWh of the thermal energy recovered by the incineration process was supplied to the network. The waste-to-energy plants already in operation are mainly located in northern Italy. According to the preliminary report, new plants awaiting authorisation tend to be in central or southern regions with a higher residual need for waste incineration (Umbria, Marche, Lazio, Campania, Abruzzo, Apulia, Sardinia and Sicily).

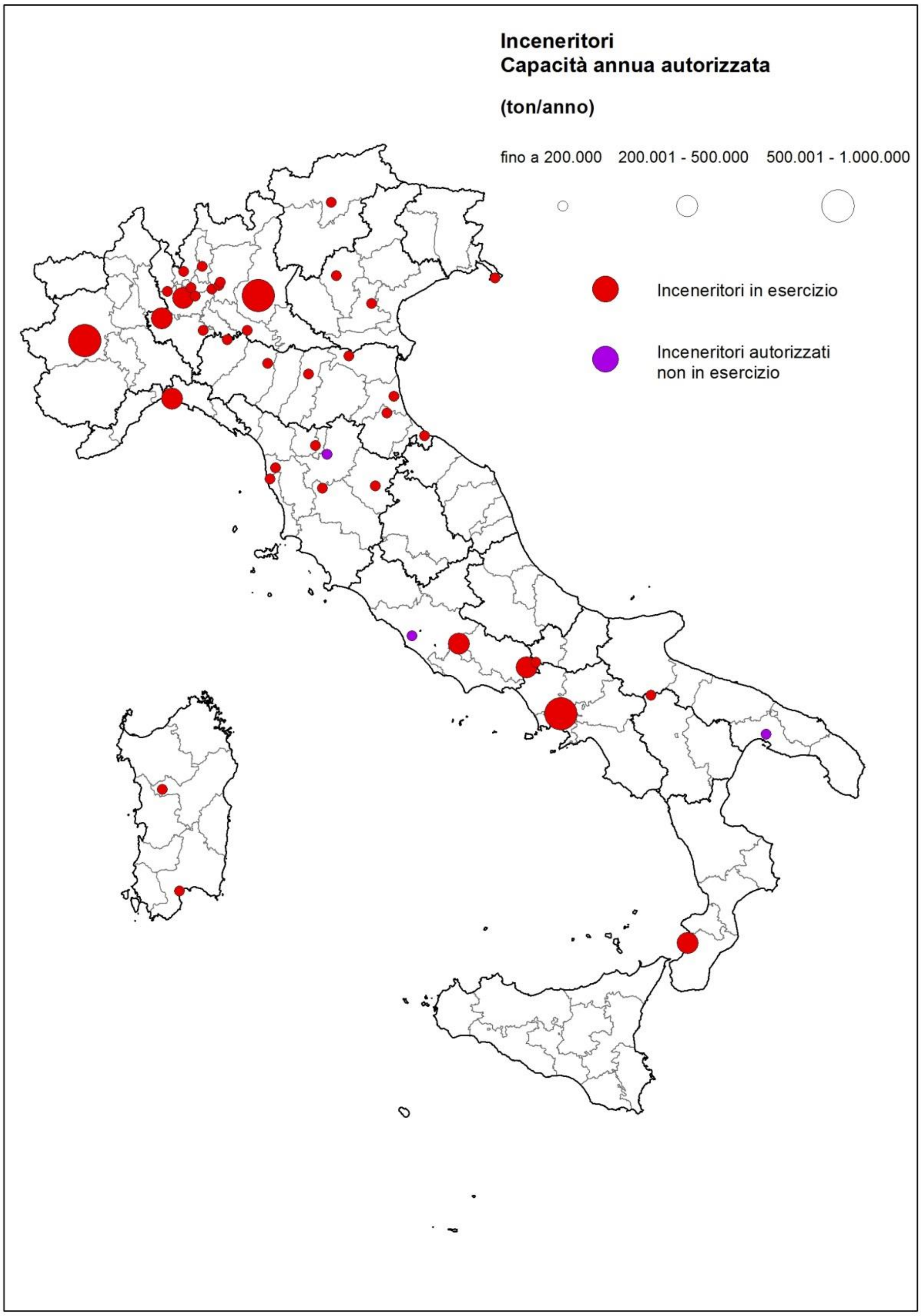
[35] Including plants with authorisation but not yet in operation and new plants awaiting authorisation in specific regions.

Table 43 – List of waste-to-energy plants in operation and to be authorised in Italy

Plant code	Region	Province	Location	Plant status	Climate condition area	Number of lines	Thermal load [MW]	Authorised hourly capacity [ton/h]	Authorised annual capacity – total waste [tonnes/year]	Authorised annual capacity – municipal waste and equivalent [tonnes/year]	Waste treated in 2013 [tonnes/year]	Heat recovered for DH in 2013
1	Piedmont	TO	Turin	in operation	E	3	206	68	526 500	526 500	112 778	
2	Lombardy	BG	Bergamo	in operation	E	1	48	9	75 000	62 000	61 458	yes
3	Lombardy	BS	Brescia	in operation	E	3	305	98	981 837	630 000	728 145	yes
4	Lombardy	VA	Busto Arsizio	in operation	E	2	61	17	116 000	93 000	106 371	
5	Lombardy	CO	Como	in operation	E	2	39	13	100 000	80 000	83 167	yes
6	Lombardy	PV	Corteolona	in operation	E	1	34	9	75 000	63 000	60 839	
7	Lombardy	CR	Cremona	in operation	E	2	36	9	72 000	58 000	64 051	yes
8	Lombardy	BG	Dalmine	in operation	E	2	56	18	151 372	144 500	134 652	
9	Lombardy	MB	Desio	in operation	E	2	41	12	91 000	60 000	72 396	yes
10	Lombardy	MI	Milan	in operation	E	3	185	60	480 000	475 400	550 924	yes
11	Lombardy	PV	Parona	in operation	E	2	148	34	380 000	340 000	233 146	
12	Lombardy	MI	Sesto S. Giovanni	in operation	E	3	31	9	72 000	71 700	69 711	yes
13	Lombardy	MI	Trezzo d'Adda	in operation	E	2	82	25	199 600	185 600	168 927	
14	Lombardy	LC	Valmadrera	in operation	E	2	45	16	123 000	87 000	86 923	
15	Trentino-Alto Adige	BZ	Bolzano	in operation	E	1	59	16	130 000	100 000	38 407	yes
16	Veneto	PD	Padua	in operation	E	3	80	25	170 000	170 000	186 692	
17	Veneto	VI	Schio	in operation	E	3	39	10	82 000	82 000	74 581	
18	Friuli Venezia Giulia	TS	Trieste	in operation	E	3	67	26	197 000	152 300	169 461	
19	Emilia Romagna	RN	Coriano	in operation	E	1	47	16	125 000	91 606	139 789	
20	Emilia Romagna	FE	Ferrara	in operation	E	2	56	18	130 000	88 900	129 832	yes
21	Emilia Romagna	FC	Forlì	in operation	D	1	47	20	120 000	120 000	119 805	yes
22	Emilia Romagna	BO	Granarolo	in operation	E	2	81	25	220 000	165 000	199 128	yes
23	Emilia Romagna	MO	Modena	in operation	E	1	78	31	180 000	140 636	190 790	
24	Emilia Romagna	PC	Piacenza	in operation	E	2	46	15	120 000	84 875	113 466	
25	Emilia Romagna	RA	Ravenna	in operation	E	1	28	6	56 500	56 000	47 873	
26	Emilia Romagna	PR	Parma	in operation	E	2	71	16	130 000	99 302	31 589	
27	Tuscany	AR	Arezzo	in operation	E	1	15	6	42 000	42 000	39 073	
28	Tuscany	LI	Livorno	in operation	D	2	31	8	64 800	64 800	79 403	
29	Tuscany	PT	Montale	in operation	D	3	23	8	50 550	50 000	51 120	
30	Tuscany	PI	Ospedaletto	in operation	D	2	21	7	65 000	52 000	44 929	
31	Tuscany	SI	Poggibonsi	in operation	D	3	35	9	70 000	66 000	57 309	
32	Lazio	RM	Colleferro	in operation	D	1	52	12	110 000	80 000	79 554	
33	Lazio	RM	Colleferro	in operation	D	1	52	12	110 000	80 000	79 554	
34	Lazio	FR	S. Vittore del Lazio	in operation	D	2	108	29	224 480	224 480	224 220	

35	Molise	IS	Pozzilli	in operation	D	1	50	12	93 500	93 500	91 408	
36	Campania	NA	Acerra	in operation	C	3	340	81	600 000	600 000	668 574	
37	Calabria	RC	Gioia Tauro	in operation	B	2	60	16	120 000	120 000	27 626	
38	Basilicata	PZ	Melfi	in operation	D	1	19	9	30 000	30 000	50 747	
39	Sardinia	CA	Capoterra	in operation	C	3	57	19	140 256	140 000	122 540	
40	Sardinia	NU	Macomer	in operation	D	2	18	6	43 200	40 000	17 627	
41	Tuscany	FI	Sesto Fiorentino	authorised but not yet operational	D	2	65	25	198 400	198 400		
42	Lazio	RM	Rome	authorised but not yet operational	D	2	236	38	182 500	182 500		
43	Lazio	FR	S. Vittore del Lazio	authorised but not yet operational	D	1	52	13	98 750	98 750		
44	Calabria	RC	Gioia Tauro	authorised but not yet operational	B	2	75	13	135 000	120 000		
45	Apulia	TA	Statte	authorised but not yet operational	C	2	21	8	73 000	66 000	5 455	
46	Umbria			New (awaiting authorisation)			61		130 000	130 000		
47	Marche			New (awaiting authorisation)			89		190 000	190 000		
48	Lazio			New (awaiting authorisation)			99		210 000	210 000		
49	Campania			New (awaiting authorisation)			141		300 000	300 000		
50	Abruzzo			New (awaiting authorisation)			57		120 000	120 000		
51	Apulia			New (awaiting authorisation)			33		70 000	70 000		
52	Sardinia			New (awaiting authorisation)			57		121 000	121 000		
53	Sicily			New (awaiting authorisation)			325		690 000	690 000		

Figure 59 – Map of waste-to-energy plants in operation and those authorised but not yet operational



Inceneritori	Waste-to-energy plants
Capacità annua autorizzata	Annual authorised capacity
(ton/anno)	(tonnes/year)

Fino a	Up to
Inceneritori in esercizio	Waste-to-energy plants in operation
Inceneritori autorizzati non in escercizio	Waste-to-energy plants authorised but not yet operational

4.3.2 Agricultural sector

The agricultural sector can provide substantial amounts of biomass for energy use, consisting of crop residue which otherwise would be solely a source of handling and disposal costs. Use of this biomass is highly variable and may change according to several factors.

The agricultural sector produces several types of biomass which can be used for energy purposes. The main distinction is between residual biomass and dedicated energy crops.

Residual biomass can be used for energy production, or for other uses, or again can be considered as waste to be disposed of in a landfill. To estimate theoretical availability, the ISTAT data for 2013 were used to measure Italy's agricultural land area. This study considers arable crops and permanent crops, excluding pastures and meadows, because its aim is to estimate the share of crop residue which is suitable in terms of quality and which technically lends itself to collection.

Table 44 – Agricultural land area in Italy (2013)

	Area (ha)
Arable land	6 488.000
Permanent crops	2 360.000
Total	**8 848.000**

Source: ISTAT, 2013

Italy has almost 9 million hectares of agricultural land, about three quarters of which are under arable crops. Specifically, 40 % of Italy's agricultural land is cultivated with cereals and rice, while 23 % is given over to rotated fodder crops. As to permanent crops, olive groves make up about 13 % of the total agricultural area.

The amount of agricultural waste by province was estimated by consulting the database of Italy's residual agricultural biomass managed by ENEA. The residual biomass from the main traditional food crops in Italy was considered, such as straw from cereals and plant cuttings from fruit crops.

The following table shows the agricultural residue available, broken down by Region:

Table 45 – Distribution of agricultural residues by region (Mton/year)

Region	Residues (Mton/year)
Abruzzo	0.57
Basilicata	0.51
Calabria	1.41
Campania	0.68
Emilia Romagna	2.03
Friuli Venezia Giulia	0.66
Lazio	0.76
Liguria	0.03
Lombardy	3.82
Marche	0.61
Molise	0.22
Piedmont	2.84
Apulia	2.43
Sardinia	0.41
Sicily	1.57
Tuscany	1.03
Trentino-Alto Adige	0.08
Umbria	0.55
Valle d'Aosta	0.00
Veneto	2.19
Grand total	22.40

According to the assessments made, the theoretical availability of agricultural residues in a given year is approximately 22.4 Mton of dry matter. Of these, 70 % is cereal straw, followed by plant cuttings/pruning residue with 22 %; 2 % is rice husks; grape marc and olive pomace together make up 6 %, while nutshells account for 1 %.

When assessing the quantity of agricultural residue that can be used for energy purposes, it was assumed that slightly less than half of that residue can actually be used, i.e. about 10.2 Mton. The most interesting regions seem to be Lombardy, Piedmont and Puglia which, together, cover almost half of the estimated availability of agricultural residue.

Considering a calorific value of 0.33 toe/t of dry matter, the quantity of agricultural waste which can be used for energy purposes would supply 3.33 Mtoe of primary energy.

As to the estimated theoretical availability of **dedicated energy crops**, this includes both grass crops and short-rotation forestry.

The dedicated energy crops can be divided into:

- cultivation of annual grass crops such as sorghum and other grasses. The results obtained are positive in terms of production efficiency, as they fall in a class of 15-20 t dry matter/ha/year;
- production of woody biomass through short-rotation forestry (SRF), e.g. poplar, with production ranging from 8 to 30 tonnes of dry matter/ha.

Thus, overall a production of about 4 Mton of biomass from dedicated energy crops is estimated, taking up about 200 000 ha of agricultural land area, with an energy contribution of some 1 Mtoe.

Table 46 – Dedicated energy crops

	Area (ha)	Quantity of biofuels and/or of dry matter (Mton)	Available energy (Mtoe)
Biofuels	600 000	0.8	0.6
Grass crops and SRF	250 000	4	1
Total	850 000		1.6

Source: RSE

4.3.3 Forestry

This section estimates the quantity of biomass available from waste wood from forested areas, in particular coppice woods and timber forests.

Based on a **forest size** of almost **11 million hectares** in 2015, it was possible to estimate the availability of forest biomass and the energy obtainable from it. The table below shows the regional distribution of woodland areas in Italy. The largest share is in Sardinia, which has more than 1.2 million ha of woodland. Next comes Tuscany.

Table 47 – Distribution in ha of woodland areas in Italy (2015)

Region	Forested area 2015
Abruzzo	475 093
Basilicata	393 864
Calabria	670 968
Campania	486 945
Emilia Romagna	629 625
Friuli Venezia Giulia	365 486
Lazio	667 704
Liguria	397 531
Lombardy	664 192
Marche	311 032
Molise	172 222
Piedmont	955 110
Apulia	189 086
Sardinia	1 241 409
Sicily	381 647
Tuscany	1 196 992
Trentino-Alto Adige	789 104
Umbria	416 660
Valle d'Aosta	111 719
Veneto	465 264
Italy	**10 981 653**

Source: Inventario Forestale Nazionale - National Forestry Inventory

Assuming an average annual increase of 4.2 m^3/ha for coppice and 5.2 m^3/ha for timber forests, the available biomass in 2023 can be estimated at around 34 Mton.

Assuming that moisture level in the wood is 43 % – and water content 30 % – we can calculate a calorific value of 12.57 Mj/kg; thus, the estimated energy contribution of forest biomass is 12.6 Mtoe.

The table below shows that greater forest area would make available a larger amount of forest biomass for use. Sardinia would be able to produce 1.4 Mtoe of energy, followed closely by Tuscany.

Table 48 – Breakdown of energy availability from forest biomass (Mtoe)

Region	Distribution of woodland in Italy (%)	Distribution of energy from forest biomass (Mtoe)
Abruzzo	4 %	0.55
Basilicata	4 %	0.45
Calabria	6 %	0.77
Campania	4 %	0.56
Emilia Romagna	6 %	0.72
Friuli Venezia Giulia	3 %	0.42
Lazio	6 %	0.77
Liguria	4 %	0.46
Lombardy	6 %	0.76
Marche	3 %	0.36
Molise	2 %	0.20
Piedmont	9 %	1.10
Apulia	2 %	0.22
Sardinia	11 %	1.42
Sicily	3 %	0.44
Tuscany	11 %	1.37
Trentino-Alto Adige	4 %	0.90
Umbria	4 %	0.48
Valle d'Aosta	1 %	0.13
Veneto	4 %	0.53
Italy		12.6

4.3.4 Industry

As to Italy's industrial sector, the potential energy contribution from organic processing residue can be estimated.

This estimate is based on data supplied by RSE [public energy research company], according to which the overall share of non-hazardous industrial waste as at 2006 amounted to about 73 Mton, including 1.6 Mton from the wood, paper and printing industries and 13.2 Mton from the agrifood industry.

The following assumptions are made:

- the amount of waste potentially usable for energy purposes is exploited entirely for the wood and paper industry, thereby making the entire share available for energy production purposes; this assumption gives an energy contribution of 0.53 Mtoe, considering a calorific value of 0.33 toe/t;
- in the agrifood sector, 10 % of the total is estimated to be potentially exploitable for energy purposes; by calculating this share at the same calorific value applied to the wood and paper sectors, the annual contribution would be 0.44 Mtoe.

4.4 Waste heat from industrial sites

The waste heat from industrial processes is generated by inefficiencies in the production process and by the thermodynamic limitations inherent in the use of the heat produced.

To estimate the waste heat available at each industrial site, geolocated according to the method illustrated earlier in this report[36], a calculation procedure was used based on the study by McKenna et al.[37]. By applying suitable factors to energy consumption data, this method can calculate the 'site heat load' $\dot{Q}$ for each industrial site and estimate the technical potential for heat recovery, thereby calculating the theoretical waste heat available.

Due to the lack of detailed data on the energy consumption of each industrial site and its components, this method was applied to the consumption data of the different sites and industrial sectors as estimated in section 1.5.2; this means, however, that the values obtained are purely indicative.

The main steps implemented to calculate the waste heat produced by each industrial site considered are the following:

1) collection of data on the energy consumption C_{ik} of each industrial site[38];
2) application of the percentage factors of potential recovery of consumed energy, obtained from a study of the Joint Research Centre[39] based on the assessment by McKenna et al. for each industrial sector;

[36] See section 1.5.2

[37] R.C. McKenna, J.B. Norman "Spatial modelling of industrial heat loads and recovery potentials in the UK", 2009

[38] See section 1.5.2

Table 49 Potential recovery factors of consumed energy by industrial sector (% of the energy consumed by industrial sites)

Subsector	χ_{WH} [%]
Iron and Steel	15
Non-Ferrous Metals	20
Chemical and Petrochemical	7
Non-Metallic Minerals	20
Mining and Quarrying	14
Food and Tobacco	7
*Textile and Leather**	14
Paper, Pulp and Print	7
*Transport Equipment**	14
*Machinery**	14
*Wood and Wood Products***	7
Construction	25
*Non-specified (Industry)**	14

*Value obtained from the average of potential recovery factors identified by JRC

**Value taken by assuming similarity with the "Paper, Pulp and Print" sector

3) estimate of the quantity of waste heat at each industrial site on the basis of the value obtained by multiplying the above-mentioned variables:

$$WH\ [GWh] = C_{ik} * \chi_{WH}$$

The waste heat values associated with each industrial subsector, calculated in this manner, are set out in the following table[40]. The industrial sites with the greatest potential for surplus heat recovery are the iron and steel industry and the chemical and petrochemical industries.

[39] JRC Science and Policy reports "Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level", Deliverable 1, July 2015

[40] The results are presented at national level, but their geographical distribution could also be shown, since the methodology considers the estimated consumption of each industrial site.

Table 50 Potential waste heat (in GWh) from industrial sites, broken down by subsector (assessed on the basis of the estimate of energy consumption in 2013 by each industrial site)

Subsector	*Waste heat potential (GWh)*
Iron and Steel	6086
Non-Ferrous Metals	545
Chemical and Petrochemical	2156
Non-Metallic Minerals	15468
Food and Tobacco	390
Textile and Leather	310
Paper, Pulp and Print	1496
Transport Equipment	178
Machinery	139
Wood and Wood Products	74
Construction	31
Non-specified (Industry)	15
Totale	**26888**

As mentioned, these values are purely indicative. The weaknesses of the method used are due to:

- the lack of precise data on each industrial site allowing the identification, within energy consumption, of the 'site heat load' value $\dot{Q}$;
- constant factor χ_{WH} assumed for each industrial sector, thereby ignoring the specific nature of processes in the different industrial sectors;
- lack of data on the waste heat temperature profiles;
- lack of data on all the industrial sectors considered.

5 Potential for HE CHP

5.1 Method used to analyse the potential for high-efficiency CHP and key for interpreting results

The potential for developing high-efficiency cogeneration has been assessed by analysing the characteristics of the demand for energy from the residential, services and industrial sectors described in the first chapter of this report and analysed in greater detail in the subsequent chapters. This analysis has served to identify clusters, or subsectors, of typical demand points making up the various use sectors and to define both the unit energy demand of customers (electrical and thermal) as well as each cluster's overall demand.

For every subsector of customers 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 demand points best placed for being served by CHP systems and to assess the amount of cogenerated capacity and energy that can truly be achieved at those demand points. 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-financial consideration.

In detail, the technical potential has been assessed through the following steps:

1. Selection of the subsectors best suited for supply by a cogenerator, in light of certain indicators and technical constraints (amount of the 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. Establishment of the size of the cogenerator and simulation of its operating conditions at the typical demand point of the subsector identified, by applying specific performance indicators obtained from the installations in operation at similar demand points in terms of energy demand.

3. Estimate of the maximum amount of cogenerated thermal energy and electricity technically obtainable in the subsectors that can be served by a cogenerator. Extension of the energy results obtained in the case study to the whole reference subsector, whose size was assessed in the demand survey stage.

After assessing the parameters of the system in operation at each typical demand point and the associated technical potential of the subsector, the **economic potential** was assessed, estimating the economic-financial sustainability of operation of the proposed system, under the current legislation and in light of the 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 commodities 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-financial performance of the investment in the CHP system, comparing it with the sector's baseline situation. Based on the economic indicators used (NPV, IRR, etc.) and assuming that customers' investment choices are guided by criteria of least cost for energy supply, the economic feasibility of the HE CHP systems was assessed, and thus their economic potential. To calculate NPV, a weighted average cost of capital (WACC) of 5 % was considered. 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. 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 compared against 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 (which was sometimes the case in the industrial sector, as described below), 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, decision-making processes, permits, etc.) and which can significantly reduce (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.

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 sectoral level 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, elaborated by GSE on the basis of the technologies assumed to have been replaced in the sectors[41], 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 the AEEGSI 2015 Consultation Paper 202/2015/R/Eel – Final Guidelines, which analysed and updated the loss factors for the national grid).

The **avoided GHG emissions** linked to the development potential of HE CHP were calculated using a method developed by GSE in cooperation with RSE, which GSE uses pursuant to Article 40 of Legislative Decree No 28/2011 to monitor the reduction in GHG emissions resulting from the spread of renewables and energy efficiency initiatives. These assessments are submitted to the European Commission every two years (Progress Report pursuant to Directive 2009/28/EC). This method assesses the emissions avoided due to the electricity produced by HE CHP systems. This takes into account specific emissions from marginal fossil fuel technologies in the Italian electricity market, the useful heat produced by HE CHP systems, and the specific emissions for heat production (taking as a benchmark a natural gas boiler), as well as the lower network losses linked to distributed production and the related self-consumption.

The saved primary energy and emissions were assessed for each typical customer of 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 each sector).

In compliance with Legislative Decree No 102/2014 and Directive 2012/27/EU, the analysis of the technical and economic potential of HE CHP has taken into account the scenarios for development of heat demand over the next ten years.

To assess the potential of CHP, GSE worked with RSE's Department for the Development of Energy Systems, and with University of Roma Tor Vergata - Department of Industrial Engineering. These two partners helped to identify the methods for assessing the CHP potential. To estimate the development of heat demand over the next decade in the sectors studied, GSE worked with the ENEA – Study and Strategy Unit – Service for Analysis and Technical and Socio-Economic Scenarios and Economic Prospects for Sustainability.

[41] More specifically, the reference electrical efficiency for separate production was equal to the average efficiency of the marginal national fossil fuel mix on the day-ahead market calculated by GSE using GME data for the ITM 2014, or 48.1 %. The reference thermal efficiency for separate heat production was 90 %.

5.2 Potential for HE CHP in the residential sector

The energy supply from HE CHP currently found in the sector, albeit with a sizeable number of installations (163 units or 16 % of the total HE CHP units installed in Italy) is somewhat low in terms of energy output. Indeed, installed electrical capacity is 4.7 MWe, or just 0.03 % of the total HE CHP capacity installed in Italy[42]. The cogenerated thermal energy amounts to almost 10 GWh and covers just 0.003 % of heat demand by the residential sector.

The factors that so far have hampered the deployment of HE 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 electricity of residential users. This demand has fairly low intensity (even in the country's coldest areas), limited duration, strong load fluctuations over time, possible time mismatch between demand for heat and for power and a heat/electricity ratio which often sees much higher demand for heat.

All these technical factors inevitably produce economic consequences. Residential customers usually demand micro-CHP installations (<50kW) 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 impact on return on investment, in view of the small number of hours of operation of residential sector installations (usually less than 2000 equivalent hours). Moreover, the variable production costs are significant on account of the high prices of fuel and poorer electrical efficiency[43] 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 spread created with the excise duty 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[44]. The schemes supporting HE CHP systems,

[42] The survey of the sectors using HE CHP systems from which the statistical data were obtained covered 83 % of the number of HE CHP systems in operation and 99.97 % of their electrical capacity; therefore, the estimates provide a good approximation of the current situation of installations in the sector.

[43] 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 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.

[44] The excise duty on gas for civil uses, taking into account the different consumption bands and standard consumption by users, ranges from 16 to 19.5 €c/Nm3, while excise duty in industrial uses ranges, according to consumption, from 0.75 to 1.25 €c/Nm3. The excise duty on the gas used by cogenerators below the specific electric consumption threshold of 0.22 kWh/Nm3 is discounted and amounts respectively to 0.04493 €c/Nm3 and 0.013479 EURc/Nm3 according to whether it applies to electricity production or self-production. For the typical efficiencies of 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 12.7-6.9

particularly white certificates, despite including elements designed to increase the premium[45] for small-size installations, are unable to offset the higher investment and operation costs.

Lastly, under the recent rules introduced on efficient systems for demand points (SEU) (Decisions AEEGSI 578/2013/R/eel as amended, Legislative Decree 115/08, Article 25-bis of Decree-Law No 91/14 converted by Law No 116/14) specific incentives are available consisting of part-exemption from general system charges, provided that certain requirements are met; in particular, to be classed as an SEU, a system must consist of installations using renewable energy sources or high-efficiency cogeneration with a capacity up to 20 MWe, operated by a single producer (who need not be the final customer) connected directly through a private connection to the consumption unit of a single end-customer (natural or legal person) and installed on a site owned by or fully available to that customer. These requirements mean that, in the residential sector, in multi-apartment buildings, the electricity demand point of a cogenerator serving the whole block can only serve the common services (such as lifts, common area lighting, electrical consumption of the heating system, etc.) and cannot serve electricity use by individual dwellings, since these are classed as different consumption units from the common demand point. This restricts significantly electricity demand, creating a strong imbalance between the thermal and electrical load, and is thus unsuitable for CHP solutions. Thus, this framework restricts to a significant degree electricity self-consumption, which is one of the main economic drivers for the sector.

Another obstacle relates to the decision-making and operational difficulties often encountered in the running of condominiums, especially large ones. All these hurdles taken together make it unlikely that any significant growth of installed capacity could be achieved in the sector under the current framework.

The following detailed analysis shows that the great theoretical potential technically feasible on a share of the energy demand from the residential sector, which is one of the country's top energy consuming sectors (making up 28.9 % of total national energy consumption), is in practice unlikely to be fulfilled owing to economic reasons under the current regulatory and market conditions.

5.2.1 Characteristics of heat demand in the residential sector

The characteristics of thermal energy demand from the residential sector, already described in detail in the first chapter of this report, were analysed on the basis of the consumption data submitted to Eurostat for 2013. This section only repeats some aggregate data to recall the main inputs for establishment of the technical potential.

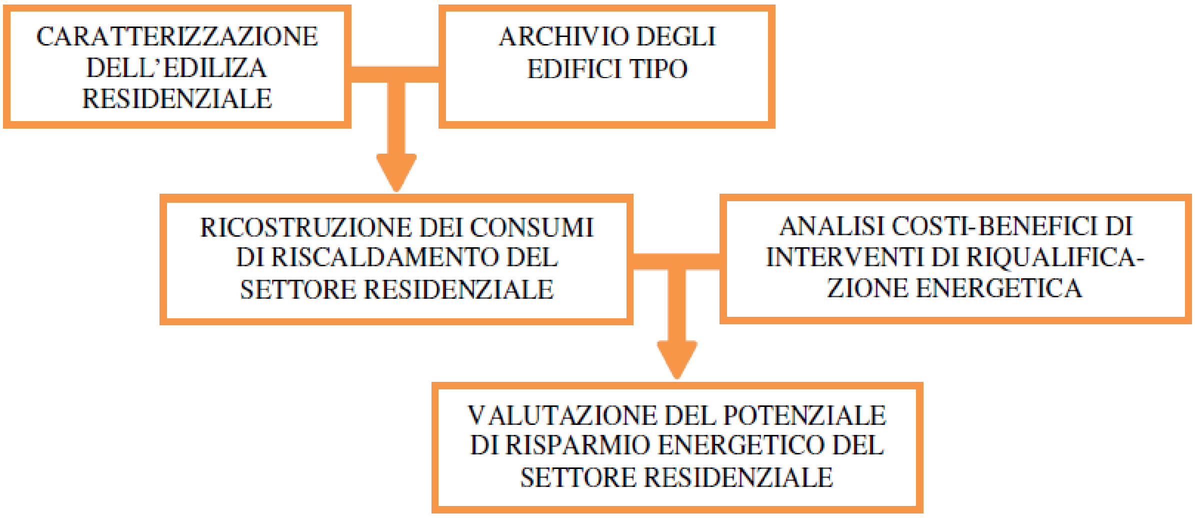
The national stock of residential buildings comprises some 24 million dwellings occupied by residents, distributed in about 12 million buildings. The built stock has been analysed using the data from the census of dwellings carried out by ISTAT, in order to calculate the number and floor area of dwellings and classify them according to the most significant parameters influencing

€c/Nm^3, thus with a final rebate on excise duty ranging from 3 to 12.5 €c/Nm^3, which is about 2.2-16.6 times higher than the rebate granted to the industrial sector.

[45] Certain factors are used to increase the calculation of the primary energy savings against which white certificates are granted. They include coefficient K, ranging between 1 and 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.

energy consumption. Moreover, typical buildings representing the types of built stock have been identified and classed by period of construction, type and climate condition area. This bottom-up approach has enabled assessment of energy consumption for space heating in the residential sector, which amounts to about 24.9 Mtoe of energy consumption, distributed among different types of buildings, according to climate class, construction period and number of dwellings in the building.

Figure 60 – Diagram summarising the process of assessing energy consumption for heating and estimating the energy saving in the residential sector



CARATTERIZZAZIONE DELL'EDILIZA RESIDENZIALE	CHARACTERISATION OF THE RESIDENTIAL BUILDING
ARCHIVIO DEGLI EDIFICI TIPO	ARCHIVE OF STANDARD BUILDINGS
RICOSTRUZIONE DEI CONSUMI DI RISCALDAMENTO DEL SETTORE RESIDENZIALE	ASSESSMENT OF ENERGY CONSUMPTION FOR HEATING IN THE RESIDENTIAL SECTOR
ANALISI COSTI-BENEFICI DI INTERVENTI DI RIQUALIFICAZIONE ENERGETICA	COST-BENEFIT ANALYSIS OF ENERGY RETROFITS
VALUTAZIONE DEL POTENZIALE DI RISPARMIO ENERGETICO DEL SETTORE RESIDENZIALE	ASSESSMENT OF THE POTENTIAL ENERGY SAVING IN THE RESIDENTIAL SECTOR

Table 51 – Heat consumption (GWh) in the residential sector in 2013 (DH: detached house; TH: terraced house or small multi-apartment building; MB: medium-sized multi-apartment building; LB: large multi-apartment building)

CLIMATE CONDITION AREA	TYPE	NUMBER OF DWELLINGS	CONSTRUCTION PERIOD							
			Before 1919	1919-1945	1946-1961	1962-1981	1982-1991	1992-2001	2002-2013	Total
B	DH	1	89	172	228	401	105	43	27	3 732
	TH	2-4	58	113	199	579	108	49	22	
	MB	5-15	69	150	220	412	81	31	14	
	LB	16 and more	12	40	102	324	64	14	4	
C	DH	1	1 013	1 227	1 759	3 154	896	382	228	28 412
	TH	2-4	814	827	1 608	4 482	881	392	182	
	MB	5-15	623	558	1 442	3 185	700	288	160	
	LB	16 and more	246	305	509	1 940	429	127	54	
D	DH	1	3 244	1 960	2 101	4 498	1 267	647	425	67 177
	TH	2-4	3 544	2 049	3 069	10 275	1 792	684	417	
	MB	5-15	2 175	1 473	4 539	8 950	1 768	658	496	
	LB	16 and more	627	1 300	1 364	6 022	1 171	373	291	
E	DH	1	10 164	5 759	6 193	13 531	2 877	1 515	1 284	176 791
	TH	2-4	10 731	6 490	8 299	29 838	3 902	2 018	1 555	
	MB	5-15	6 622	4 165	8 606	20 846	3 662	2 228	2 459	
	LB	16 and more	1 342	1 960	3 124	13 370	2 045	1 148	1 059	
F	DH	1	1 383	527	377	875	213	148	118	13 489
	TH	2-4	1 591	659	659	2 100	275	157	106	
	MB	5-15	751	285	395	1 281	230	157	136	
	LB	16 and more	82	72	141	552	103	63	51	

Residential heating consumption is distributed unevenly between the different types of users characterising the different geographical areas of the country, but can be summarised as follows:

- 66 % of consumption is concentrated in the country's climate condition areas E-F;
- 44 % of consumption is by dwellings built between 1962 and 1981, which make up the largest part of the residential stock and that with intermediate specific consumption;
- the breakdown of consumption by type of residential building is as follows: 24 % by detached houses, 35 % terraced houses, 27 % medium-sized multi-apartment buildings, and the remaining 14 % large multi-apartment buildings.

Add to the heating consumption about 2.8 Mtoe of DHW distributed between the various types of dwellings, exclusively on the basis of the distribution of the resident population and presumably without specific intensity according to climate condition area and type of building, which instead influence heating consumption.

5.2.2 Technical potential in the residential sector

The 27.7 Mtoe of consumption for residential heating and DHW cannot all be covered by CHP installations, nor can electrical demand, due to technical factors, apart from economic assessments, which restrict CHP deployment.

In a national-level assessment such as the one carried out, seeking to focus the analysis on the main phenomena, the first constraint that can reasonably be assumed is the climate condition area; it seems appropriate to consider only the colder climate areas as suitable for CHP systems, where in winter the number of hours of operation of heating equipment might justify the installation of a CHP system. Climate areas B to D have been excluded from the analysis because, under the assumption of following thermal load only and thus not to disperse the heat produced, the hours of operation envisaged in these areas would not suffice to justify installation of a CHP system. For instance, in climate area D, 12 hours of daily heating are allowed, from 1 November to 15 April, for a total of about 2000 hours, only a minimal part of which under full load. These hours of operation are not felt to be sufficient to justify the installation of a CHP system intended to produce exclusively the heat required without dispersing excess heat. In climate area C the hours of operation drop to 1400. Thus, the technical potential assessed in this study only includes the demand for heat in climate condition areas E and F.

The second technical barrier concerns the heat distribution system within the building. In residential buildings such as multi-apartment buildings, the CHP unit must provide central heating. If 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 unfeasible. Consequently, it was felt more realistic to include in the estimate of the technical potential only multi-apartment buildings with central heating.

The third technical aspect excludes the most recent dwellings both on account of their lower thermal energy demand thanks to their better insulation and energy efficiency and due to the reluctance of residents to opt for system conversion.

Thus, applying the above constraints, the following standard types of customers have been selected to assess the technical potential in the residential sector:

- detached house climate areas E-F built before the year 2000;
- medium-sized multi-apartment building in climate areas E-F with central heating, built before 2000;
- large multi-apartment building in climate areas E-F with central heating built before 2000.

For each customer the demand for heat and power has been characterised both in terms of the individual customer and in overall national terms. In the case of detached houses, the total demand for heat and power has been considered (excluding demand for cooking). In the case of multi-apartment buildings, the CHP system can only cover the demand for power in the building's common areas (lighting, lifts, etc.) on account of legislation on efficient demand point systems[46]. Furthermore, with regard to heat consumption, the only demand technically attributable to the

[46] These systems include installations using renewable energy sources or high-efficiency cogeneration with capacity up to 20 MWe, operated by a single producer (who need not be the final customer) connected directly through a private connection to the consumption unit of a single end-customer (natural or legal person) and installed in a site owned by or fully available to the customer. Each flat is treated as an individual final customer/legal entity.

CHP system is that for space heating, excluding the demand for DHW which is almost always covered by individual units[47]. The specific demand for heating based on which the users' demand has been calculated refers to homes built in the 1970s and located in climate area E, as they are the most representative of the customer class considered in terms of number and intermediate intensity of consumption. The number of dwellings considered for a medium-sized multi-apartment building is 8, that in large multi-apartment buildings is 40.

Table 52 – Energy demand from standard customers in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
No of flats	1	5-15	>16
Year of construction	Before 2000	Before 2000	Before 2000
Climate condition area	E-F	E-F	E-F
Type of heating	Single-home	centralised	centralised
Annual heating energy demand	19.4 MWh	115.3 MWh	442.8 MWh
Annual DHW demand	1.4 MWh	0.0 MWh	0.0 MWh
Annual electricity demand	3 000 kWh	9 000 kWh	15 000 kWh
User heat/electricity ratio	6.3	12.8	29.5

Next, the size and type of the CHP systems that can be installed at the demand points were identified: in the case of detached houses, 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 multi-apartment buildings, a commercial micro-CHP system of slightly larger size has been envisaged (13.4 kWt) while in the case of large multi-apartment buildings the CHP system chosen has a thermal capacity of 137 kWt which is typical of applications in large multi-apartment buildings.

Operating conditions were simulated using the specific performance indicators taken from operating data of residential demand points having similar energy demand, held in GSE's database on HE CHP.

The new CHP system is assumed to 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.

[47] In Italy, 73.9% of households have independent DHW systems. Source: ISTAT 2013.

Table 53 – Technical parameters for 'typical' HE CHP systems in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
Type of technology	Stirling - gas	MCI - gas	MCI - gas
Electrical capacity of CHP system	1 kWe	6 kWe	60 kWe
Thermal capacity of CHP system	5 kWt	13 kWt	137 kWt
Heat/electricity ratio of the system	5.0	2.4	2.3
Electrical efficiency of CHP system	15 %	27 %	28 %
Thermal efficiency of CHP system	75 %	64 %	64 %
Share of electricity produced by High-Efficiency CHP	100 %	100 %	100 %
Share of electricity self-produced/consumed[48]	49 %	22 %	8 %
Equivalent hours under HE CHP	3 000 heq	1 943 heq	1 481 heq
Thermal efficiency of boilers	90 %	90 %	90 %

As shown by the results of the simulations, only a share of the demand point'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 unfavourable for CHP applications. Although there are technical 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.

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 demand point, especially in multi-apartment buildings. 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 demand point's overall thermal demand. Hence, boilers continue to play a major role in covering the demand for heat.

[48] This means the electricity generated by the installation and consumed directly at the demand point without going through the grid.

Table 54 – Energy output from simulation of the operating conditions of CHP systems in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
Heat produced by the CHP system	15.0 MWh	25.7 MWh	204.0 MWh
Share of demand for CHP heat	60 %	22 %	46 %
Heat generated by backup boiler	3.9 MWh	89.7 MWh	238.8 MWh
HE CHP electricity produced by the CHP system	3.0 MWh	10.9 MWh	88.9 MWh
Total electricity produced by the CHP system	3.0 MWh	10.9 MWh	88.9 MWh
Electricity injected into the grid	1.5 MWh	8.5 MWh	81.4 MWh
Self-consumed electricity	1.5 MWh	2.4 MWh	7.5 MWh
Electricity off-taken from the grid	1.5 MWh	6.6 MWh	7.5 MWh
Electricity exchanged with the grid	1.5 MWh	6.6 MWh	7.5 MWh
Consumption of HE CHP system	20.0 MWh	40.2 MWh	321.0 MWh
Total CHP system consumption	20.0 MWh	40.2 MWh	321.0 MWh
Consumption of backup boiler	4.4 MWh	99.7 MWh	265.3 MWh
Electricity off-taken ex-ante	3.0 MWh	9.0 MWh	15.0 MWh
Boiler consumption ex-ante	21.0 MWh	128.2 MWh	492.0 MWh

By extending the energy outputs obtained in the case study to the entire reference subsector (as measured in the demand characterisation stage) it is possible to estimate technical potential, which in the residential sector amounts overall to 42 TWht and 10 TWhe of thermal energy and electricity obtainable from HE CHP, corresponding to an installed capacity of about 4.5 GWe.

These values represent, on the basis of the assumptions made, the maximum amount of cogenerated thermal energy and electricity technically obtainable in the subsectors that can be served by a cogenerator. As previously stated, the technical potential for deployment of CHP systems presented here is entirely theoretical, and has been assessed in view of the technical constraints applied to identify the share of demand for heat which could be met by a CHP system, without considering economic and financial factors, which are discussed subsequently.

Table 55 – Overall demand from the subsector of typical residential customers and associated technical potential for development of high-efficiency cogeneration

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
Heat demand by subsector (2013)	41 857 GWh	22 230 GWh	9 114 GWh
Electricity demand by subsector (2013)	6 467 GWh	1 054 GWh	685 GWh
Technical potential for HE CHP heat	33 171 GWh	4 946 GWh	4 199 GWh
Technical potential for HE CHP electricity	6 634 GWh	2 097 GWh	1 829 GWh
Technical potential for HE CHP thermal capacity	11 057 MWt	2 545 MWt	2 835 MWt
Technical potential for HE CHP electrical capacity	2 211 MWe	1 079 MWe	1 235 MWe

5.2.3 Analysis of costs and economic potential in the residential sector

The case studies described and simulated in assessment of the technical potential have also been analysed from the viewpoint of technological costs, and have been used to make an economic simulation to verify which of the possible HE CHP solutions would be economically viable.

The technological costs of the micro-CHP systems identified through a survey of the sectoral market are high. The specific investment costs grow almost exponentially with decreasing size, also on account of some additional features of these micro-systems when compared with the standard ICE systems. Specific investment costs have been obtained by reconstructing a cost curve by interpolating the prices quoted in the price lists of the main suppliers which did not include sizes below 30 KWe and which stood at about 3000 €/kWe. The specific investment costs of the micro-CHP system considered suitable for a medium-sized multi-apartment building are in line with those set out in studies by RSE. As to detached houses, a mid-point has been sought where the data in the literature differed. For maintenance purposes, the typical cost of full service contracts was applied. Their value is set on the basis of the system's hours of operation. The maintenance cost per hour of operation offered by suppliers rises almost linearly with the size of the system; for small plants for which no market information was available, reference was made to values supplied by RSE[49].

The useful life of small-size installations, based on manufacturers' data, is 20 000-40 000 hours of operation. This poses another constraint on these small-size installations.

Since the existing boilers are maintained after deployment of the CHP system too, for backup purposes, their investment and maintenance costs and useful life have not been factored in. Indeed, it is assumed that at the end of their useful life, these boilers would be repurchased whether or not the CHP system is installed; thus, the same investment cost would apply in both scenarios. This assumptions does not consider, in the CHP scenario, the possible lower investment costs for a low-efficiency backup boiler which, being intended only to cover the demand not covered by the CHP system, would have a lower capacity than a stand-alone boiler. However, in the residential context and in the cases considered, this cost saving, where present, is not particularly significant; indeed, the capacity of CHP systems is always far lower than that of the existing boilers which would remain necessary even in the CHP scenario.

Regarding commodities, the final consumer prices of the gas and electricity drawn by demand points were taken from Eurostat, using 2014 as the reference year[50]. The different tariffs applied to the various types of residential customers are due to the different incidence of certain tariff components, both fixed and variable according to consumption. Furthermore, some tariff components differ according to whether the customer is a "resident" (a single household) or is classified as "other uses" (the common-area uses in multi-apartment buildings).

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[49] Perego O., Bazzocchi F. Benini M. 'Rapporto RSE RdS 14009625' 2014

CODE2 Cogeneration Observatory and Dissemination Europe "Micro-CHP potential analysis European level report" December 2014
http://www.code2-project.eu/wp-content/uploads/D2.5-2014-12-micro-CHP-potential-analysis_final.pdf

Danish energy agency "Technology data for energy plants" 2012
http://www.ens.dk/sites/ens.dk/files/dokumenter/publikationer/downloads/technology_data_for_individual_heating_plants_and_energy_transport.pdf

[50] "Electricity prices for domestic consumers - bi-annual data (from 2007 onwards)" "Gas prices for domestic consumers - bi-annual data (from 2007 onwards) (nrg_pc_202)" http://ec.europa.eu/eurostat/web/energy/data/database

The installations considered in the residential sector, which are all HE CHP with a capacity below 200 kWe, are eligible for the net metering scheme[51]. The power produced by the cogenerator and exchanged with the grid, i.e. the difference between the power drawn and that fed in, is priced at a net metering tariff calculated as the average of the NM tariffs applied to HE CHP systems in 2014 by GSE. If the power fed into the grid exceeds that drawn from the grid, not all the power offtaken is priced at the net metering tariff. The excess quantity is priced at the wholesale market price. The wholesale price of electricity taken as a reference for the calculations is the single national average price in 2014 on the day ahead market (PUN MGP 2014)[52].

Self-consumed electricity is liable for excise duty on electricity, like consumed electricity. The amount of the excise duty on electricity varies according to consumption band.

New HE CHP systems below 20 MWe can request classification as SEU (efficient demand point system), which involves partial exemption from the general system charges. The exemption is total for installations classed as SEU with a capacity of less than 20 KWe and connected in low voltage (this is the scenario considered for detached houses and medium-sized multi-apartment buildings). SEU installations connected in low voltage with a capacity of more than 20 kWe (the CHP scenario considered for large multi-apartment buildings) are charged a fixed excise duty of 36 €/year (value in 2015, pursuant to Decision AEEGSI 609/2014/R/eel as amended).

The price of the gas consumed by the CHP was obtained from the final price of the gas described earlier, net of the rebate on excise duties for the self-production of electricity, in accordance with the current provisions 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 deductible and the consumption of gas by the boiler are subject to the excise duty for civil uses.

The price of the energy efficiency certificates or white certificates (type II-HE CHP) was inferred from GME's statistical data on average prices in the centralised market for EEC in 2014[53].

The weighted average cost of capital (WACC) was considered to be lower than 5 %. In the event of extensive recourse to bank loans, this value might be rather low. However, as a first approximation, it was felt preferable to consider a return on investment not unduly influenced by the manner of raising capital and by the need for high financial return, given the purpose of the analysis[54].

Table 56 – Economic-financial parameters used in the financial simulation for the residential sector

[51] Net metering (NM), which is governed by Decision AEEGSI 570/2012/R/efr, is an electricity pricing method enabling a particular form of self-consumption, whereby power producers feed into the grid the electricity produced but not directly self-consumed by then, and can then draw it at a later time from the grid. This scheme makes it possible to offset the economic value of the electricity produced and fed into the grid against the theoretical economic value of the electricity drawn and consumed at a time different from that of production. The contributo in conto scambio (CS) consists of reimbursement of part of the costs borne by the user to draw electricity from the grid.

[52] In actual fact, a zone price is applied, but since this study addresses the national level and the zone price spreads of the Italian electricity market are by now quite low, this aspect is felt to be negligible.

[53] http://www.mercatoelettrico.org/It/Statistiche/TEE/StatisticheTEE.aspx

[54] This approach reflects the JRC guidelines 'Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level' 2015.

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
Specific Inv. cost of CHP system	6 000 €/kW	4 800 €/kW	2 168 €/kW
Variable maintenance costs	0.00 €/h	0.00 €/h	1.91 €/h
Fixed maintenance costs	180 €/kWyear	313 €/kWyear	0 €/kWyear
Useful life of CHP system (hours of operation)	20 000 h	20 000 h	40 000 h
Useful life of CHP system (calendar years)	6.0 years	9.3 years	15.0 years
Price of gas taken for thermal use	87.40 €/MWh	74.60 €/MWh	58.80 €/MWh
Price of gas for CHP	81.84 €/MWh	63.71 €/MWh	47.53 €/MWh
Price of electricity off-taken	239.20 €/MWh	314.05 €/MWh	314.05 €/MWh
Wholesale price of electricity	52.08 €/MWh	52.08 €/MWh	52.08 €/MWh
Price of electricity under the net-metering system	158.00 €/MWh	158.00 €/MWh	158.00 €/MWh
Excise duty on consumption of gas for civil use	17.71 €/MWh	19.23 €/MWh	19.45 €/MWh
Excise duty on gas for electricity self-production	0.02 €/MWh	0.02 €/MWh	0.02 €/MWh
Deductible on excise duty on gas for electricity self-production	0.22 Smc/kWh	0.22 Smc/kWh	0.22 Smc/kWh
Excise duty on gas applied to the CHP unit	12.15 €/MWh	8.34 €/MWh	8.18 €MWh
Excise duty on electricity consumed	9.08 €/MWh	12.50 €/MWh	12.50 €/MWh
Fixed charges applied for self-consumption (SEU - Efficient User Systems)	0 €/year	0 €/year	36 €/year
Variable charges applied for self-consumption (SEU)	0.00 €/MWh	0.00 €/MWh	0.00 €/MWh
Total charges per unit of self-consumed energy (SEU)	0.00 €/MWh	0.00 €/MWh	4.80 €/MWh
Price of EECs (II-HE CHP)	116.00 €/WC	116.00 €/WC	116.00 €/WC
WACC	5 %	5 %	5 %

The energy flows in the CHP scenario and those in the prior situation have been priced so as to obtain the cash flows allowing calculation of the economic and financial indicators of return on investment.

Note that for all the simulated demand points, the CHP scenario involves an inevitable increase in the costs of gas, including the gas consumed for the backup boiler. For the CHP system to be cost effective, the increased gas costs must be balanced by a reduction in the costs of the electricity drawn and by possible revenues from the sale of electricity to the grid and by access to the current support schemes (white certificates).

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. The white certificates granted in the case of detached houses are zero in that the savings calculated in accordance with the Ministerial Decree of 5 September 2011 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.

Table 57 – Costs and revenues obtained from the financial simulation in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
CHP investment cost	€6 000	€26 877	€130 087
CHP O&M annual cost	180 €/year	1 750 €/year	3 540 €/year
CHP fuel cost	1 637 €/year	2 564 €/year	15 256 €/year
Backup boiler fuel cost	381 €/year	7,434 €/year	15,601 €/year
Cost of electricity off-taken	366 €/year	2,068 €/year	2,355 €/year
Cost of excise duty on self-consumed electricity	13 €/year	30 €/year	94 €/year
Cost of charges on self-consumed electricity	0 €/year	0 €/year	36 €/year
Revenues from electricity injected into the grid	0 €/year	98 €/year	3 847 €/year
Revenues from exchanged electricity	242 €/year	1 041 €/year	1 185 €/year
White certificates awarded	0	2	14
Revenues from white certificates	0 €/year	232 €/year	1 624 €/year
Ex-ante backup boiler fuel cost	1 838 €/year	9 561 €/year	28 929 €/year
Ex-ante cost of electricity from the grid	718 €/year	2 826 €/year	4 711 €/year

Table 58 – Results of the economic analysis of possible CHP projects in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building
NPV	-€4 884	-€27 502	-€94 656
IRR	-	-	-
Time for return on investment (discounted)	-	-	-
Profitability index (NPV/I)	-	-	-
Feasibility percentage	0 %	0 %	0 %

The economic analysis of the cash flows generated during useful life by the investment in the micro-CHP system shows the lack of cost-effectiveness of the investment in the various case studies examined in the residential sector. In all cases considered, the net present value (NPV) is actually negative, annulling the likelihood of financial investment in these initiatives (feasibility share) and the associated economic potential, which is the product of the feasibility share multiplied by the technical potential.

This result, albeit unequivocal, clearly does not claim to cover any possible HE CHP initiatives in the residential sector since this study, while detailed, addresses average typical demand points. In view of the presence of varied subgroups within the clusters considered, one cannot discount the possibility, albeit marginal, that some niche customers might have specific heat and power demand high enough to justify investment[55].

The results obtained as to the economic potential are in line with the data on the installations operating in the sector, which are somewhat small in terms of energy supplied and installed capacity. Based on the analysis conducted, under the present regulatory and market conditions, the growth in the penetration of HE CHP in the residential sector is expected to continue at the slow pace of past years, and to be largely limited to specific niche residential settings (such as large apartment buildings and complexes).

Table 59 – Technical and economic potential of the residential sector on the basis of demand in 2013

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building	Total residential under HE CHP conditions
Heat demand by subsector (2013)	41 857 GWh	22 230 GWh	9 114 GWh	73 201 GWh
Electricity demand by subsector (2013)	6 467 GWh	1 054 GWh	685 GWh	8 206 GWh
Heat from HE CHP in the subsector (2013)	0.7 GWh	1.1 GWh	8.0 GWh	9.8 GWh
Electricity from HE CHP in the subsector (2013)	0.3 GWh	0.5 GWh	4.9 GWh	5.7 GWh
HE CHP thermal capacity in the subsector(2013)	0.4 MWt	0.6 MWt	7.0 MWt	8.0 MWt
HE CHP electrical capacity in the subsector(2013)	0.2 MWe	0.2 MWe	4.2 MWe	4.6 MWe
Share of thermal demand covered by HE CHP (2013)	0.002 %	0.005 %	0.088 %	0.013 %
Share of electrical demand covered by HE CHP (2013)	0.005 %	0.045 %	0.713 %	0.069 %
Technical potential for HE CHP heat	33 171 GWh	4 946 GWh	4 199 GWh	42 315 GWh
Technical potential for HE CHP electricity	6 634 GWh	2 097 GWh	1 829 GWh	10 560 GWh
Technical potential for HE CHP thermal capacity	11 057 MWt	2 545 MWt	2 835 MWt	16 437 MWt
Technical potential for HE CHP electrical capacity	2 211 MWe	1 079 MWe	1 235 MWe	4 526 MWe
Economic potential for HE CHP heat	0.7 GWh	1.1 GWh	8.0 GWh	9.8 GWh
Economic potential for HE CHP electricity	0.3 GWh	0.5 GWh	4.9 GWh	5.7 GWh
Economic potential for HE CHP thermal capacity	0.4 MWt	0.6 MWt	7.0 MWt	8.0 MWt
Economic potential for HE CHP electrical capacity	0.2 MWe	0.2 MWe	4.2 MWe	4.6 MWe

[55] Some examples would be luxury villas, large apartment buildings and complexes with various common facilities such as swimming pools, which can benefit from economies of scale. These cases are not covered in this study as they are felt to be marginal at national level.

5.2.4 Analysis of the benefits linked to development of potential in the residential sector

Assessment of the technical and economic potential was accompanied by assessment of environmental benefits, such as GHG emission savings and primary energy savings, associated with development of the incremental technical and economic potential for HE CHP.

The primary energy savings were calculated on the basis of the efficiency reference values of separate heat and power production, elaborated by GSE on the basis of technologies assumed to have been replaced in the sectors. GHG emission savings were calculated with the GSE method used to monitor the GHG emissions saved through the development of renewables and energy efficiency, as explained in detail in the section on methodology at the beginning of this chapter.

The reference electrical efficiency for the separate production of electricity used to calculate primary energy savings was reduced from the average marginal market value (48.1 %) owing to the correction factors, which take into account the lower electrical losses from low-voltage installations which consume the electricity they generate (factors taken from Consultation Paper 202/2015/R/Eel AEEGSI 2015).

The overall savings which can be estimated on the incremental technical potential in the residential sector amount to about 1 017 ktoe, which would reduce primary energy consumption in the sector by about 2 %. On the other hand, primary energy savings from the incremental economic potential are nil.

The CO_2 savings are positive in the case studies analysed, with an abatement of emissions vis-à-vis separate production of between 20 % and 30 %. Overall, the incremental technical potential would make it possible to reduce emissions from the residential sector by about 3 Mton CO_2 or about 6 % of the total GHG emissions of the residential sector, taking 2013 as the reference year (source: NIR 2013 ISPRA).

Table 60 – Primary energy savings linked to individual HE CHP initiatives and to the incremental technical and economic potential in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building	Total residential under HE CHP conditions
Reference electrical efficiency	45.0 %	45.3 %	45.5 %	
Reference thermal efficiency	90.0 %	90.0 %	90.0 %	
User primary energy savings	0.3 toe	1.1 toe	8.7 toe	
PES incremental technical potential	634.8 ktoe	203.8 ktoe	178.6 ktoe	1 017.2 ktoe
PES incremental economic potential	0.0 ktoe	0.0 ktoe	0.0 ktoe	0.0 ktoe

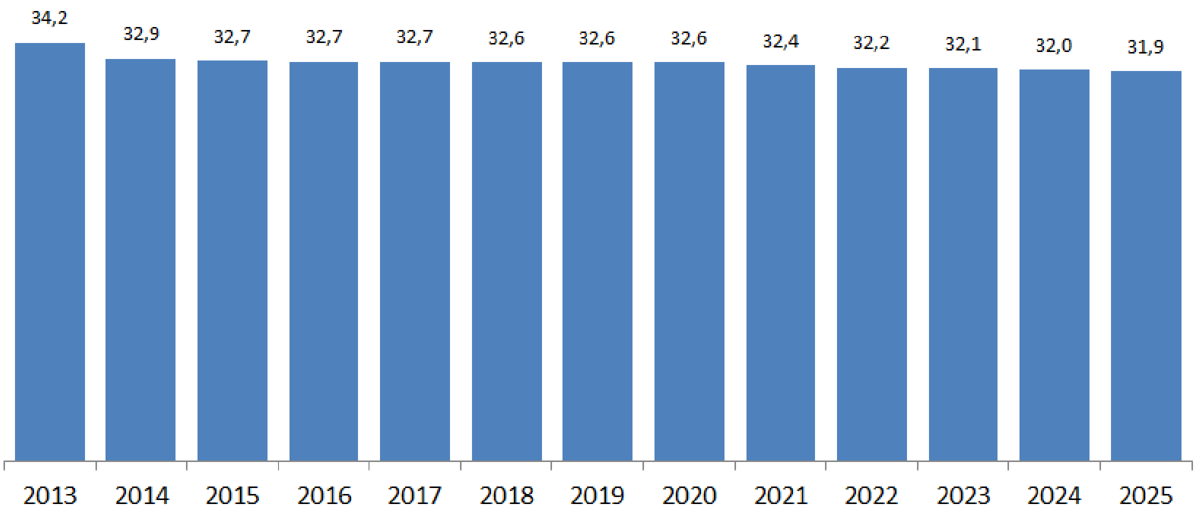
Table 61 – CO_2 savings linked to individual HE CHP initiatives and to the incremental technical and economic potential in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building	Total residential under HE CHP conditions
Emissions produced by HE CHP	4.1 tCO_2	8.3 tCO_2	66.0 tCO_2	
Emissions produced by substitute technologies	5.1 tCO_2	11.7 tCO_2	94.4 tCO_2	
CO_2 savings by users	0.9 tCO_2	3.5 tCO_2	28.4 tCO_2	
Percent emission reduction	-18.7 %	-29.5 %	-30.1 %	
CO_2 savings incremental technical potential	2 093.4 $ktCO_2$	667.7 $ktCO_2$	583.4 $ktCO_2$	3 344.5 $ktCO_2$
CO_2 savings incremental economic potential	0.0 $ktCO_2$	0.0 $ktCO_2$	0.0 $ktCO_2$	0.0 $ktCO_2$

5.2.5 Demand in the residential sector and impact on analysis of potential

According to the ENEA scenarios simulated using the Times model, the final consumption of the residential sector should decrease by about 6 % over the next 10 years, mainly as a result of energy efficiency improvements, especially as concerns thermal energy.

Figure 61 – Final consumption in the residential sector (source: ENEA 2015)



All other factors being equal (regulatory framework, costs, etc.) the significant reduction in consumption expected in the sector would have an impact on the technical potential for HE CHP, which would decrease in terms of thermal energy and electricity by 2.3 GWht and 0.5 GWhe respectively; in terms of electrical capacity, the technical potential would decrease by about 219 MWe.

Table 62 – Technical and economic potential of HE CHP in the residential sector on the basis of demand in 2023

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building	Total residential under HE CHP conditions
Technical potential for HE CHP heat	31 130 GWh	4 642 GWh	3 941 GWh	39 712 GWh
Technical potential for HE CHP electricity	6 226 GWh	1 968 GWh	1 717 GWh	9 911 GWh
Technical potential for HE CHP thermal capacity	10 377 MWt	2 389 MWt	2 661 MWt	15 426 MWt
Technical potential for HE CHP electrical capacity	2 075 MWe	1 013 MWe	1 159 MWe	4 247 MWe
Economic potential for HE CHP heat	1 GWh	1 GWh	8 GWh	10 GWh
Economic potential for HE CHP electricity	0 GWh	1 GWh	5 GWh	6 GWh
Economic potential for HE CHP thermal capacity	0 MWt	1 MWt	7 MWt	8 MWt
Economic potential for HE CHP electrical capacity	0 MWe	0 MWe	4 MWe	5 MWe

5.3 Potential for HE CHP in the services sector

As done when assessing the residential sector, the potential for HE CHP in the services sector was assessed by characterising the demand for thermal energy. Within the overall demand for heat, a series of technical factors and constraints were applied to identify the share that can technically be met by high-efficiency cogeneration. This share is defined as the technical potential. Through an economic feasibility analysis made on the different scenarios of application of CHP installations, the economic potential was identified, in terms of the amount of heat that can be produced by HE CHP and, hence of the capacity that can be installed.

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 sectoral level.

5.3.1 Characterisation of heat demand in the services sector

As described in greater detail in the initial chapter on demand analysis, in 2013 the thermal energy consumption by the services sector considered to be of interest to this study amounted to 95 314 GWh (8.2 Mtoe).

Breakdown by subsector shows that the largest users of heating are healthcare facilities (16 %) and sports facilities (15 %), followed by hotels and public offices (both making up about 12 %). In light of the level of consumption, the average size of demand points and the typical annual profile, the most promising subsectors for HE CHP installations are healthcare, hotels and a subset of sports facilities, or more specifically swimming pools. Aggregate consumption by these subsectors comes to about 30 % of overall heating consumption.

As to the fuels used in 2013, natural gas covered almost 89 % of the consumption selected for this report. The share of petroleum products was 7 % and that of derived heat and renewable energy sources was approximately 2 %. Hence, the reference fuel considered for this study was natural gas.

The following table analyses consumption by the service sector in 2013[56], by the main public and private subsectors, focusing on those best suited for cogeneration.

[56] Reconstructed by GSE on the basis of some studies by RSE quoted in Perego O., Bazzocchi F. Benini M. "Rapporto RSE RdS 14009625" 2014 and of the Eurostat 2013 and Terna 2013 databases

Table 63 – Consumption by the service sector in Italy in 2013, by subsector and use.

Service subsector	Electricity consumption (GWh)	Thermal energy consumption (GWh)	Overall energy consumption (GWh)	Overall energy consumption (ktoe)
Public administration Public	4 662	11 212	15 873	1 365
Healthcare	6 494	14 996	21 490	1 848
Leisure activities	600	3 356	3 956	340
Education	1 623	11 595	13 218	1 137
Hotels	11 273	7 380	18 653	1 604
of which 4 and 5 star	5 057	3 311	8 368	720
Sports facilities	2 730	13 930	16 660	1 433
of which swimming pools	842	4 027	4 869	419
Offices (in Services)	5 384	9 635	15 019	1 291
Commerce - Supermarket chains	8 989	999	9 988	859
Communications	4 112	0	4 112	354
Public lighting	5 977	0	5 977	514
Other	37 139	22 212	59 351	5 103
Total	88 982	95 314	184 296	15 847

5.3.2 Technical potential in the services sector

Demand characterisation for the various subcategories of the services sector served to estimate the share of heat which, from a strictly technical viewpoint, can be supplied, at least in part, by a high-efficiency CHP system.

This was done by selecting those customers with high simultaneous demand for both heat and power, such as hospitals, sports facilities and hotels. Specifically, only those sports facilities with swimming pools were selected, as they have high power consumption coupled with very high heat demand throughout the year[57].

Since these customers tend to have high demand for heat throughout the year, and not only in the winter months, this increases significantly the hours of operation of the CHP system and by the same token reduces the time for obtaining return on investment. Moreover, in these cases the climate factor has a far lower impact compared with the residential sector.

The other customers from the services sector have not been included in the analysis on the basis of the technical and installation considerations set out below.

Large supermarkets have a heat consumption of less than 10 % of the total consumption of the individual supermarket. To produce this heat, the supermarkets as a rule use heat pumps, on account of the strong demand for cooling too (both space cooling and food refrigeration). Therefore, it was not considered worthwhile designing a business case for the replacement of a heat pump with a CHP system sized to deliver the heat required.

[57] These considerations are in line with several sectoral studies (e.g. R. Loschi 'La cogenerazione: applicazione nel settore terziario in Italia', M. Vio 'Impianti di cogenerazione', etc.).

The main demand by offices is for cooling, both for structural reasons (they often have large glass surfaces) and for the substantial internal loads. Moreover, the demand for domestic hot water by offices is usually low. For these reasons the CHP option has not been analysed for offices. Consider moreover that offices, especially large ones in dedicated buildings as opposed to mixed-use buildings (residential-services), mainly have terminal units such as fan coils or radiators. These installations require low temperature (no more than 40°C), while CHP systems are designed to supply water at far higher temperatures.

As to schools, they need heating only for several hours in the day, while the demand for domestic hot water is almost nil. The hours of operation of the cogenerator would therefore be rather low, except in the case of a school with its own sports centre, a particular case not considered in this study.

Thus, in the light of the above remarks and constraints, the following standard types of customers have been selected to assess the technical potential for HE CHP in the services sector:

- large healthcare facilities such as hospitals and care homes
- smaller healthcare facilities such as local health authority centres, outpatient clinics, etc.
- medium-large hotels
- small hotels
- sports facilities with swimming pools.

The technical-economic simulation required in-depth characterisation of the typical customers in order to size correctly the CHP system and simulate realistically its operating conditions. To this end, the healthcare and hotel sectors have been divided into two classes of typical customers: small structures with lower demand and larger, more energy intensive structures.

For healthcare facilities, the case studies show the average thermal demand calculated by GSE by analysing the data on energy certificates stored in the databases held by the Lombardy region[58]. The hospitals have been characterised, from the viewpoint of demand, based on the average values of healthcare buildings with volume above 45 000 m3, while the smaller healthcare facilities have been averaged from the structures below the same threshold volume. The data analysed show that the change in thermal energy demand in the different climate condition areas by these facilities is negligible[59]. Hospitals are particularly suitable for CHP solutions since they have a very high stable demand for heat and power, year round.

As to hotel classification, one, two and three-star hotels were classed as medium-small hotels while four and five-star hotels were classed as medium-large. This simplification was needed to combine the economic analysis with overall consumption data, which have been classed according to hotel category. The data of this case study are taken from an actual case that was analysed[60]. The large hotel used as a benchmark has about 200 rooms, a conference room and a wellness centre and is located in climate condition area E; it is open year-round. The high demand of heat is also due to the presence of the wellness centre and a swimming pool. The thermal energy demand of the medium-small hotel was obtained by scaling down the demand of the large hotel.

[58] https://www.dati.lombardia.it/Energia/CENED-Certificazione-ENergetica-degli-EDifici/rsg3-xhvk

[59] On this point, the databases of the Marche region were also used http://goodpa.regione.marche.it/

[60] The results are provided in A. Gelmini, F. Bazzocchi “GDPint - un applicativo per la valutazione tecnico economica di distretti energetici”, McTer presentation, Milan, 28 June 2012.

The sector of sports facilities, in particular swimming pools has a very high heat demand for space heating, for heating the swimming pool water, and for producing domestic hot water. The case study considered was taken from sectoral studies[61]; it is felt to be highly representative of the type of customers considered. To calculate annual demand, it was assumed that the swimming pool would not close in the summer months.

Table 64 – Energy demand from typical demand points in the service sector

	Healthcare		Hotels		Sports facilities
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool
Annual heating energy demand	19.4 MWh	20.9 MWh	13.6 MWh	10.1 MWh	10.2 MWh
Annual electricity demand	335.0 MWh	4703.2 MWh	227.0 MWh	750.0 MWh	981.0 MWh
User heat/electricity ratio	0.6	0.6	2.1	2.6	2.0

The reference technology was chosen by analysing the current market trends in the sector, with the vast majority of systems based on internal combustion engines using natural gas.

The CHP systems have been sized case by case, based on the typical capacities of existing CHP installations in the sectors, as recorded on GSE's HE CHP database, taking into account the customer's H/E ratio, the typical hours of operation of the installations and the share of CHP heat, obtained from several case studies analysed by RSE.

Operating conditions have been simulated using the specific performance indicators taken from operating data of demand points having similar energy demand, held in the database on HE CHP. The new CHP system is assumed to 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 demand point'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 which is not always favourable for CHP applications. Although there are technical solutions, such as hot water tanks and electrical batteries, to stagger the thermal and electrical load over time, costs and space constraints hinder their deployment.

[61] C. Aprea et al. 'Riqualificazione energetica di una piscina', AICARR Journal, September 2014 (detailed description of a real CHP application).

Table 65 – Technical parameters and energy outputs of HE CHP systems under the operating conditions assumed for the service sector

	Healthcare		Hotels		Sports facilities
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool
Type of technology	MCI - gas	MCI - gas	MCI - gas	MCI - gas	MCI - gas
Electrical capacity of CHP system	16 kWe	281 kWe	20 kWe	111 kWe	321 kWe
Thermal capacity of CHP system	38 kWt	362 kWt	46 kWt	160 kWt	485 kWt
Heat/electricity ratio of the system	2,4	1,3	2,3	1,4	1,5
Electrical efficiency of CHP system	27 %	35 %	27 %	34 %	33 %
Thermal efficiency of CHP system	65 %	44 %	62 %	40 %	49 %
Share of electricity produced by High-Efficiency CHP	100 %	92 %	100 %	97 %	97 %
Share of self-consumed electricity	100 %	98 %	27 %	82 %	43 %
Equivalent hours under HE CHP	2 893 heq	4 257 heq	2 802 heq	2 791 heq	3 059 heq
Thermal efficiency of boilers	90 %	90 %	90 %	90 %	90 %
Heat produced by the CHP system	109.7 MWh	1540.7 MWh	130.1 MWh	445.6 MWh	1484.3 MWh
Share of demand for CHP heat	52 %	52 %	27 %	23 %	81 %
Heat generated by backup boiler	101.3 MWh	1422.2 MWh	354.9 MWh	1491.9 MWh	473.7 MWh
HE CHP electricity produced by the CHP system	45.8 MWh	1194.9 MWh	56.5 MWh	310.1 MWh	981.0 MWh
Total electricity produced by the CHP system	45.8 MWh	1300.8 MWh	56.7 MWh	321.3 MWh	1012.8 MWh
Electricity injected into the grid	0.0 MWh	29.5 MWh	41.4 MWh	59.0 MWh	581.0 MWh
Self-consumed electricity	45.8 MWh	1271.3 MWh	15.3 MWh	262.3 MWh	431.9 MWh
Electricity off-taken from the grid	289.2 MWh	3431.9 MWh	211.7 MWh	487.7 MWh	549.1 MWh
Electricity exchanged with the grid	0.0 MWh	29.5 MWh	41.4 MWh	59.0 MWh	549.1 MWh
Consumption of HE CHP system	168.4 MWh	3454.4 MWh	210.5 MWh	908.5 MWh	2979.6 MWh
Total CHP system consumption	168.4 MWh	3760.5 MWh	211.1 MWh	941.3 MWh	3074.1 MWh
Consumption of backup boiler	112.6 MWh	1580.2 MWh	394.3 MWh	1657.6 MWh	526.3 MWh
Electricity off-taken ex-ante	335.0 MWh	4703.2 MWh	227.0 MWh	750.0 MWh	981.0 MWh
Boiler consumption ex-ante	234.5 MWh	3292.1 MWh	538.9 MWh	2152.8 MWh	2175.6 MWh

By extending the energy outputs obtained in the case study to the entire reference subsector it is possible to estimate technical potential, which in the services sector amounts overall to 11.4 TWht and 6.8 TWhe of thermal energy and electricity obtainable from HE CHP, corresponding to an installed capacity of about 2 GWe and 3.5 GWt.

These values represent, on the basis of the assumptions made, the theoretical maximum amount of cogenerated thermal energy and electricity technically obtainable in the services sector that can be served by a cogenerator, without considering economic and financial factors, which are discussed later.

Table 66 – Demand of the services subsector relevant for the purposes of HE CHP, and associated technical potential for development of high-efficiency cogeneration

	Healthcare		Hotels		Sports facilities
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool
Heat demand by subsector (2013)	7 336 GWh	6 160 GWh	2 980 GWh	3 662 GWh	3 624 GWh
Electricity demand by subsector (2013)	3 530 GWh	2 964 GWh	5 057 GWh	6 216 GWh	842 GWh
Technical potential for HE CHP heat	3 815 GWh	3 203 GWh	799 GWh	842 GWh	2 748 GWh
Technical potential for HE CHP electricity	1 591 GWh	2 484 GWh	347 GWh	586 GWh	1 816 GWh
Technical potential for HE CHP thermal capacity	1 319 MWt	753 MWt	285 MWt	302 MWt	898 MWt
Technical potential for HE CHP electrical capacity	550 MWe	584 MWe	124 MWe	210 MWe	594 MWe

5.3.3 Analysis of costs and economic potential in the services sector

The case studies described and simulated to assess technical potential have also been analysed as to technological costs. This estimate has been used to make an economic simulation to verify which of the possible HE CHP solutions would be economically viable. The assumptions and tools used are very similar to those used for economic analysis in the residential sector, with adaptation of the inputs needed to represent the peculiar features of the sector.

The technological costs of ICE CHP systems vary widely with their size. The specific investment costs obtained from market surveys performed by GSE increase significantly with decreasing size. For maintenance purposes, the typical cost of full service contracts was applied. Their value is set on the basis of the system's hours of operation. The maintenance cost per hour of operation offered by suppliers grows almost linearly with the size of the system.

Based on manufacturers' data, useful life of CHP systems is about 20 000 hours of operation for small-size installations (micro-HE CHP <20 KW) and about 40 000 hours of operation for medium-sized installations (20-500 kW). Thus, useful life in calendar years depends both on size and use intensity (hours of operation) of the equipment and ranges in the different case studies between 6 and 15 years.

In the services sector too, existing boilers are considered to be maintained after deployment of CHP, for backup purposes. Therefore, their investment and maintenance costs and their useful life have not been factored in.

Regarding commodities, the final consumer prices of the gas and electricity drawn by demand points were taken from Eurostat, using 2014 as the reference year[62]. The different tariffs applied between the various types of services customers are due to the different consumption levels, which result in a different incidence of certain tariff components, both fixed and variable.

[62] "Electricity prices for industrial consumers - bi-annual data (from 2007 onwards)", "Gas prices for industrial consumers - bi-annual data (from 2007 onwards) (nrg_pc_202)"
http://ec.europa.eu/eurostat/web/energy/data/database

The HE CHP installations considered for hotels and small healthcare facilities have a capacity below 200 kWe, and hence would be eligible for the net metering scheme. The power produced by the cogenerator and exchanged with the grid, is priced for these users at a tariff calculated as the average of the NM tariffs applied to HE CHP systems in 2014 by GSE. 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 in these cases is priced at the wholesale market price. Hospitals and sports facilities with swimming pools usually require installations of capacity in excess of 200 kW, and thus cannot access the NM scheme. All the energy they feed into the grid is priced at wholesale market prices. The wholesale price of electricity taken as a reference for the calculations is the single national average price in 2014 on the day ahead market (PUN MGP 2014)[63].

Self-consumed electricity is liable for excise duty on electricity, like consumed electricity. The amount of the excise duty on electricity varies according to consumption band.

All the installations considered for the typical customers modelled for the services sector are HE CHP systems below 20 MWe, and are therefore eligible for classification as SEU, which benefits from partial exemption from general system charges. The exemption is total for installations classed as SEU with a capacity of less than 20 KWe and connected in low voltage (this is the scenario considered, for instance, in the case of small healthcare centres). SEU installations connected in low voltage with a capacity of more than 20 kWe (e.g. the CHP scenario considered for small hotels) are charged a fixed excise duty of 36 €/year (as envisaged for 2015) while non-energy intensive customers connected in medium voltage (e.g. large hotels, hospitals and swimming pools) are charged a fixed annual amount according to the system's rating, pursuant to Decision AEEGSI 609/2014/R/eel as amended[64].

The price of the gas consumed by the CHP was obtained from the final price of the gas described earlier, net of the rebate on excise duties for the self-production of electricity, in accordance with the current provisions 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 deductible and consumption of gas by the boiler are subject to the excise duty for civil uses in the case of swimming pools and to excise duty for industrial uses in the case of hotels and healthcare facilities.

The price of the energy efficiency certificates or white certificates (type II-HE CHP) was inferred from GME's statistical data on average prices in the centralised market for EEC in 2014[65].

The weighted average cost of capital (WACC) has been set at 5 %. In the event of extensive recourse to bank loans, this value might be rather low. However, as a first approximation, it was felt preferable to consider a return on investment not unduly influenced by the manner of raising capital and by the need for high financial return, given the purpose of the analysis[66].

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[63] 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 now quite low, this aspect is felt to be negligible.

[64] The charge on the self-consumed power, defined as additional charge A3, is calculated for 2015 as follows: Additional charge A3 = NomC x hours x α x rate. The rate is 0.273 EURc/kWh while the factor α and the hours are, in the case of HE CHP systems, 0.6 and 5 000 respectively.

[65] http://www.mercatoelettrico.org/It/Statistiche/TEE/StatisticheTEE.aspx

[66] This approach reflects the JRC guidelines 'Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level' 2015.

Table 67 – Economic and financial parameters used in the financial simulation for the service sector

	Healthcare		Hotels		Sports facilities
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool
Cost of specific investment in a CHP system	3 919 €/kW	1 093 €/kW	3 518 €/kW	1 649 €/kW	1 030 €/kW
Variable maintenance costs	1.48 €/h	4.07 €/h	1.52 €/h	2.41 €/h	4.46 €/h
Useful life of CHP system (hours of operation)	20 000 h	40 000 h	40 000 h	40 000 h	40 000 h
Useful life of CHP system (calendar years)	6.2 years	7.8 years	12.9 years	12.5 years	11.4 years
Price of gas taken for thermal use	74.60 €/MWh	40.75 €/MWh	49.40 €/MWh	49.40 €/MWh	49.40 €/MWh
Price of gas for CHP	73.86 €/MWh	39.81 €/MWh	48.67 €/MWh	48.47 €/MWh	35.94 €/MWh
Price of electricity off-taken	236.95 €/MWh	175.45 €/MWh	197.40 €/MWh	172.75 €/MWh	172.75 €/MWh
Wholesale price of electricity	52.08 €/MWh	52.08 €/MWh	52.08 €/MWh	52.08 €/MWh	52.08 €/MWh
Price of electricity under the net-metering system	158.00 €/MWh	158.00 €/MWh	158.00 €/MWh	158.00 €/MWh	158.00 €/MWh
Excise duty on consumption of gas for civil use	19.36 €/MWh	19.52 €/MWh	19.46 €/MWh	19.51 €/MWh	19.51 €/MWh
Excise duty on gas for electricity self-production	0.02 €/MWh	0.02 €/MWh	0.02 €/MWh	0.02 €/MWh	0.02 €/MWh
Deductible on excise duty on gas for electricity self-production	0.22 Smc/kWh	0.22 Smc/kWh	0.22 Smc/kWh	0.22 Smc/kWh	0.22 Smc/kWh
Excise duty on gas applied to the CHP unit	0.57 €/MWh	0.37 €/MWh	0.58 €/MWh	0.38 €/MWh	6.05 €/MWh
Excise duty on electricity consumed	12.50 €/MWh	10.05 €/MWh	12.50 €/MWh	12.50 €/MWh	12.50 €/MWh
Fixed charges applied for self-consumption (SEU - Efficient User Systems)	0 €/year	2 299 €/year	36 €/year	910 €/year	2 627 €/year
Variable charges applied for self-consumption (SEU)	0.00 €/MWh	0.00 €/MWh	0.00 €/MWh	0.00 €/MWh	0.00 €/MWh
Total charges per unit of self-consumed energy	0.00 €/MWh	1.81 €/MWh	2.35 €/MWh	3.47 €/MWh	6.08 €/MWh
Price of EECs (II-HE CHP)	116.00 €/WC	116.00 €/WC	116.00 €/WC	116.00 €/WC	116.00 €/WC
WACC	5 %	5 %	5 %	5 %	5 %

The energy flows in the CHP scenario and those in the prior situation have been priced so as to obtain the cash flows allowing calculation of the economic and financial indicators of return on investment.

Table 68 – Costs and revenues obtained from the financial simulation in the service sector

	Healthcare		Hotels		Sports facilities
	Minor healthcare facility minore	Hospital	Small hotel	Large hotel	Swimming pool
CHP investment cost	€61 995	€306 757	€70 967	€183 261	€330 368
CHP O&M annual cost	5 350 €/year	23 589 €/year	5 331 €/year	8 719 €/year	17 621 €/year
CHP fuel cost	12 441 €/year	149 708 €/year	10 275 €/year	45 629 €/year	110 486 €/year
Backup boiler fuel cost	8 397 €/year	64 394 €/year	19 480 €/year	81 887 €/year	26 001 €/year
Cost of electricity off-taken	68 535 €/year	602 132 €/year	41 788 €/year	84 250 €/year	94 862 €/year
Cost of excise duty on self-consumed electricity	572 €/year	12 778 €/year	191 €/year	3 279 €/year	5 398 €/year
Cost of charges on self-consumed electricity	0 €/year	2 299 €/year	36 €/year	910 €/year	2 627 €/year
Revenues from electricity injected into the grid	0 €/year	1 536 €/year	0 €/year	0 €/year	30 256 €/year
Revenues from exchanged electricity	1 €/year	0 €/year	6 537 €/year	9 325 €/year	0 €/year
White certificates awarded	8	128	8	38	114
Revenues from white certificates	928 €/year	14 848 €/year	928 €/year	4 408 €/year	13 224 €/year
Ex-ante backup boiler fuel cost	17 493 €/year	134 154 €/year	26 621 €/year	106 347 €/year	107 472 €/year
Ex-ante cost of electricity from the grid	79 378 €/year	825 178 €/year	44 810 €/year	129 563 €/year	169 468 €/year

Table 69 – Results of the economic analysis of possible CHP projects in the service sector

	Healthcare		Hotels		Sports facilities
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool
NPV	-€49 278	€392 325	-€55 062	€38 038	€196 463
IRR	-	34 %	-	9 %	15 %
Time for return on investment (discounted)	-	2.8	-	9.4	6.2
Profitability index (NPV/I)	-	1.3	-	0.2	0.6
Feasibility percentage	0 %	100 %	0 %	35 %	100 %

The economic analysis of the cash flows generated during the useful life by the investment in the micro-CHP system shows the lack of cost-effectiveness of the investment in small healthcare facilities and in small hotels. In these cases, the net present value (NPV) is actually negative, annulling the likelihood of financial investment in these initiatives (feasibility share) and the associated economic potential, which is the product of the feasibility share multiplied by the technical potential. Conversely, the return from installing HE CHP systems in large healthcare facilities (hospitals, clinics, care homes etc.) and in sports facilities (with swimming pools) seems very interesting. The high NPV and IRR suggest that all the economic conditions for investing on HE CHP solutions are met. For large hotels, the results of the economic simulation are less clear-cut: the positive NPV and an IRR of 9 % suggest marginal cost-effectiveness; thus differences between individual hotels (e.g. borrowing conditions, differences in energy demand, etc.) can determine whether or not each project is cost effective. By applying the criteria set out in the part on method at the start of the chapter, the feasibility share assessed on the basis of the economic indicators shown is 35 %.

Table 70 – Technical and economic potential of the service sector on the basis of demand in 2013

	Healthcare		Hotels		Sports facilities	Other service activities	Total Service sector potentially served by HE CHP
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool		
Heat from HE CHP in the subsector (2013)	1.1 GWh	409.6 GWh	1.6 GWh	6.5 GWh	64.3 GWh	503.2 GWh	986.3 GWh
Electricity from HE CHP in the subsector (2013)	0.4 GWh	391.0 GWh	0.8 GWh	7.4 GWh	45.6 GWh	544.1 GWh	989.3 GWh
HE CHP thermal capacity in the subsector(2013)	0.4 MWt	96.1 MWt	0.8 MWt	3.0 MWt	22.4 MWt	163.9 MWt	286.6 MWt
HE CHP electrical capacity in the subsector(2013)	0.2 MWe	91.7 MWe	0.4 MWe	3.4 MWe	15.9 MWe	175.3 MWe	286.9 MWe
Technical potential for HE CHP heat	3 815 GWh	3 203 GWh	799 GWh	842 GWh	2 748 GWh		11 910 GWh
Technical potential for HE CHP electricity	1 591 GWh	2 484 GWh	347 GWh	586 GWh	1 816 GWh		7 369 GWh
Technical potential for HE CHP thermal capacity	1 319 MWt	753 MWt	285 MWt	302 MWt	898 MWt		3 720 MWt
Technical potential for HE CHP electrical capacity	550 MWe	584 MWe	124 MWe	210 MWe	594 MWe		2 237 MWe
Economic potential for HE CHP heat	0 GWh	3 203 GWh	0 GWh	296 GWh	2 748 GWh		6 750 GWh
Economic potential for HE CHP electricity	0 GWh	2 484 GWh	0 GWh	206 GWh	1 816 GWh		5 050 GWh
Economic potential for HE CHP thermal capacity	0 MWt	753 MWt	0 MWt	106 MWt	898 MWt		1 921 MWt
Economic potential for HE CHP electrical capacity	0 MWe	584 MWe	0 MWe	74 MWe	594 MWe		1 426 MWe

Note that these results, albeit unequivocal, clearly do not claim to cover any possible HE CHP initiative in the services sector since this study, while detailed, addresses average typical demand points. The results obtained as to economic potential show interesting potential growth of HE CHP in the services sector.

Considering the difference between the assessed economic potential for HE CHP and the systems already in operation in 2013 in the sectors analysed, the incremental potential for heat and power from HE CHP is estimated to be 5.8 TWht and 4.1 TWhe respectively, and about 1.1 GWe in terms of electrical capacity.

5.3.4 Analysis of the benefits linked to development of potential in the services sector

Assessment of the technical and economic potential was accompanied by assessment of environmental benefits, such as primary energy savings and GHG emission savings, associated with development of the incremental technical and economic potential for HE CHP.

The primary energy savings were calculated on the basis of the efficiency reference values of separate heat and power production, elaborated by GSE on the basis of technologies assumed to have been replaced in the sectors. GHG emission savings were calculated with the GSE method used to monitor the GHG emissions saved through the development of renewables and energy efficiency, as explained in detail in the section on methodology at the beginning of this chapter.

The overall savings which can be estimated on the incremental technical and economic potential in the service sector amount to 486 ktoe and 259 ktoe respectively, which would reduce primary energy consumption in the sector by about 2 % and 1 %.

The CO_2 savings from the proposed initiatives would abate emissions vis-à-vis the current situation by almost 30 %. Overall, the incremental technical and economic potential would make it possible to reduce emissions from the services sector respectively by about 1.7 and 1 Mton CO_2 or about 5 % and 3 % of the total GHG emissions by the services sector, taking 2013 as the reference year (source: NIR 2013 ISPRA).

Table 71 – Primary energy savings linked to individual HE CHP initiatives and to the incremental technical and economic potential in the service sector

	Healthcare		Hotels		Sports facilities	Total Service sector served by HE CHP
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool	
Reference electrical efficiency	44.3 %	46.4 %	45.2 %	46.5 %	46.7 %	
Reference thermal efficiency	90.0 %	90.0 %	90.0 %	90.0 %	90.0 %	
User primary energy savings	4.9 toe	71.6 toe	5.1 toe	21.8 toe	66.1 toe	
PES incremental technical potential	169.6 ktoe	125.5 ktoe	31.1 ktoe	41.0 ktoe	119.4 ktoe	486.6 ktoe
PES incremental economic potential	0.0 ktoe	125.5 ktoe	0.0 ktoe	14.3 ktoe	119.4 ktoe	259.2 ktoe

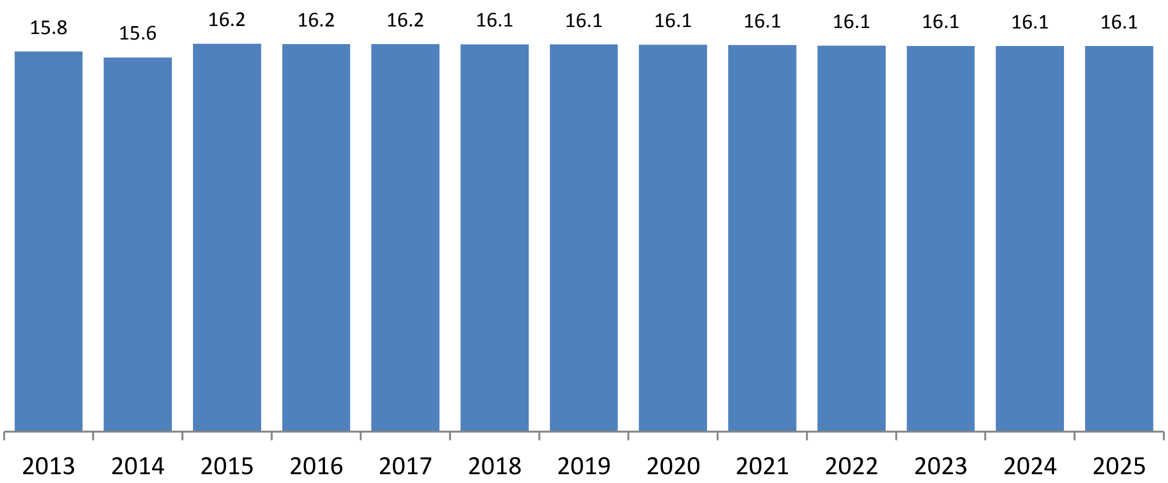
Table 72 – CO_2 savings linked to individual HE CHP initiatives and to the incremental technical and economic potential in the service sector

	Healthcare		Hotels		Sports facilities	Total Service sector potentially served by HE CHP
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool	
Emissions produced by HE CHP	34.6 tCO2	710.6 tCO2	43.3 tCO2	186.9 tCO2	613.0 tCO2	
Emissions produced by substitute technologies	50.3 tCO2	982.1 tCO2	60.3 tCO2	265.0 tCO2	853.0 tCO2	
CO2 savings by users	15.7 tCO2	271.5 tCO2	17.0 tCO2	78.1 tCO2	240.0 tCO2	
Percent emission reduction	-31,2 %	-27,6 %	-28,2 %	-29,5 %	-28,1 %	
CO2 savings incremental technical potential	545.5 ktCO2	476.0 ktCO2	104.2 ktCO2	146.6 ktCO2	433.2 ktCO2	1 705.5 ktCO2
CO2 savings incremental economic potential	0.0 ktCO2	476.0 ktCO2	0.0 ktCO2	50.8 ktCO2	433.2 ktCO2	960.0 ktCO2

5.3.5 Demand evolution scenarios in the services sector and impact on analysis of potential

According to the ENEA scenarios simulated using the Times model, the final consumption of the services sector should increase by about 1 % over the next 10 years.

Figure 62 – Final consumption in the service sector (source: ENEA 2015)



The limited growth of consumption expected in the sector has a negligible impact on the results of the technical and economic potential assessed on the sector's demand in 2013. Thus, the potential as at 2023, all other factors remaining equal (regulatory framework, costs, etc.) would not vary significantly from 2013.

Table 73 – Technical and economic potential of the service sector on the basis of demand in 2023

	Healthcare		Hotels		Sports facilities	Total Service sector potentially served by HE CHP
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool	
Technical potential for HE CHP heat	3 871 GWh	3 251 GWh	811 GWh	855 GWh	2 788 GWh	12 079 GWh
Technical potential for HE CHP electricity	1 614 GWh	2 521 GWh	352 GWh	595 GWh	1 843 GWh	7 469 GWh
Technical potential for HE CHP thermal capacity	1 338 MWt	764 MWt	290 MWt	306 MWt	912 MWt	3 773 MWt
Technical potential for HE CHP electrical capacity	558 MWe	592 MWe	126 MWe	213 MWe	602 MWe	2 267 MWe
Economic potential for HE CHP heat	0 GWh	3 251 GWh	0 GWh	300 GWh	2 788 GWh	6 842 GWh
Economic potential for HE CHP electricity	0 GWh	2 521 GWh	0 GWh	209 GWh	1 843 GWh	5 117 GWh
Economic potential for HE CHP thermal capacity	0 MWt	764 MWt	0 MWt	108 MWt	912 MWt	1 947 MWt
Economic potential for HE CHP electrical capacity	0 MWe	592 MWe	0 MWe	75 MWe	602 MWe	1 445 MWe

5.4 Potential for HE CHP in the industrial sector

Analysis of the potential for development of high-efficiency cogeneration in the industrial sector started from a survey of the various industrial sectors and their demand for electricity and thermal energy.

Attention was focused on the industry subsectors whose heat and power demand profiles best match supply by high-efficiency cogeneration. Next, the specific consumption of 'typical' companies in each subsector was assessed.

Thereafter, a method was developed to optimise selection of the HE CHP technology and system size best fitting the heat and power characteristics of the production process of a typical company in each subsector.

This sizing has made it possible to estimate the maximum demand for heat and power which can be covered by HE CHP in the industrial sector, defined as the technical potential for HE CHP.

Lastly, an economic feasibility analysis was conducted in order to estimate the share of the technical potential from HE CHP which is sustainable from the economic viewpoint in each industrial subsector considered, hence in the overall industrial sector.

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 a proxy for regional demand for heat in the various industrial subsectors[67], checking whether the regional distribution of the sector potential calculated matched the high-efficiency cogeneration existing at regional sectoral level. In cases where the regional potential was found to be less than the existing high-efficiency cogeneration in the region, the potential in those sectors was raised to equal the existing level, since this apparent surplus capacity and overproduction of the existing high-efficiency CHP plants appeared to be due to different technical and economic feasibility conditions[68] than those currently represented in the model which, given that the plants are almost fully amortised[69], justify their continued operation in the short to medium term.

5.4.1 Characterisation of heat demand in the industrial sector

In 2013, demand in the industrial sector and the energy industries[70] in Italy totalled 31.6 Mtoe. This consisted of 20.9 Mtoe of heat for industrial processes[71] and 10.7 Mtoe for unavoidable electricity

[67] Without regional estimates of demand for heat in individual industrial subsectors, sectoral emissions of ETS plants were used; it was assumed that these were distributed in roughly the same way as the demand for heat.

[68] The key points included: higher productivity and consumption than current levels; profitability of the electricity market; business diversification of energy-intensive industrial companies that had decided to operate in the electricity sector.

[69] The production costs assessed by the model used take into account amortisations, which for the existing HE CHP systems have mostly been completed.

[70] The analysis considers as an integral part of the industrial sector the consumption for energy purposes by processing industries. Consumption by the processing sector does not include consumption by the central installations producing heat and electricity and the associated pumping and auxiliary consumption, but only the consumption for energy

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 19 %, is covered by derived heat (which includes the heat self-produced in cogeneration mode), while electricity demand is mainly covered by off-taking from the national grid, with about 15 % by self-produced electricity.

In order to assess the technical potential for HE CHP it was necessary to carry out in-depth characterisation of the demand for heat and power of 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 2013 has been broken down using ISTAT statistical data on individual industrial sectors on the energy expenditure of companies and on 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).

5.4.2 Technical potential in the industrial sector

Demand characterisation for the various subcategories of the industrial sector served to estimate the share of heat which, from a strictly technical viewpoint, can be supplied, at least in part, by a high-efficiency CHP system.

To this end, those industrial sectors were selected which have a high demand for heat and power or which already have HE CHP systems in operation, as reported in GES's database on HE CHP.

In addition, 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[72].

This analysis served to calculate the demand for heat and power which can be covered by CHP systems from typical customers in the various sectors, with appropriate technical sizing.

The choice of technology was oriented to the current market trends concerning the plants in operation, with different technologies dominating depending on the plant capacity (gas-powered ICE below 10 MW and GT or CCGT for higher capacity installations).[73]

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purposes by the energy industries (such as refineries, coke ovens, etc.) net of the consumption of raw materials. Demand was calculated from direct consumption, assuming conversion efficiency of 90 %.

[71] The share of the demand for space heating and cooking in this sector is negligible.

[72] Gambini M. Vellini. M. “Illustrazione dei principali processi industriali rilevanti ai fini CAR” 2015.

[73] These technology choices are the most cost effective, as also shown by the study cited in the previous footnote ([72]), which compared the different HE CHP technologies.

The size of the HE CHP systems was chosen to maximise coverage of the heat and power demand by the process. This involved:

- minimising the amount of electricity fed into the national grid, hence sizing of the system at an electrical capacity not exceeding that required by the process;
- maximising the heat made available by the cogenerator and, hence, exploiting fully 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 $H/E_{customer\text{-}chp}$ which could be met by cogeneration and comparing it with the ratio $(H/E)_{cog}$ 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 demand of the process, while auxiliary boilers are used to meet the thermal 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.

Notwithstanding the methods applied to plan the plant’s size, the share of energy effectively produced in HE CHP mode and the share of self-consumed electricity were not considered to equal 100 % of the energy produced by the cogenerator, but were obtained from the average recorded from installations in operation in each sector. It was felt that this addressed the problem of combining user and plant thermal and electrical loads specific to the production process[74]. The typical installations were then characterised using technical performance indicators (efficiency, H/E ratios, etc.) taken from in-depth analysis of the HE CHP systems in operation in the different industrial sectors according to GSE’s HE CHP database.

The results obtained in terms of technical potential are highly heterogeneous according to the industrial sectors considered. Some particularly energy-intensive industrial sectors (e.g. refineries, iron and steel, pulp and paper) seem to have already saturated much of their technical development potential. This saturation of potential is stronger in the electric than in the heat portion of the system. There are a number of reasons for this:

- the most power-hungry industries have already invested for several years now in self-producing CHP installations, with the aim of reducing their energy bill;

[74] Spikes in heat and power demand, time mismatch between process electrical and thermal loads, heat to power ratios different from those of the industrial plant, etc.

- the CHP system's H/E ratio tends to favour electricity for technical and economic reasons, on account of the higher price of electricity and the easier management of surplus electricity production rather than surplus heat. This is due to the possibility of feeding surplus electricity into the grid, which in the past also ensured a good return;
- over the years, some energy-intensive industries have developed diversified lines of business which include the wholesale of electricity among their core operations;
- some energy-intensive industries, partly downsized by the economic crisis, have a large amount of capacity which in recent years has been under-utilised and which indirectly also covers the scope for growth of other industrial operations in the same sector.

For these sectors we can assume, at the end of the useful life of the assets, the possibility of partial conversion of the CHP installations to reduce electrical capacity and increase heat recovery. Possible options include converting condensing combined cycles into counter-pressure CCs, or even simple GTs, and of condensing steam cycles into counter-pressure cycles.

However, other, less energy-intensive industries still have a margin for increased exploitation of technical potential. They include:

- Chemical and Petrochemical: in particular, some subsectors of the non-basic chemical industry (e.g. the production of soaps, detergents etc. and pharmaceuticals);
- Food and tobacco, in almost all food production sectors;
- Machinery: including the production of various types of machinery and tools;
- Non-Metallic Minerals: in the production of building materials (ceramics);
- Non-specified (Industry): mainly in the production of rubber and furniture;
- Textile and Leather: in particular finishing, tanneries and other textile industries;
- Wood and Wood Products: production of wood and wood products.

For the industrial sector, the overall technical potential has been calculated to be 44.9 TWht and 34.9 TWhe of thermal energy and electricity obtainable from HE CHP, corresponding to a capacity to be installed of about 18.2 GWt and 15.4 GWe respectively. These values constitute the theoretical maximum amount of cogenerated thermal energy and electricity technically obtainable in the subsectors that can be served by a cogenerator, without considering economic and financial factors, which are discussed later.

Table 74 – Technical potential for the development of HE CHP and current situation in the industrial sector

	HE CHP heat 2013	HE CHP electricity 2013	HE CHP thermal capacity 2013	HE CHP electrical capacity 2013	Technical potential for HE CHP heat	Technical potential for HE CHP electricity	Technical potential for HE CHP thermal capacity	Technical potential for HE CHP electrical capacity
Chemical and Petrochemical	4 725GWh	4 573GWh	2 145MWt	3 185MWe	12 391GWh	10 519GWh	4 502MWt	4 658MWe
Coke Ovens	49GWh	50GWh	27MWt	28MWe	49GWh	50GWh	27MWt	28MWe
Refineries	9 311GWh	6 959GWh	3 733MWt	2 807MWe	11 218GWh	7 981GWh	4 464MWt	3 084MWe
Food and Tobacco	1 882GWh	1 496GWh	471MWt	407MWe	4 828GWh	3 674GWh	1 390MWt	1 298MWe
Iron and Steel	620GWh	565GWh	825MWt	778MWe	745GWh	672GWh	926MWt	863MWe
Machinery	152GWh	131GWh	136MWt	98MWe	4 532GWh	3 071GWh	2 396MWt	1 618MWe
Mining and Quarrying	12GWh	16GWh	3MWt	4MWe	12GWh	16GWh	3MWt	4MWe
Non-Ferrous Metals	19GWh	32GWh	4MWt	6MWe	122GWh	173GWh	31MWt	44MWe
Non-Metallic Minerals	325GWh	269GWh	109MWt	91MWe	1 215GWh	1 432GWh	412MWt	496MWe
Non-specified (Industry)	328GWh	333GWh	110MWt	102MWe	1 148GWh	1 038GWh	1 232MWt	985MWe
Paper, Pulp and Print	5 188GWh	3 299GWh	1 493MWt	944MWe	6 082GWh	3 772GWh	1 603MWt	1 106MWe
Textile and Leather	217GWh	180GWh	75MWt	75MWe	1 610GWh	1 462GWh	717MWt	639MWe
Transport Equipment	308GWh	301GWh	196MWt	209MWe	483GWh	516GWh	295MWt	334MWe
Wood and W. Products	103GWh	124GWh	35MWt	40MWe	469GWh	531GWh	229MWt	259MWe
Total	**23 239GWh**	**18 327GWh**	**9 361MWt**	**8 773MWe**	**44 904GWh**	**34 908GWh**	**18 227MWt**	**15 415MWe**

Table 75 – Incremental technical potential for development of HE CHP in the industrial sector

	Incremental technical potential for HE CHP heat	Incremental technical potential for HE CHP electricity	Incremental technical potential for HE CHP thermal capacity	Incremental technical potential for HE CHP electrical capacity
Chemical and Petrochemical	7 666GWh	5 946GWh	2 357MWt	1 473MWe
Coke Ovens	-	-	-	-
Refineries	1 908GWh	1 022GWh	730MWt	277MWe
Food and Tobacco	2 946GWh	2 178GWh	920MWt	891MWe
Iron and Steel	125GWh	107GWh	102MWt	85MWe
Machinery	4 380GWh	2 941GWh	2 260MWt	1 519MWe
Mining and Quarrying	-	-	-	-
Non-Ferrous Metals	103GWh	141GWh	27MWt	37MWe
Non-Metallic Minerals	890GWh	1 163GWh	303MWt	406MWe
Non-specified (Industry)	820GWh	706GWh	1 122MWt	883MWe
Paper, Pulp and Print	894GWh	473GWh	110MWt	162MWe
Textile and Leather	1 394GWh	1 282GWh	642MWt	564MWe
Transport Equipment	176GWh	215GWh	99MWt	125MWe
Wood and W. Products	365GWh	407GWh	194MWt	219MWe
Total	**21 666GWh**	**16 581GWh**	**8 866MWt**	**6 642MWe**

5.4.3 Analysis of costs and economic potential in the industrial sector

The typical companies in the industrial subsectors simulated by the study have also been analysed in-depth as to technological costs. This estimate has been used to make an economic simulation to verify which of the possible HE CHP solutions would be economically viable.

The assumptions and tools used are very similar to those used for economic analysis in the residential and services sectors, with adaptation of some inputs needed to represent the peculiar features of the sector.

The technological costs of ICE CHP systems vary widely with their size. The specific investment costs obtained from market surveys performed by GSE increase significantly with decreasing size. For maintenance purposes, the typical cost of full service contracts was applied. Their value is set on the basis of the system's hours of operation. The maintenance cost per hour of operation offered by suppliers grows almost linearly with the size of the system. The useful life of ICE installations was established from the manufacturers' specifications. For small-size installations (micro-HE CHP <20 KW) useful life is estimated at 20 000 hours of operation, for medium-sized installations between 20-500 kW, about 40 000 hours of operation are assumed, while for medium-large ICE installations (>500 Kw) useful life is estimated in the range of 60 000-70 000 hours. Thus, useful life in calendar years depends both on size and use intensity (hours of operation) of the equipment and ranges in the different case studies between 6 and 15 years. For CCGT installations (considered only in large companies in the most energy-intensive sectors such as: basic chemicals, refineries, iron and steel, pulp and paper) the following parameters were applied: investment costs of 1 000 €/kWe, fixed maintenance costs of 4 % of investment costs[75] and useful life of 75 000 hours and not exceeding 15 years. In industrial sector applications also the existing boilers are maintained after deployment of the CHP system, for backup purposes; therefore, their investment and maintenance costs and useful life have not been factored in.

Regarding commodities, the final consumer prices of the gas and electricity drawn by demand points were taken from Eurostat, using 2014 as the reference year[76]. The different tariffs applied to the various types of industrial customers are due to the different consumption levels, which result in a different incidence of certain tariff components, both fixed and variable.

The HE CHP systems considered for SMEs are often below 200 kWe and thus, where this is the case, they are considered to access the net metering scheme. In these cases, the power produced by the cogenerator and exchanged with the grid, is thus priced at a NM tariff calculated as the average of the NM tariffs applied to HE CHP systems in 2014 by GSE. 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 for which installations with capacity above 200 kW have been assumed, cannot access the NM scheme. Therefore, all the energy they feed into the grid is priced at wholesale market prices.

[75] Gambini M. Vellini. M. "Illustrazione dei principali processi industriali rilevanti ai fini CAR" 2015

[76] "Electricity prices for industrial consumers - bi-annual data (from 2007 onwards)", "Gas prices for industrial consumers - bi-annual data (from 2007 onwards) (nrg_pc_202)"
http://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 2014 on the day ahead market (PUN MGP 2014)[77].

Self-consumed electricity is liable for excise duty on electricity, like consumed electricity. The amount of the excise duty on electricity varies according to consumption band.

All the installations considered for the typical customers modelled for the industrial sector are HE CHP systems below 20 MWe, and are therefore eligible for classification as SEU, which benefits from partial exemption from general system charges. The exemption is total for installations classed as SEU with a capacity of less than 20 KWe with and connected in low voltage. Conversely, SEU installations connected in low voltage with a capacity of more than 20 kW are charged a fixed excise duty of 36 €/year (in 2015), while non-energy intensive installations connected in medium voltage are charged a lump-sum annual duty established according to the system's capacity, pursuant to Decision AEEGSI 609/2014/R/eel as amended[78]. Lastly, energy-intensive high and medium voltage systems are charged 5 % of the variable system costs on the amount of power self-produced/self-consumed.

The price of the gas consumed by the CHP was obtained from the final price of the gas described earlier, net of the rebate on excise duties for the self-production of electricity, in accordance with the current provisions 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 deductible and the consumption of gas by the boiler are subject to the excise duty for industrial uses.

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 EEC/WC in 2014[79].

The weighted average cost of capital (WACC) has been set at 5 %. This value might be rather low for the industrial sector. However, as a first approximation, it was felt preferable to consider a return on investment not unduly influenced by the manner of raising capital or by investors' expectations, given the purpose of the analysis[80]. The energy flows in the CHP scenario and those in the prior situation have been priced so as to obtain the cash flows allowing calculation of the economic and financial indicators of return on investment.

Economic analysis of the cash flows generated by investment in the CHP system during its useful life has shown limited or no benefit in investing in some of the subsectors with interesting incremental technical potential, such as: mechanical engineering, wood, part of the textile industry (yarns, weaving, other textile industries), other non-specified industries (rubber, other equipment, etc.).

[77] 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 felt to be negligible.

[78] The charge on the self-consumed power, defined as additional charge A3, is calculated for 2015 as follows: Additional charge A3 = NomC x hours x α x rate. The rate is 0.273 EURc/kWh while the factor α and the hours are, in the case of HE CHP systems, 0.6 and 5 000 respectively.

[79] http://www.mercatoelettrico.org/It/Statistiche/TEE/StatisticheTEE.aspx

[80] This approach reflects the JRC guidelines "Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level" 2015.

For more energy-intensive sectors (refineries, iron and steel, pulp and paper), despite the benefits shown by the economic simulations, the high economic potential seems in large part to be already covered by the installations currently in operation in these sectors.

Conversely, incremental economic potential seems to be particularly concentrated in the chemicals and petrochemicals sector (about 6 TWh), food sector (about 1.6 TWht from almost all its various subsectors), and in the manufacture of building materials (about 00.7 TWht, mainly from ceramic industries).

Table 76 – Economic development potential of HE CHP in the industrial sector

	HE CHP heat 2013	HE CHP electricity 2013	HE CHP thermal capacity 2013	HE CHP electrical capacity 2013	Economic potential for HE CHP heat	Economic potential for HE CHP electricity	Economic potential for HE CHP thermal capacity	Economic potential for HE CHP electrical capacity
Chemical and Petrochemical	4 725GWh	4 573GWh	2 145MWt	3 185MWe	10 772GWh	8 977GWh	3 910MWt	4 159MWe
Coke Ovens	49GWh	50GWh	27MWt	28MWe	49GWh	50GWh	27MWt	28MWe
Refineries	9 311GWh	6 959GWh	3 733MWt	2 807MWe	11 194GWh	7 955GWh	4 445MWt	3 076MWe
Food and Tobacco	1 882GWh	1 496GWh	471MWt	407MWe	3 465GWh	2 869GWh	991MWt	865MWe
Iron and Steel	620GWh	565GWh	825MWt	778MWe	745GWh	672GWh	904MWt	842MWe
Machinery	152GWh	131GWh	136MWt	98MWe	152GWh	131GWh	136MWt	98MWe
Mining and Quarrying	12GWh	16GWh	3MWt	4MWe	12GWh	16GWh	3MWt	4MWe
Non-Ferrous Metals	19GWh	32GWh	4MWt	6MWe	57GWh	86GWh	12MWt	18MWe
Non-Metallic Minerals	325GWh	269GWh	109MWt	91MWe	1 055GWh	1 226GWh	341MWt	395MWe
Non-specified (Industry)	328GWh	333GWh	110MWt	102MWe	328GWh	333GWh	110MWt	102MWe
Paper, Pulp and Print	5 188GWh	3 299GWh	1 493MWt	944MWe	5 622GWh	3 772GWh	1 603MWt	1 106MWe
Textile and Leather	217GWh	180GWh	75MWt	75MWe	240GWh	196GWh	104MWt	94MWe
Transport Equipment	308GWh	301GWh	196MWt	209MWe	310GWh	304GWh	197MWt	211MWe
Wood and W. Products	103GWh	124GWh	35MWt	40MWe	112GWh	133GWh	38MWt	43MWe
Total	**23 239GWh**	**18 327GWh**	**9 361MWt**	**8 773MWe**	**34 113GWh**	**26 719GWh**	**12 821MWt**	**11 041MWe**

Table 77 – Incremental economic potential for development of HE CHP in the industrial sector

	Incremental economic potential for HE CHP heat	Incremental economic potential for HE CHP electricity	Incremental economic potential for HE CHP thermal capacity	Incremental economic potential for HE CHP electrical capacity
Chemical and Petrochemical	6 047GWh	4 404GWh	1 765MWt	974MWe
Coke Ovens	-	-	-	-
Refineries	1 884GWh	996GWh	712MWt	269MWe
Food and Tobacco	1 583GWh	1 373GWh	520MWt	457MWe
Iron and Steel	125GWh	107GWh	79MWt	65MWe
Machinery	-	-	-	-
Mining and Quarrying	-	-	-	-
Non-Ferrous Metals	38GWh	54GWh	8MWt	12MWe
Non-Metallic Minerals	730GWh	957GWh	232MWt	304MWe
Non-specified (Industry)	-	-	-	-
Paper, Pulp and Print	435GWh	473GWh	110MWt	162MWe
Textile and Leather	23GWh	16GWh	29MWt	19MWe
Transport Equipment	2GWh	3GWh	1MWt	2MWe
Wood and W. Products	8GWh	9GWh	3MWt	4MWe
Total	**10 874GWh**	**8 392GWh**	**3 460MWt**	**2 268MWe**

The incremental economic potential for heat and power from HE CHP in the industrial sector is estimated to be 10.8 TWht and 8.4 TWhe respectively, and about 2.3 GWe and 3.4 GWt in terms of capacity.

5.4.4 Analysis of the benefits linked to development of potential in the industrial sector

Assessment of the technical and economic potential was accompanied by assessment of environmental benefits, such as GHG emission savings and primary energy savings, associated with development of the incremental technical and economic potential for HE CHP.

The primary energy savings were calculated on the basis of the efficiency reference values of separate heat and power production, elaborated by GSE on the basis of technologies assumed to have been replaced in the sectors. GHG emission savings were calculated with the GSE method used to monitor the GHG emissions saved through the development of renewables and energy efficiency, as explained in detail in the section on methodology at the beginning of this chapter.

The overall savings which can be estimated on the incremental technical and economic potential in the industrial sector amount respectively to 1232 ktoe and 636 ktoe.

Overall, exploitation of the incremental technical and economic potential would make it possible to reduce GHG emissions by the industrial sector by about 4.3 and 2.2 $MtCO_2$ respectively.

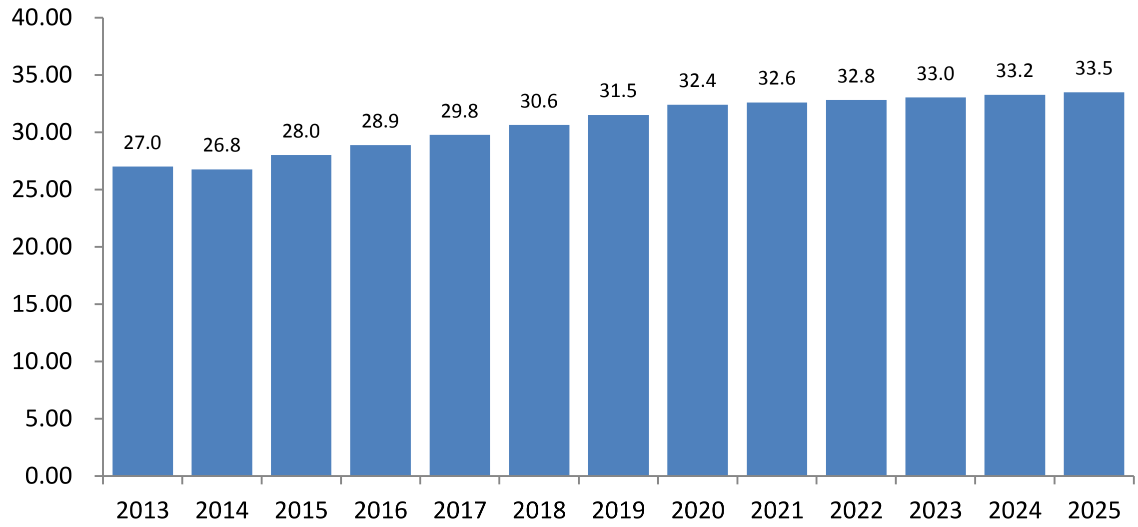
Table 78 – Primary energy savings linked to the incremental technical and economic potential in the industrial sector

	CO_2 savings incremental technical potential	CO_2 savings incremental economic potential	PES incremental technical potential	PES incremental economic potential
Chemical and Petrochemical	1 540 $ktCO_2$	1 225 $ktCO_2$	434 ktoe	357 ktoe
Coke Ovens	-	-	-	-
Refineries	365 $ktCO_2$	361 $ktCO_2$	116 ktoe	116 ktoe
Food and Tobacco	614 $ktCO_2$	325 $ktCO_2$	180 ktoe	87 ktoe
Iron and Steel	24 $ktCO_2$	24 $ktCO_2$	6 ktoe	6 ktoe
Machinery	747 $ktCO_2$	-	209 ktoe	-
Mining and Quarrying	-	-	-	-
Non-Ferrous Metals	32 $ktCO_2$	12 $ktCO_2$	9 ktoe	3 ktoe
Non-Metallic Minerals	251 $ktCO_2$	206 $ktCO_2$	64 ktoe	52 ktoe
Non-specified (Industry)	176 $ktCO_2$	-	49 ktoe	-
Paper, Pulp and Print	173 $ktCO_2$	68 $ktCO_2$	56 ktoe	12 ktoe
Textile and Leather	285 $ktCO_2$	5 $ktCO_2$	74 ktoe	1 ktoe
Transport Equipment	48 $ktCO_2$	1 $ktCO_2$	12 ktoe	0 ktoe
Wood and W. Products	89 $ktCO_2$	2 $ktCO_2$	23 ktoe	0 ktoe
Total	4 343 $ktCO_2$	2 228 $ktCO_2$	1 232 ktoe	636 ktoe

5.4.5 Demand evolution scenarios in the industrial sector and impact on analysis of potential

According to the ENEA scenarios simulated using the Times model, final consumption by the industrial sector should recover over the next 10 years.

Figure 63 – Final consumption in the industrial sector (source: ENEA 2015)



The rise in consumption expected in the sector has a measurable impact on economic potential as shown in the following table.

Table 79 – Technical and economic potential of HE CHP in the industrial sector on the basis of demand in 2023

	Technical potential for HE CHP heat	Technical potential for HE CHP electricity	Technical potential for HE CHP thermal capacity	Technical potential for HE CHP electrical capacity	Economic potential for HE CHP heat	Economic potential for HE CHP electricity	Economic potential for HE CHP thermal capacity	Economic potential for HE CHP electrical capacity
Chemical and Petrochemical	16 217GWh	13 768GWh	5 892MWt	6 097MWe	14 098GWh	11 749GWh	5 117MWt	5 443MWe
Coke Ovens	51GWh	53GWh	28MWt	29MWe	51GWh	53GWh	28MWt	29MWe
Refineries	11 810GWh	8 401GWh	4 699MWt	3 246MWe	11 784GWh	8 374GWh	4 679MWt	3 239MWe
Food and Tobacco	5 083GWh	3 867GWh	1 464MWt	1 367MWe	3 648GWh	3 021GWh	1 043MWt	910MWe
Iron and Steel	872GWh	787GWh	1 085MWt	1 010MWe	872GWh	787GWh	1 059MWt	987MWe
Machinery	4 771GWh	3 233GWh	2 522MWt	1 703MWe	160GWh	138GWh	143MWt	104MWe
Mining and Quarrying	13GWh	16GWh	3MWt	4MWe	13GWh	16GWh	3MWt	4MWe
Non-Ferrous Metals	159GWh	225GWh	40MWt	57MWe	74GWh	112GWh	16MWt	24MWe
Non-Metallic Minerals	1 552GWh	1 829GWh	526MWt	634MWe	1 347GWh	1 565GWh	435MWt	504MWe
Non-specified (Industry)	1 209GWh	1 093GWh	1 297MWt	1 037MWe	346GWh	350GWh	116MWt	108MWe
Paper, Pulp and Print	7 614GWh	4 722GWh	2 007MWt	1 384MWe	7 039GWh	4 722GWh	2 007MWt	1 384MWe
Textile and Leather	1 695GWh	1 539GWh	755MWt	673MWe	253GWh	207GWh	109MWt	99MWe
Transport Equipment	509GWh	544GWh	311MWt	352MWe	326GWh	320GWh	208MWt	222MWe
Wood and W. Products	493GWh	559GWh	241MWt	273MWe	117GWh	140GWh	40MWt	46MWe
	52 047GWh	**40 637GWh**	**20 870MWt**	**17 865MWe**	**40 128GWh**	**31 553GWh**	**15 004MWt**	**13 102MWe**

5.4.6 Analytical Appendix - detailed tables for the industrial sector

Table 80 – Demand in the industrial sector 2013 broken down by ATECO sector. We provide as an example, a summary of the data analysed for the chemical and petrochemical sector and the food sector (source: GSE based on Eurostat and ISTAT data)

Eurostat sector	ATECO code	Description ATECO code 3L	Electricity demand by subsector	Thermal demand by subsector	Total electricity demand by SMEs (10-50 workers)	Total thermal demand by SMEs (10-50 workers)	Electricity demand by a typical SME	Thermal demand by a typical SME	Total electricity demand by medium-large enterprises (>50 workers)	Total thermal demand by medium-large enterprises (>50 workers)	Electricity demand by a typical medium-large enterprise (>50 workers)	Thermal demand by a typical medium-large enterprise (>50 workers)
			GWh/year	GWh/year	GWh/year	GWh/year	GWh/year	GWh/year	GWh/year	GWh/year	GWh/year	GWh/year
Chemical and Petrochemical	20.1	MANUFACTURE OF BASIC CHEMICALS, FERTILISERS AND NITROGEN COMPOUNDS, PLASTICS AND SYNTHETIC RUBBER IN PRIMARY FORMS	11733	24682	326	686	0.98	2.06	11313	23799	84	178
Chemical and Petrochemical	20.2	MANUFACTURE OF PESTICIDES AND OTHER AGROCHEMICAL PRODUCTS	9	19	4	9	0.25	0.53	5	10	0	1
Chemical and Petrochemical	20.3	MANUFACTURE OF PAINTS, VARNISHES AND SIMILAR COATINGS, PRINTING INK AND MASTICS	312	657	142	298	0.53	1.11	119	250	2	4
Chemical and Petrochemical	20.4	MANUFACTURE OF SOAP AND DETERGENTS, CLEANING AND POLISHING PREPARATIONS, PERFUMES AND TOILET PREPARATIONS	563	1184	247	520	0.83	1.75	303	637	3	7
Chemical and Petrochemical	20.5	MANUFACTURE OF OTHER CHEMICAL PRODUCTS	1624	3416	568	1194	1.83	3.85	1015	2136	10	20
Chemical and Petrochemical	20.6	MANUFACTURE OF MAN-MADE FIBRES	49	103	8	16	0.54	1.14	39	81	2	4
Chemical and Petrochemical	21.1	MANUFACTURE OF BASIC PHARMACEUTICAL PRODUCTS	317	667	3	7	0.16	0.33	313	659	6	12
Chemical and Petrochemical	21.2	MANUFACTURE OF PHARMACEUTICAL PREPARATIONS	236	497	5	11	0.06	0.12	231	485	2	4
Food and Tobacco	10.1	PROCESSING AND PRESERVING OF MEAT ...	1240	1801	249	362	0.28	0.41	944	1371	6	8
Food and Tobacco	10.2	PROCESSING AND PRESERVING OF FISH, CRUSTACEANS AND MOLLUSCS	31	45	12	17	0.12	0.18	15	21	0	1
Food and Tobacco	10.3	PROCESSING AND PRESERVING OF FRUIT AND VEGETABLES	1396	2028	430	625	0.98	1.43	915	1329	9	13
Food and Tobacco	10.4	MANUFACTURE OF VEGETABLE AND ANIMAL OILS AND FATS	153	222	47	69	0.44	0.63	56	81	1	2
Food and Tobacco	10.5	MANUFACTURE OF DAIRY PRODUCTS	1893	2750	623	905	0.80	1.16	1051	1527	9	13
Food and Tobacco	10.6	MANUFACTURE OF GRAIN MILL PRODUCTS, STARCHES AND STARCH PRODUCTS	1176	1709	393	571	2.34	3.40	743	1079	14	21
Food and Tobacco	10.7	MANUFACTURE OF BAKERY AND FARINACEOUS PRODUCTS	2188	3178	635	922	0.24	0.35	432	627	3	4
Food and Tobacco	10.8	MANUFACTURE OF OTHER FOOD PRODUCTS	2372	3446	264	383	0.36	0.52	2003	2910	15	22
Food and Tobacco	10.9	MANUFACTURE OF PREPARED ANIMAL FEEDS	733	1065	273	396	2.11	3.06	421	611	8	11
Food and Tobacco	11.0	MANUFACTURE OF BEVERAGES	770	1118	191	277	0.37	0.53	508	737	5	7
Food and Tobacco	12.0	MANUFACTURE OF TOBACCO PRODUCTS	1	1	0	0	0.00	0.00	1	1	0	0

Table 81 – Sizing of CHP systems and simulation of their operating conditions in medium-large industrial companies (>50 workers)

Industry	Chemical and petrochemical			Coke ovens	Oil&Gas	Food								
Industrial subsector	Basic chemicals, fertilisers and nitrogen compounds	Pharmaceuticals	Production of soaps, detergents and cosmetics	Coke ovens	Extraction and refining of crude petroleum	Manufacture of beverages	Dairy industry	Processing and preserving of meat	Processing and preserving of fruit and vegetables	Manufacture of grain mill products and starches	Manufacture of other food products (cocoa, sugar etc.)	Manufacture of other food products and tobacco	Production of animal feeds	Manufacture of bakery products and farinaceous products
Heat demand [MWh/year]	155 065	5 962	6 566	138 868	489 275	7 374	13 052	8 258	12 539	20 756	21 556	1 187	11 012	3 971
Electricity demand [MWh/year]	73 712	2 834	3 121	14 028	55 935	5 076	8 985	5 684	8 632	14 288	14 839	817	7 580	2 734
User heat/electricity ratio []	2.1	2.1	2.1	9.9	8.7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Type of technology []	CCGT - NG	ICE - NG	ICE - NG	ICE - NG	CCGT - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG
Electrical capacity of CHP system [MWe]	18.0	0.6	1.1	4.5	21.7	0.7	0.9	0.7	0.4	2.0	1.9	0.1	1.6	0.2
Thermal capacity of CHP system [MWt]	22.1	0.6	0.9	4.2	41.8	0.6	1.0	0.9	0.4	2.3	2.1	0.1	1.4	0.2
Heat/electricity ratio of the system []	1.2	0.9	0.9	0.9	1.9	1.0	1.1	1.3	1.0	1.1	1.1	0.9	0.9	0.9
Electrical efficiency of CHP system [%]	36 %	39 %	40 %	38 %	34 %	38 %	37 %	36 %	38 %	35 %	37 %	40 %	39 %	41 %
Thermal efficiency of CHP system [%]	44 %	36 %	35 %	37 %	46 %	37 %	41 %	44 %	37 %	40 %	40 %	37 %	36 %	35 %
Share of electricity produced by High- Efficiency CHP [%]	50 %	75 %	56 %	49 %	57 %	66 %	86 %	90 %	88 %	82 %	79 %	75 %	68 %	72 %
Share of self-produced electricity [%]	53 %	91 %	92 %	98 %	53 %	82 %	90 %	89 %	92 %	100 %	79 %	81 %	88 %	82 %
Equivalent hours under HE CHP [heq]	3 083	4 544	2 969	3 134	2 579	2 969	3 038	3 836	3 513	2 246	4 082	2 513	1 963	3 259
Thermal efficiency of boilers [%]	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %
Heat produced by the CHP system [MWh]	68 229	2 664	2 754	13 320	107 794	1 843	3 002	3 303	1 254	5 189	8 622	298	2 795	596
Share of demand for CHP heat [%]	44 %	45 %	60 %	15 %	36 %	25 %	23 %	40 %	10 %	25 %	40 %	25 %	25 %	15 %
Heat generated by backup boiler [MWh]	86 837	3 298	3 812	125 548	381 481	5 530	10 050	4 955	11 285	15 567	12 934	890	8 216	3 375
HE CHP electricity produced by the CHP system [MWh]	55 531	2 834	3 121	14 028	55 935	1 935	2 702	2 539	1 303	4 589	7 626	319	3 066	687
Total electricity produced by the CHP system [MWh]	111 061	3 768	5 564	28 685	97 913	2 911	3 159	2 808	1 478	5 623	9 674	427	4 516	952
Electricity injected into the grid [MWh]	51 929	329	441	466	45 781	532	321	315	124	-	2 066	79	528	167
Self-consumed electricity [MWh]	59 132	3 438	5 124	28 219	52 132	2 379	2 839	2 493	1 354	5 623	7 608	348	3 988	785
Electricity off-taken from the grid [MWh]	14 580	-	-	-	3 804	2 697	6 146	3 192	7 278	8 666	7 231	470	3 592	1 949
Electricity exchanged with the grid [MWh]	14 580	-	-	-	3 804	532	321	315	124	-	2 066	79	528	167
Consumption of HE CHP system [MWh]	153 727	7 265	7 833	36 466	162 466	5 029	7 330	7 103	3 389	13 039	20 788	801	7 787	1 675
Total CHP system consumption [MWh]	278 157	9 678	13 965	74 565	257 371	7 566	8 547	7 813	3 825	15 975	26 231	1 067	11 471	2 332
Consumption of backup boiler [MWh]	96 485	3 665	4 235	139 497	423 868	6 145	11 167	5 505	12 539	17 297	14 371	989	9 129	3 750
Electricity off-taken ex-ante [MWh]	73 712	2 834	3 121	14 028	55 935	5 076	8 985	5 684	8 632	14 288	14 839	817	7 580	2 734
Boiler consumption ex-ante [MWh]	172 295	6 624	7 296	154 298	543 639	8 193	14 502	9 175	13 932	23 062	23 951	1 319	12 235	4 412

Industry	Iron and steel	Mechanical engineering	Mining	Other metals	Ceramics and glass		Other industries		Paper	Textile			Automotive	Wood
Industrial subsector	Iron and steel production and manufacture of sectioned tubes, etc.	Manufacture of machinery and equipment for miscellaneous uses	Mining and quarrying of minerals	Foundries	Manufacture of clay building materials (ceramic and other mineral materials)	Manufacture of glass and glass products	Manufacture of other products (furniture, medical equipment)	Manufacture of plastic and rubber products	Manufacture of pulp, paper and paperboard, articles of paper and paperboard and printed articles	leather, luggage, handbags, leather goods and saddlery;	Preparation and spinning of textile fibres	other textile industries, sewing and manufacture of items of clothing and	Manufacture of motor vehicles and accessories	Manufacture of wooden, cork and wickerwork goods
Heat demand [MWh/year]	170 924	1 951	812	11 511	39 869	92 236	715	1 539	105 254	2 603	2 624	3 610	2 067	2 318
Electricity demand [MWh/year]	82 032	2 227	926	6 160	8 595	19 884	3 963	8 529	70 115	1 867	1 882	2 589	7 486	4 386
User heat/electricity ratio []	2.1	0.9	0.9	1.9	4.6	4.6	0.2	0.2	1.5	1.4	1.4	1.4	0.3	0.5
Type of technology []	CCGT - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	CCGT - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG
Electrical capacity of CHP system [MWe]	2.8	0.3	-	0.2	1.3	0.9	0.6	0.2	12.5	0.5	0.2	0.3	0.8	0.6
Thermal capacity of CHP system [MWt]	3.4	0.4	0.0	0.2	1.0	0.7	0.7	0.2	19.5	0.6	0.2	0.3	0.6	0.5
Heat/electricity ratio of the system []	1.2	1.5	0.8	0.7	0.8	0.8	1.3	1.0	1.6	1.3	1.0	1.1	0.8	0.9
Electrical efficiency of CHP system [%]	36 %	34 %	41 %	44 %	42 %	42 %	37 %	38 %	33 %	35 %	38 %	37 %	42 %	40 %
Thermal efficiency of CHP system [%]	44 %	46 %	34 %	31 %	33 %	33 %	48 %	38 %	49 %	47 %	37 %	37 %	33 %	35 %
Share of electricity produced by High- Efficiency CHP [%]	50 %	83 %	57 %	67 %	64 %	64 %	100 %	83 %	81 %	100 %	63 %	83 %	58 %	47 %
Share of self-produced electricity [%]	53 %	70 %	99 %	94 %	85 %	85 %	100 %	87 %	75 %	100 %	67 %	77 %	87 %	98 %
Equivalent hours under HE CHP [heq]	3 000	2 293	3 762	4 482	3 210	3 210	527	4 027	4 150	1 712	2 909	2 963	1 693	2 553
Thermal efficiency of boilers [%]	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %
Heat produced by the CHP system [MWh]	10 255	976	122	691	3 190	2 306	393	677	81 045	1 067	630	1 011	1 034	1 275
Share of demand for CHP heat [%]	6 %	50 %	15 %	6 %	8 %	3 %	55 %	44 %	77 %	41 %	24 %	28 %	50 %	55 %
Heat generated by backup boiler [MWh]	160 668	976	690	10 820	36 679	89 930	322	862	24 208	1 536	1 994	2 599	1 034	1 043
HE CHP electricity produced by the CHP system [MWh]	8 347	662	144	980	4 112	2 973	300	666	51 915	801	648	938	1 304	1 444
Total electricity produced by the CHP system [MWh]	16 694	795	252	1 455	6 458	4 669	300	806	63 724	801	1 030	1 124	2 251	3 049
Electricity injected into the grid [MWh]	7 805	239	3	94	948	685	0	106	15 637	-	343	256	295	69
Self-consumed electricity [MWh]	8 888	556	249	1 360	5 510	3 983	300	700	48 087	801	687	867	1 956	2 979
Electricity off-taken from the grid [MWh]	73 143	1 671	677	4 800	3 085	15 901	3 663	7 828	22 027	1 066	1 195	1 722	5 530	1 407
Electricity exchanged with the grid [MWh]	7 805	239	3	94	948	685	0	106	15 637	-	343	256	295	69
Consumption of HE CHP system [MWh]	23 107	1 973	353	2 209	9 710	7 020	803	1 750	158 401	2 271	1 696	2 503	3 115	3 608
Total CHP system consumption [MWh]	41 810	2 319	618	3 280	15 250	11 025	803	2 117	190 103	2 271	2 696	3 009	5 374	7 617
Consumption of backup boiler [MWh]	178 520	1 084	767	12 022	40 755	99 922	358	958	26 898	1 706	2 216	2 888	1 149	1 159
Electricity off-taken ex-ante [MWh]	82 032	2 227	926	6 160	8 595	19 884	3 963	8 529	70 115	1 867	1 882	2 589	7 486	4 386
Boiler consumption ex-ante [MWh]	189 915	2 168	902	12 790	44 299	102 484	795	1 710	116 949	2 892	2 915	4 011	2 297	2 576

Table 82 – Sizing of CHP systems and simulation of their operating conditions in small and medium-sized industrial companies (10-50 workers)

Industry	Chemical and petrochemical			Coke ovens	Oil&Gas	Food								
Industrial subsector	Basic chemicals, fertilisers and nitrogen compounds	Pharmaceuticals	Production of soaps, detergents and cosmetics	Coke ovens	Extraction and refining of crude petroleum	Manufacture of beverages	Dairy industry	Processing and preserving of meat	Processing and preserving of fruit and vegetables	Manufacture of grain mill products and starches	Manufacture of other food products (cocoa, sugar etc.)	Manufacture of other food products and tobacco	Production of animal feeds	Manufacture of bakery products and farinaceous products
Heat demand [MWh/year]	2 022	158	1 745	138 868	4 423	535	1 160	409	1 426	3 399	524	422	3 059	347
Electricity demand [MWh/year]	961	75	830	14 028	506	368	799	281	982	2 340	360	291	2 106	239
User heat/electricity ratio []	2.1	2.1	2.1	9.9	8.7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Type of technology []	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG
Electrical capacity of CHP system [MWe]	0.4	-	0.4	6.4	0.3	0.1	0.1	-	0.1	0.5	0.1	0.1	0.6	-
Thermal capacity of CHP system [MWt]	0.4	0.0	0.4	6.1	0.3	0.1	0.1	0.1	0.1	0.5	0.1	0.1	0.6	0.0
Heat/electricity ratio of the system []	0.9	0.9	0.9	0.9	0.9	1.0	1.1	1.3	1.0	1.1	1.1	0.9	0.9	0.9
Electrical efficiency of CHP system [%]	40 %	39 %	40 %	38 %	41 %	38 %	37 %	36 %	38 %	35 %	37 %	40 %	39 %	41 %
Thermal efficiency of CHP system [%]	36 %	36 %	35 %	37 %	37 %	37 %	41 %	44 %	37 %	40 %	40 %	37 %	36 %	35 %
Share of electricity produced by High- Efficiency CHP [%]	69 %	75 %	56 %	49 %	82 %	66 %	86 %	90 %	88 %	82 %	79 %	75 %	68 %	72 %
Share of self-produced electricity [%]	95 %	91 %	92 %	98 %	97 %	82 %	90 %	89 %	92 %	100 %	79 %	81 %	88 %	82 %
Equivalent hours under HE CHP [heq]	2 158	3 181	2 078	2 194	1 805	2 078	2 126	2 685	2 459	1 573	2 858	1 759	1 374	2 281
Thermal efficiency of boilers [%]	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %
Heat produced by the CHP system [MWh]	857	71	732	13 320	468	134	267	163	143	850	209	106	777	52
Share of demand for CHP heat [%]	44 %	45 %	60 %	15 %	36 %	25 %	23 %	40 %	10 %	25 %	40 %	25 %	25 %	15 %
Heat generated by backup boiler [MWh]	1 166	88	1 013	125 548	3 955	401	893	245	1 284	2 549	314	316	2 283	295
HE CHP electricity produced by the CHP system [MWh]	961	75	830	14 028	506	140	240	126	148	752	185	113	852	60
Total electricity produced by the CHP system [MWh]	1 387	100	1 479	28 685	620	211	281	139	168	921	235	152	1 255	83
Electricity injected into the grid [MWh]	64	9	117	466	21	39	29	16	14	-	50	28	147	15
Self-consumed electricity [MWh]	1 323	91	1 362	28 219	600	173	252	123	154	921	185	124	1 108	68
Electricity off-taken from the grid [MWh]	-	-	-	-	-	196	546	158	828	1 419	176	167	998	170
Electricity exchanged with the grid [MWh]	-	-	-	-	-	39	29	16	14	-	50	28	147	15
Consumption of HE CHP system [MWh]	2 390	193	2 082	36 466	1 248	365	651	352	385	2 135	505	285	2 163	146
Total CHP system consumption [MWh]	3 472	257	3 712	74 565	1 517	549	760	387	435	2 616	637	380	3 187	203
Consumption of backup boiler [MWh]	1 295	97	1 126	139 497	4 394	446	992	272	1 426	2 832	349	352	2 536	327
Electricity off-taken ex-ante [MWh]	961	75	830	14 028	506	368	799	281	982	2 340	360	291	2 106	239
Boiler consumption ex-ante [MWh]	2 247	176	1 939	154 298	4 915	594	1 289	454	1 585	3 777	582	469	3 399	385

Industry	Iron and steel	Mechanical engineering	Mining	Other metals	Ceramics and glass		Other industries		Paper	Textile			Automotive	Wood
Industrial subsector	Iron and steel production and manufacture of sectioned tubes, etc.	Manufacture of machinery and equipment for miscellaneous uses	Mining and quarrying of minerals	Foundries	Manufacture of clay building materials (ceramic and other mineral materials)	Manufacture of glass and glass products	Manufacture of other products (furniture, medical equipment)	Manufacture of plastic and rubber products	Manufacture of pulp, paper and paperboard, articles of paper and paperboard and printed articles	luggage, handbags, leather goods and saddlery;	Preparation and spinning of textile fibres	other textile industries, sewing and manufacture of items of clothing and	Manufacture of motor vehicles and accessories	Manufacture of wooden, cork and wickerwork goods
Heat demand [MWh/year]	1 443	210	283	1 914	5 631	3 025	137	173	17 778	204	738	282	99	244
Electricity demand [MWh/year]	693	240	324	1 024	1 214	652	760	956	11 843	146	530	202	359	461
User heat/electricity ratio []	2.1	0.9	0.9	1.9	4.6	4.6	0.2	0.2	1.5	1.4	1.4	1.4	0.3	0.5
Type of technology []	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG	ICE - NG
Electrical capacity of CHP system [MWe]	0.1	-	-	0.1	0.3	-	0.2	-	4.1	0.1	0.1	-	0.1	0.1
Thermal capacity of CHP system [MWt]	0.0	0.1	0.0	0.0	0.2	0.0	0.2	0.0	3.6	0.1	0.1	0.0	0.0	0.1
Heat/electricity ratio of the system []	0.7	1.5	0.8	0.7	0.8	0.8	1.3	1.0	0.9	1.3	1.0	1.1	0.8	0.9
Electrical efficiency of CHP system [%]	44 %	34 %	41 %	44 %	42 %	42 %	37 %	38 %	40 %	35 %	38 %	37 %	42 %	40 %
Thermal efficiency of CHP system [%]	31 %	46 %	34 %	31 %	33 %	33 %	48 %	38 %	35 %	47 %	37 %	37 %	33 %	35 %
Share of electricity produced by High- Efficiency CHP [%]	67 %	83 %	57 %	67 %	64 %	64 %	100 %	83 %	78 %	100 %	63 %	83 %	58 %	47 %
Share of self-produced electricity [%]	94 %	70 %	99 %	94 %	85 %	85 %	100 %	87 %	88 %	100 %	67 %	77 %	87 %	98 %
Equivalent hours under HE CHP [heq]	2 100	1 605	2 633	3 137	2 247	2 247	369	2 819	2 905	1 198	2 036	2 074	1 185	1 787
Thermal efficiency of boilers [%]	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %	90 %
Heat produced by the CHP system [MWh]	87	105	43	115	451	76	75	76	10 446	84	177	79	50	134
Share of demand for CHP heat [%]	6 %	50 %	15 %	6 %	8 %	3 %	55 %	44 %	77 %	41 %	24 %	28 %	50 %	55 %
Heat generated by backup boiler [MWh]	1 357	105	241	1 799	5 181	2 950	62	97	7 332	120	561	203	50	110
HE CHP electricity produced by the CHP system [MWh]	123	71	50	163	581	97	58	75	11 843	63	182	73	63	152
Total electricity produced by the CHP system [MWh]	182	86	88	242	912	153	58	90	15 122	63	290	88	108	321
Electricity injected into the grid [MWh]	12	26	1	16	134	22	0	12	1 842	-	97	20	14	7
Self-consumed electricity [MWh]	171	60	87	226	778	131	58	78	13 280	63	193	68	94	313
Electricity off-taken from the grid [MWh]	522	180	237	798	436	522	703	878	-	84	336	134	265	148
Electricity exchanged with the grid [MWh]	12	26	1	16	134	22	0	12	-	-	97	20	14	7
Consumption of HE CHP system [MWh]	277	213	123	367	1 371	230	154	196	29 318	178	477	196	149	379
Total CHP system consumption [MWh]	411	250	216	546	2 154	362	154	237	37 558	178	759	235	258	801
Consumption of backup boiler [MWh]	1 507	117	268	1 999	5 756	3 277	69	107	8 146	134	623	226	55	122
Electricity off-taken ex-ante [MWh]	693	240	324	1 024	1 214	652	760	956	11 843	146	530	202	359	461
Boiler consumption ex-ante [MWh]	1 604	234	315	2 127	6 257	3 361	152	192	19 753	227	820	313	110	271

Table 83 – Economic and financial parameters of HE CHP in medium-large industrial companies (>50 workers)

Industry	Chemical and petrochemical			Coke ovens	Oil&Gas	Food									Iron and steel	Mechanical engineering	Mining	Other metals	Ceramics and glass		Other industries		Paper	Textile			Automotive	Wood
Industrial subsector	Basic chemicals, fertilisers and nitrogen compounds	Pharmaceuticals	Production of soaps, detergents and cosmetics	Coke ovens	Extraction and refining of crude petroleum	Manufacture of beverages	Dairy industry	Processing and preserving of meat	Processing and preserving of fruit and vegetables	Manufacture of grain mill products and starches	Manufacture of other food products	Manufacture of other food products and tobacco	Production of animal feeds	Manufacture of bakery products and farinaceous products	Iron and steel production and manufacture of sectioned tubes, etc.	Manufacture of machinery and equipment for miscellaneous uses	Mining and quarrying of minerals	Foundries	ceramics and other mineral materials	Manufacture of glass and glass products	Manufacture of other products (furniture etc.)	Manufacture of plastic and rubber products	Manufacture of pulp-paper, paper and paperboard	Tanning and dressing of leather, etc.	Preparation and spinning of textile fibres	other textile industries, sewing and manufacture of items of clothing and	Manufacture of motor vehicles and accessories	Manufacture of wooden, cork and wickerwork goods
Cost of specific investment in a CHP system [€/kWe]	1 000	808	699	613	1 000	800	732	797	966	674	678	1 554	686	1 241	1 000	1 079	2 649	1 221	693	721	824	1 382	1 000	871	1 211	1 036	766	825
Variable maintenance costs [€/h]	-	7.4	11.6	45.1	-	7.7	10.0	7.8	5.0	21.3	19.6	2.6	16.6	3.4	-	4.2	1.7	3.5	13.9	10.4	6.9	2.9	-	5.9	3.5	4.4	8.9	6.9
Fixed maintenance costs [€/kW year]	40	-	-	-	40	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	-	40	-	-	-	-	-
Useful life of CHP system (hours of operation) [h]	75 000	60 000	60 000	60 000	75 000	60 000	60 000	60 000	40 000	60 000	60 000	40 000	60 000	40 000	75 000	40 000	40 000	40 000	60 000	60 000	60 000	40 000	75 000	40 000	40 000	40 000	60 000	60 000
Useful life of CHP system (calendar years) [h]	8.5	7.0	7.9	6.6	11.6	9.4	11.8	9.9	7.0	15.0	8.1	8.3	14.5	6.2	8.8	10.2	4.2	4.2	8.3	8.3	15.0	5.7	10.3	15.0	6.1	7.9	14.4	7.8
Price of gas taken for thermal use [€/MWh]	30.60	36.15	36.15	30.60	29.15	36.15	36.15	36.15	36.15	36.15	36.15	49.40	36.15	36.15	30.60	49.40	49.40	36.15	30.60	30.60	49.40	49.40	30.60	36.15	36.15	36.15	49.40	49.40
Price of CHP gas [€/MWh]	29.93	35.09	35.07	29.95	28.53	35.10	35.23	35.17	35.18	35.39	35.36	48.31	35.11	35.04	29.93	48.47	48.29	35.00	29.80	29.86	48.38	48.37	30.02	35.19	35.11	35.14	48.26	48.31
Price of electricity off-taken [€/MWh]	136.20	155.70	155.70	155.70	136.20	155.70	155.70	155.70	155.70	155.70	155.70	172.75	155.70	155.70	136.20	155.70	172.75	155.70	155.70	155.70	155.70	155.70	136.20	172.75	172.75	155.70	155.70	155.70
Wholesale price of electricity [€/MWh]	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08
Price of electricity under the net-metering system [€/MWh]	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00
Excise duty on consumption of gas for civil use [€/MWh]	19.53	19.52	19.52	19.53	19.53	19.52	19.52	19.52	19.52	19.53	19.53	19.50	19.52	19.52	19.53	19.51	19.49	19.52	19.53	19.53	19.48	19.51	19.53	19.51	19.51	19.52	19.51	19.51
Excise duty on gas for electricity self-production [€/MWh]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Deductible on excise duty on gas for electricity self-production [€/MWh]	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Excise duty on gas applied to the CHP unit [€/MWh]	0.15	0.25	0.23	0.17	0.17	0.27	0.28	0.34	0.24	0.29	0.25	0.23	0.24	0.20	0.15	0.38	0.21	0.10	0.12	0.11	0.30	0.28	0.26	0.35	0.27	0.30	0.17	0.22
Excise duty on electricity consumed [€/MWh]	1.19	11.73	11.34	8.36	1.57	9.86	8.84	9.61	8.89	8.34	5.92	12.50	9.08	11.89	1.07	12.50	12.50	9.45	8.90	4.42	10.53	8.91	1.25	12.50	12.50	12.13	9.10	10.24
Price of WC (II) HE CHP [€/WC]	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00
WACC [%]	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %
NPV [€]	7 049 996	130 705	- 808 984	-3 777 986	16 651 002	439 849	1 026 005	840 753	183 252	2 590 078	2 125 366	- 60 087	1 400 788	-42 552	972 711	-182 294	- 89 855	39 835	1 796 772	1 375 500	-340 418	-76 456	16 841 073	371 727	-83 671	-33 877	15 030	45 538
IRR [%]	14 %	13 %	-	-	18 %	21 %	29 %	34 %	18 %	27 %	38 %	-	22 %	-	13 %	-	-	11 %	44 %	45 %	-	-	28 %	17 %	-	2 %	5 %	8 %
Time for return on investment (discounted) [years]	5.4	4.6	-	-	5.5	4.4	3.6	3.0	4.4	4.1	2.6	12.8	4.9	7.4	5.6	54.6	-	3.4	2.3	2.3	-	8.1	3.7	6.5	9.4	8.0	13.5	6.3
Profitability index (NPV/I) []	0.4	0.3	-	-	0.8	0.8	1.6	1.6	0.5	1.9	1.7	-	1.3	-	0.3	-	-	0.1	2.0	2.1	-	-	1.3	0.9	-	-	0.0	0.1
Share implemented [%]	90 %	77 %	0 %	0 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	0 %	100 %	0 %	81 %	0 %	0 %	63 %	100 %	100 %	0 %	0 %	100 %	100 %	0 %	0 %	4 %	26 %

Table 84 – Economic and financial parameters of HE CHP in small and medium industrial companies (10-50 workers)

Industry	Chemical and petrochemical			Coke ovens	Oil&Gas	Food									Iron and steel	Mechanical engineering	Mining	Other metals	Ceramics and glass		Other industries		Paper	Textile			Automotive	Wood
Industrial subsector	Basic chemicals, fertilisers and nitrogen compounds	Pharmaceuticals	Production of soaps, detergents and cosmetics	Coke ovens	Extraction and refining of crude petroleum	Manufacture of beverages	Dairy industry	Processing and preserving of meat	Processing and preserving of fruit and vegetables	Manufacture of grain mill products and starches	Manufacture of other food products	Manufacture of other food products and tobacco	Production of animal feeds	Manufacture of bakery products and farinaceous products	Iron and steel production and manufacture of sectioned tubes, etc.	Manufacture of machinery and equipment for miscellaneous uses	Mining and quarrying of minerals	Foundries	ceramics and other mineral materials	Manufacture of glass and glass products	Manufacture of other products (furniture etc.)	Manufacture of plastic and rubber products	Manufacture of pulp-paper, paper and paperboard	Tanning and dressing of leather, etc.	Preparation and spinning of textile fibres	other textile industries, sewing and manufacture of items of clothing and	Manufacture of motor vehicles and accessories	Manufacture of wooden, cork and wickerwork goods
Cost of specific investment in a CHP system [€/kWe]	890	3 276	935	600	1 094	2 057	1 637	2 421	2 164	863	2 095	2 099	810	3 129	2 193	2 476	3 606	2 312	1 134	2 504	1 418	3 117	623	2 304	1 815	2 744	2 296	1 858
Variable maintenance costs [€/h]	5.7	1.6	5.2	63.9	4.1	2.0	2.4	1.8	1.9	6.0	2.0	2.0	7.4	1.6	1.9	1.8	1.5	1.8	3.9	1.7	2.9	1.6	41.2	1.8	2.2	1.7	1.8	2.2
Fixed maintenance costs [€/kW year]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Useful life of CHP system (hours of operation) [h]	40 000	40 000	40 000	60 000	40 000	40 000	40 000	40 000	40 000	40 000	40 000	40 000	60 000	40 000	40 000	40 000	20 000	40 000	40 000	40 000	40 000	40 000	60 000	40 000	40 000	40 000	40 000	40 000
Useful life of CHP system (calendar years) [h]	9.0	6.6	7.6	9.4	12.6	9.0	11.3	9.4	10.0	14.5	7.7	11.9	15.0	8.9	9.0	14.5	3.0	6.0	7.9	7.9	15.0	8.2	11.3	15.0	8.7	11.3	13.7	7.4
Price of gas taken for thermal use [€/MWh]	49.40	61.70	49.40	30.60	36.15	49.40	49.40	49.40	49.40	36.15	49.40	49.40	36.15	49.40	49.40	61.70	49.40	49.40	36.15	36.15	61.70	61.70	36.15	61.70	49.40	49.40	61.70	49.40
Price of CHP gas [€/MWh]	48.31	60.64	48.32	29.95	35.04	48.35	48.40	48.42	48.35	35.19	48.40	48.31	35.08	48.29	48.20	60.77	48.29	48.20	35.00	35.00	60.68	60.67	35.24	60.74	48.36	48.39	60.56	48.31
Price of electricity off-taken [€/MWh]	172.75	197.40	172.75	155.70	172.75	197.40	172.75	197.40	172.75	155.70	197.40	197.40	155.70	197.40	172.75	197.40	197.40	172.75	172.75	172.75	172.75	172.75	155.70	197.40	172.75	197.40	197.40	197.40
Wholesale price of electricity [€/MWh]	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08	52.08
Price of electricity under the net-metering system [€/MWh]	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00	158.00
Excise duty on consumption of gas for civil use [€/MWh]	19.51	19.31	19.51	19.53	19.52	19.46	19.50	19.44	19.50	19.52	19.46	19.45	19.52	19.43	19.50	19.36	19.41	19.51	19.52	19.52	19.28	19.33	19.53	19.36	19.48	19.41	19.18	19.39
Excise duty on gas for electricity self-production [€/MWh]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Deductible on excise duty on gas for electricity self-production [€/MWh]	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Excise duty on gas applied to the CHP unit [€/MWh]	0.23	0.25	0.23	0.17	0.20	0.27	0.31	0.34	0.26	0.36	0.31	0.23	0.24	0.20	0.11	0.38	0.21	0.11	0.16	0.16	0.30	0.28	0.18	0.35	0.27	0.30	0.17	0.22
Excise duty on electricity consumed [€/MWh]	12.50	12.50	12.50	8.36	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	8.51	12.50	12.50	12.50	12.50	12.50
Price of WC (II) HE CHP [€/WC]	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00	116.00
WACC [%]	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %	5 %
NPV [€]	-355 444	-101 944	-569 971	-5 319 032	-7 472	-67 472	- 65 181	-49 896	-76 084	139 477	-55 298	-60 470	143 461	- 71 016	- 84 638	-81 229	-70 284	-78 948	27 835	- 69 299	-227 803	-92 333	3 280 295	- 81 545	-95 390	-68 212	- 96 276	-56 078
IRR [%]	-	-	-	-	5 %	-	-	-	-	10 %	-	-	9 %	-	-	-	-	-	8 %	-	-	-	25 %	-	-	-	-	-
Time for return on investment (discounted) [years]	-	-	-	-	12.4	20.3	21.0	20.7	53.6	9.5	13.7	28.4	10.6	-	61.5	-	-	27.7	6.3	32.9	-	-	4.1	-	31.2	-	-	12.2
Profitability index (NPV/I) []	-	-	-	-	-	-	-	-	-	0.3	-	-	0.3	-	-	-	-	-	0.1	-	-	-	1.3	-	-	-	-	-
Share implemented [%]	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %	49 %	0 %	0 %	40 %	0 %	0 %	0 %	0 %	0 %	26 %	0 %	0 %	0 %	100 %	0 %	0 %	0 %	0 %	0 %

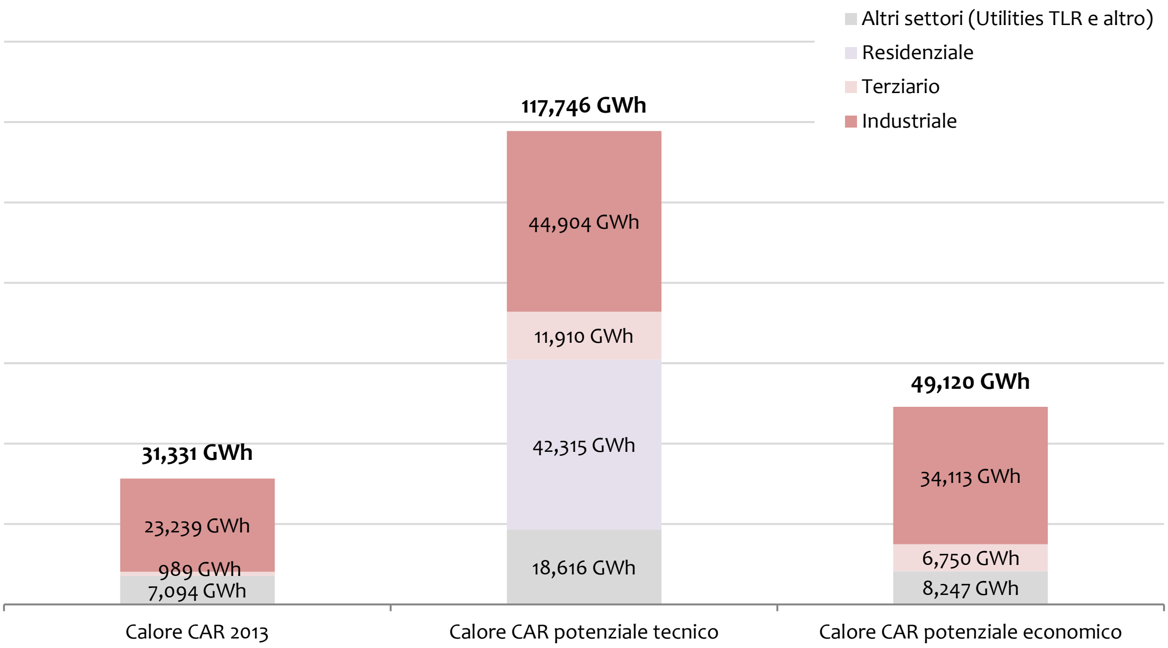
5.5 National sectoral and regional potential for high-efficiency CHP

By aggregating the results for the high-efficiency CHP potential analysed earlier for the residential, service and industrial sectors, including the results for district heating networks served by high-efficiency CHP[81], the technical potential and economic potential of cogenerated heat are found to be around 4 times and 1.5 times higher respectively than the existing capacity.

The incremental technical potential amounts to around 86 TWh. The residential sector accounts for 49 %, the industrial sector 25 %, the service sector 13 % and other sectors 13 % (mostly utilities involved in district heating).

If it were realised, the economic potential would result in an increase of 17.8 TWh in cogenerated heat, mainly due to the industrial sector (61 %), followed by the service sector (32 %) and to a lesser extent other sectors (6 %).

Figure 64 Comparison between the heat currently produced from high-efficiency CHP and its technical and economic potential at the national level by sector of use



Altri settori (Utilities TLR e altro)	Other sectors (DH Utilities and other)
Residenziale	Residential
Terziario	Services
Industriale	Industrial
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

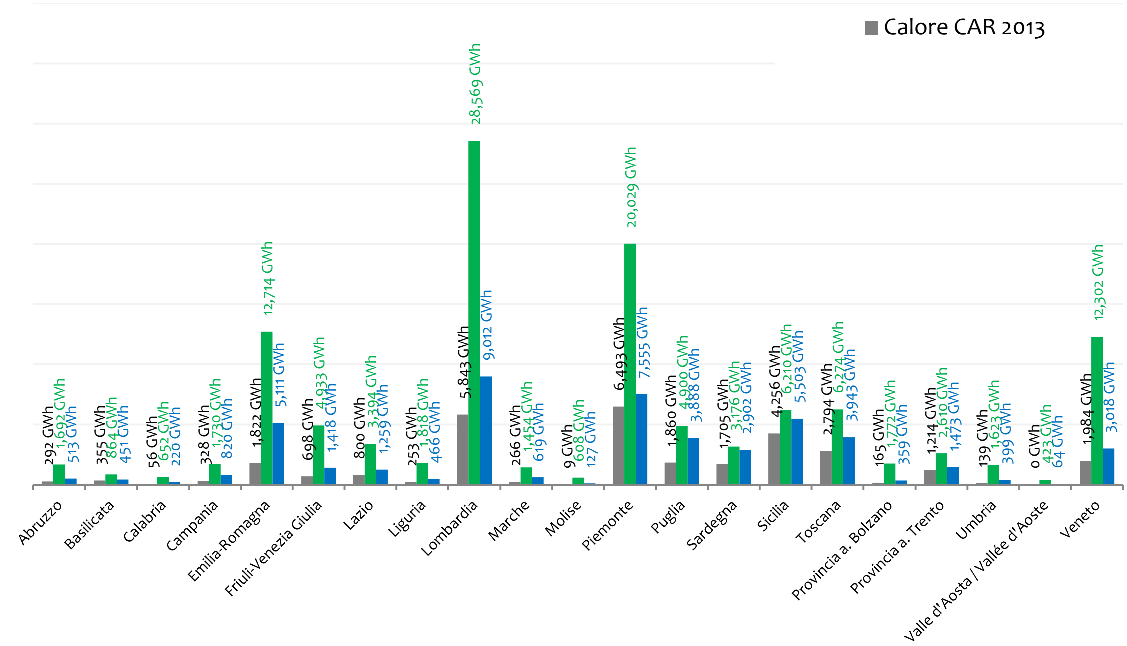
[81] This is covered in more detail in sections 6.2.1, 6.3, 6.4.1 and 6.5.1 on the potential for efficient DH from natural gas cogeneration.

The results of the high-efficiency CHP potential at the national level were recalculated for the regional level using a top-down approach. This involved:

- 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 the regional level by distributing the potential calculated at the national level according to the regional demand for heat in each sector (or in some cases by adopting proxies) – 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;
- 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 regional results for the potential of high-efficiency CHP show that, on balance, all regions have a development margin for high-efficiency CHP. The highest increase was in northern Italy, which has the largest concentration of residential heat demand (which only affects the technical potential) and industrial and service sector demand (which affects both the technical and economic potential).

Figure 65 Comparison between the heat currently produced from HE CHP and its technical and economic potential at the regional level [GWh]



Residenziale	Residential
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

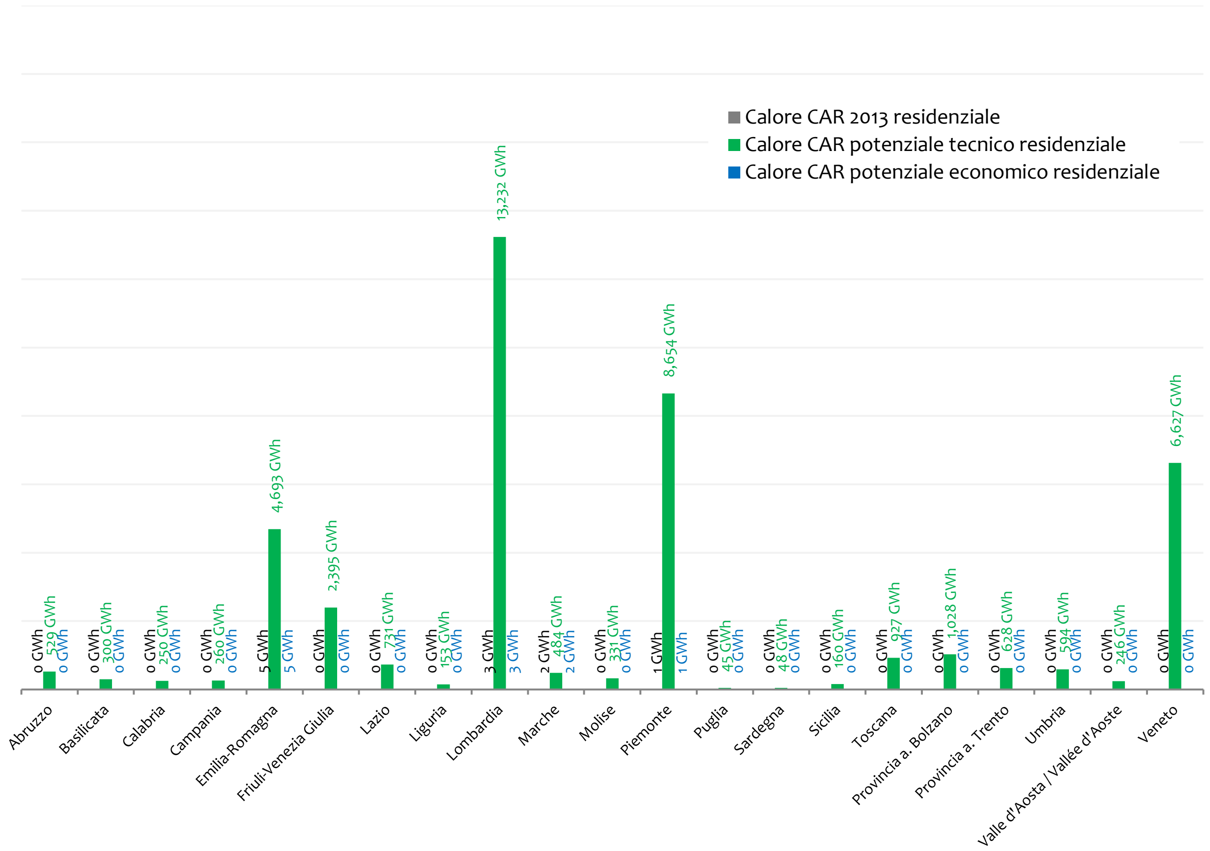
	Residential			Services			Industrial			Other sectors (processing, agriculture, etc.)			Total sectors		
	HE CHP heat 2013	HE CHP technical potential	HE CHP economic potential	HE CHP heat 2013	HE CHP technical potential	HE CHP economic potential	HE CHP heat 2013	HE CHP technical potential	HE CHP economic potential	HE CHP heat 2013	HE CHP technical potential	HE CHP economic potential	HE CHP heat 2013	HE CHP technical potential	HE CHP economic potential
Abruzzo	-	529	-	4	290	169	282	746	339	5	128	5	292	1 692	513
Basilicata	-	300	-	-	87	48	355	415	403	-	62	-	355	864	451
Calabria	-	250	-	22	331	173	2	19	16	32	53	32	56	652	220
Campania	-	260	-	-	659	350	328	789	469	0	22	0	328	1 730	820
Emilia-Romagna	5	4 693	5	44	1 269	710	1 407	5 251	3 896	366	1 501	500	1 822	12 714	5 111
Friuli-Venezia Giulia	-	2 395	-	12	385	208	681	1 805	1 205	5	347	6	698	4 933	1 418
Lazio	0	731	0	120	812	481	678	1 065	777	1	785	1	800	3 394	1 259
Liguria	-	153	-	17	294	152	204	324	269	31	1 047	45	253	1 818	466
Lombardy	3	13 232	3	577	2 296	1 454	2 981	7 812	4 820	2 282	5 228	2 735	5 843	28 569	9 012
Marche	2	484	2	4	295	172	251	439	436	9	237	9	266	1 454	619
Molise	-	331	-	-	71	39	9	167	88	-	38	-	9	608	127
Piedmont	1	8 654	1	65	1 262	713	3 691	5 261	3 753	2 737	4 852	3 088	6 493	20 029	7 555
Apulia	-	45	-	10	405	227	1 184	3 487	2 994	666	963	666	1 860	4 900	3 888
Sardinia	-	48	-	-	199	108	1 705	2 930	2 794	-	-	-	1 705	3 176	2 902
Sicily	-	160	-	-	443	228	4 256	5 487	5 275	-	120	-	4 256	6 210	5 503
Tuscany	-	927	-	6	724	424	2 787	4 093	3 516	1	529	4	2 794	6 274	3 943
Autonomous Province of Bolzano	-	1 028	-	22	335	135	58	62	59	85	347	165	165	1 772	359
Autonomous Province of Trento	-	628	-	0	225	105	566	710	615	648	1 047	753	1 214	2 610	1 473
Umbria	-	594	-	11	282	169	103	598	204	25	149	25	139	1 623	399
Valle d'Aosta	-	246	-	-	106	50	-	4	4	-	67	11	-	423	64
Veneto	-	6 627	-	74	1 141	634	1 710	3 442	2 182	200	1 093	202	1 984	12 302	3 018
Italy	**10**	**42 315**	**10**	**989**	**11 910**	**6 750**	**23 239**	**44 904**	**34 113**	**7 094**	**18 616**	**8 247**	**31 331**	**117 746**	**49 120**

5.5.1 Regional potential of high-efficiency CHP in the residential sector

Considering the 10 GWh of heat currently cogenerated in the residential sector, the technical potential at the national level is equal to 42.3 TWh. The economic potential reflects the existing capacity, no profitability having been identified for the residential sector in the case studies analysed.

As stated in section 5.2, the technical potential of high-efficiency CHP in the residential sector is around 80 % linked to single-family dwellings built before 2000 and situated in climate condition areas E-F. The regional distribution of the demand for heat of these types of dwellings is mainly concentrated in Lombardy, Piedmont, Veneto, Emilia Romagna and Friuli Venezia Giulia. As a result, the technical potential of high-efficiency CHP is mostly found in these regions. For all regions, the economic potential is negligible in the current market and under current regulations.

Figure 66 Comparison between the heat currently produced from HE CHP and its technical and economic potential at the regional level for the residential sector



Residenziale	Residential
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

Residential sector

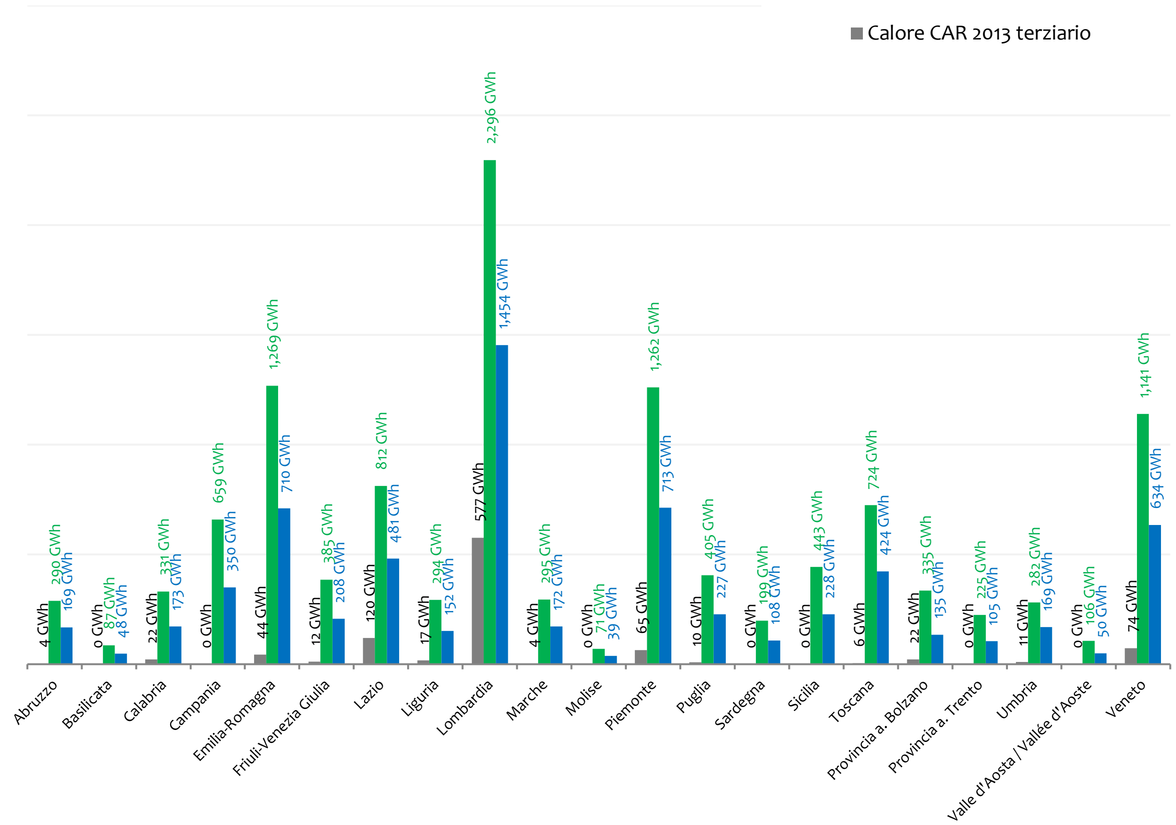
	HE CHP heat [GWh]			HE CHP electricity [GWh]			Electrical capacity [MW]		
	2013	Technical potential	Economic potential	2013	Technical potential	Economic potential	2013	Technical potential	Economic potential
Abruzzo	-	529	-	-	132	-	-	57	-
Basilicata	-	300	-	-	75	-	-	32	-
Calabria	-	250	-	-	62	-	-	27	-
Campania	-	260	-	-	65	-	-	28	-
Emilia-Romagna	5	4 693	5	2	1 171	2	1	502	1
Friuli-Venezia Giulia	-	2 395	-	-	598	-	-	256	-
Lazio	0	731	0	0	183	0	0	78	0
Liguria	-	153	-	-	38	-	-	16	-
Lombardy	3	13 232	3	1	3 302	1	1	1 415	1
Marche	2	484	2	1	121	1	1	52	1
Molise	-	331	-	-	83	-	-	35	-
Piedmont	1	8 654	1	1	2 160	1	1	926	1
Apulia	-	45	-	-	11	-	-	5	-
Sardinia	-	48	-	-	12	-	-	5	-
Sicily	-	160	-	-	40	-	-	17	-
Tuscany	-	927	-	-	231	-	-	99	-
Autonomous Province of Bolzano	-	1 028	-	-	256	-	-	110	-
Autonomous Province of Trento	-	628	-	-	157	-	-	67	-
Umbria	-	594	-	-	148	-	-	63	-
Valle d’Aosta	-	246	-	-	61	-	-	26	-
Veneto	-	6 627	-	-	1 654	-	-	709	-
Italy	10	42 315	10	6	10 560	6	5	4 526	5

5.5.2 Regional potential of high-efficiency CHP in the service sector

Considering the 989 GWh of heat currently cogenerated in the service sector, the technical potential at the national level is equal to 11.91 TWh, while the economic potential is 6.75 TWh.

As described in section 5.3, the technical and economic potential of high-efficiency CHP in the service sector is about 50 % composed of heating demand from healthcare facilities, and to a lesser extent sports facilities with swimming pools. By distributing regional consumption in these sectors, it was possible to reconstruct the geographical location of the economic and technical potential of high-efficiency CHP in the service sector.

Figure 67 Comparison between the heat current produced from HE CHP and its technical and economic potential at the regional level for the service sector



Terziario	Service
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

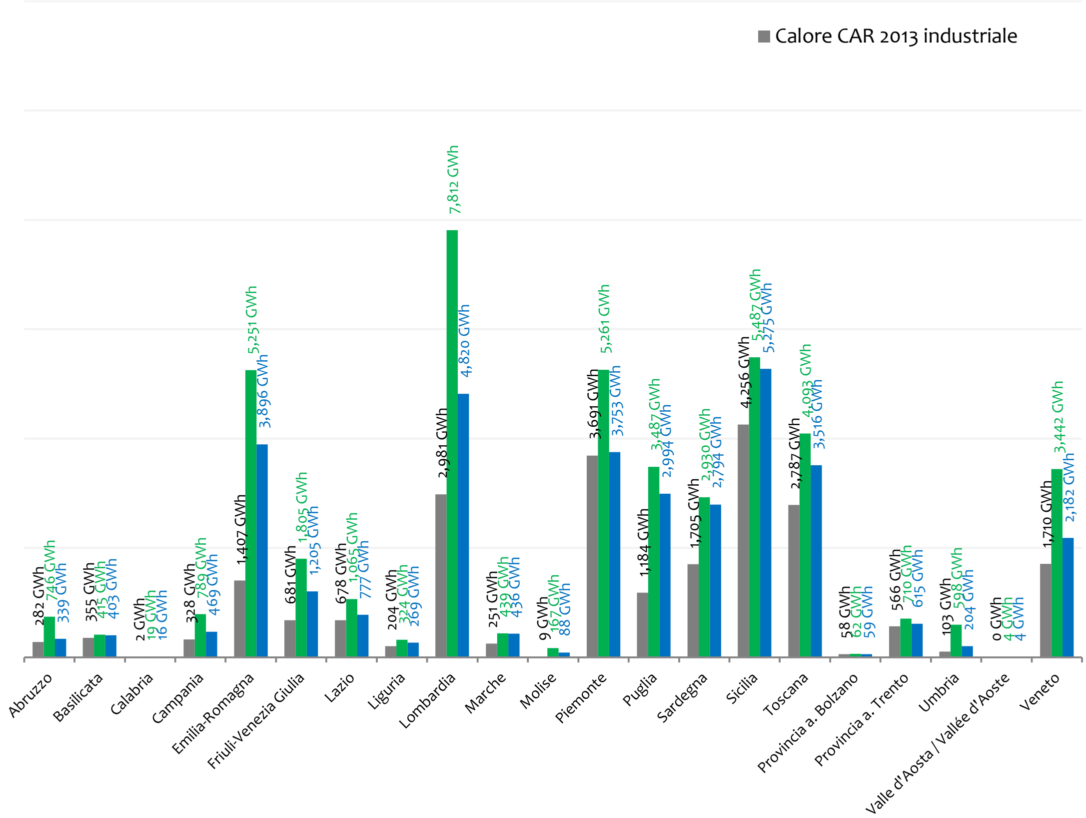
Service sector

	HE CHP heat [GWh]			HE CHP electricity [GWh]			Electrical capacity [MW]		
	2013	Technical potential	Economic potential	2013	Technical potential	Economic potential	2013	Technical potential	Economic potential
Abruzzo	4	290	169	4	175	121	3	55	36
Basilicata	-	87	48	-	52	35	-	16	10
Calabria	22	331	173	20	199	130	8	60	36
Campania	-	659	350	-	391	257	-	115	68
Emilia-Romagna	44	1 269	710	40	769	515	15	234	145
Friuli-Venezia Giulia	12	385	208	12	232	153	6	71	43
Lazio	120	812	481	124	537	391	33	157	106
Liguria	17	294	152	17	175	110	4	53	31
Lombardy	577	2 296	1 454	601	1 539	1 173	163	463	335
Marche	4	295	172	2	178	122	1	55	35
Molise	-	71	39	-	43	28	-	13	8
Piedmont	65	1 262	713	58	758	518	18	228	144
Apulia	10	405	227	7	243	164	2	73	46
Sardinia	-	199	108	-	119	78	-	36	22
Sicily	-	443	228	-	262	168	-	77	44
Tuscany	6	724	424	6	440	303	2	135	87
Autonomous Province of Bolzano	22	335	135	16	197	95	6	66	29
Autonomous Province of Trento	0	225	105	0	134	74	0	43	22
Umbria	11	282	169	10	171	119	4	53	35
Valle d'Aosta	-	106	50	-	63	35	-	20	10
Veneto	74	1 141	634	72	692	460	22	215	133
Italy	989	11 910	6 750	989	7 369	5 050	287	2 237	1 426

5.5.3 Regional potential of high-efficiency CHP in the industrial sector

Considering the 23.2 GWh of heat currently cogenerated in the industrial sector, the technical potential at the national level is equal to 44.9 TWh, while the economic potential is 34.11 TWh. Using the regional distribution of emissions from industrial sectors, elaborated from emissions data for stationary installations held in ETS records, it was possible to loosely reconstruct the regional energy demand of the different industrial sectors and thus recalculate its potential for high-efficiency CHP at a regional level.

Figure 68 Comparison between the heat currently produced from HE CHP and its technical and economic potential at the regional level for the industrial sector



Industriale	Industrial
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

Industrial sector

	HE CHP heat [GWh]			HE CHP electricity [GWh]			Electrical capacity [MW]		
	2013	Technical potential	Economic potential	2013	Technical potential	Economic potential	2013	Technical potential	Economic potential
Abruzzo	282	746	339	249	531	289	199	325	199
Basilicata	355	415	403	232	300	288	73	107	101
Calabria	2	19	16	2	23	20	1	8	7
Campania	328	789	469	321	700	436	153	380	202
Emilia-Romagna	1 407	5 251	3 896	1 502	4 303	3 316	559	1 497	1 060
Friuli-Venezia Giulia	681	1 805	1 205	441	1 461	990	995	1 230	1 025
Lazio	678	1 065	777	473	845	581	155	335	192
Liguria	204	324	269	155	247	211	44	90	71
Lombardy	2 981	7 812	4 820	3 338	7 236	4 938	1 494	3 155	2 020
Marche	251	439	436	170	275	272	33	74	73
Molise	9	167	88	10	154	90	6	79	31
Piedmont	3 691	5 261	3 753	2 527	3 808	2 606	696	1 709	737
Apulia	1 184	3 487	2 994	1 301	2 850	2 409	1 059	1 457	1 259
Sardinia	1 705	2 930	2 794	864	1 732	1 587	663	815	765
Sicily	4 256	5 487	5 275	2 806	3 879	3 676	833	1 187	1 111
Tuscany	2 787	4 093	3 516	2 211	2 937	2 709	638	889	807
Autonomous Province of Bolzano	58	62	59	35	49	36	6	18	12
Autonomous Province of Trento	566	710	615	469	599	513	100	188	113
Umbria	103	598	204	71	534	189	13	232	59
Valle d'Aosta	-	4	4	-	3	3	-	4	3
Veneto	1 710	3 442	2 182	1 150	2 440	1 561	1 054	1 636	1 195
Italy	23 239	44 904	34 113	18 327	34 908	26 719	8 773	15 415	11 041

6 Potential for efficient district heating

The potential for efficient district heating was analysed by GSE using the maps on heat demand, identifying the areas technically suitable for district heating and performing a technical and economic feasibility assessment on them.

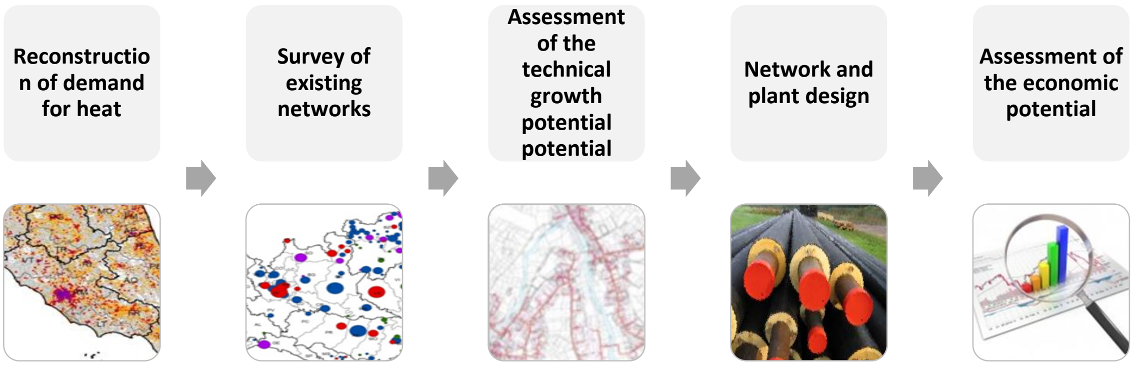
The development potential of district heating in Italy was assessed on the basis of a detailed estimate of the demand for heat by sector, type of use and geographical zone, described in Chapter 1, and of parametric estimates, derived from the analysis of the district heating networks already existing in Italy.

The results obtained provide an overall indication of the development potential of efficient district heating, based on the following sources:

- natural-gas fuelled CHP systems in the areas served by methane pipelines;
- use of wood biomass in areas not served by methane pipelines;
- waste incineration.

Clearly, individual district heating projects should undergo specific feasibility assessments that factor in the features of each investment and site-specific aspects which cannot be adequately considered by a national-level analysis.

Figure 69 – Diagram of the method for assessing the potential for efficient DH



The method used to build the scenario included the following steps:

- Characterisation of heat demand:
  - reconstruction of the national heat demand at municipal level, by sector and type of use;

- Survey of existing networks:
  - survey of the heat demand at municipal level currently covered by district heating networks;

- Estimate of the technical potential for further deployment of district heating:
  - identification of the share of heat demand (gross technical potential for DH) suitable for deployment of district heating;
  - adjustment of the gross technical potential by applying correction factors to model certain aspects impacting on current network development (switch rate, network expansion times, etc.);
  - calculation of the incremental technical potential for district heating as the difference between (adjusted) technical potential and the heat demand already covered by district heating;

- Planning of the size of district heating networks and systems and estimate of investment and operating costs:
  - planning of the size of the network (length, capacity of demand point substations) required to meet the incremental potential and estimate of the distribution costs associated with the network;
  - planning of the size of the systems, choice of technologies and sources, definition of operating conditions fulfilling the incremental potential and estimate of heat generation costs;

- Economic analysis and estimate of the technical-economic potential for expanding district heating:
  - estimate of the revenues from the sale of heat and electricity, on the basis of the current market trends;
  - assessment of the return on investment in the networks suitable for expansion, thereby identifying the incremental technical potential-economic potential for the development of district heating.

6.1 Heat demand

The reconstruction of the municipal heat demand by sector and type of use, which provided the input for assessing the technical potential, is described in Chapter 1 of this report.

The survey of municipal heat demand currently covered by district heating networks was obtained by processing data from the SISTAN renewable derived heat survey carried out by GSE and data from the AIRU 2014 yearbook.

The main driver used to identify the areas with technical potential for development of DH was heat demand for space heating from the residential and service sectors, disaggregated for each census zone.

The residential sector is currently the most conducive to the development of district heating infrastructure in Italy:

- 64 % of the energy supplied by DH networks goes to the residential sector;
- 1 % of the existing networks only supply negligible energy to the residential sector;
- 98 % of the energy supplied by DH networks is located in areas with colder winters (climate condition areas E-F).

The service sector accounts for 29 % of the energy supplied by district heating networks, mainly in climate condition areas E-F.

The contribution of heat demand from industrial customers to development of district heating networks (currently about 7 % of the energy supplied) was not considered in this assessment because it is limited to highly circumscribed contexts which are difficult to replicate on a national scale.

In the residential sector, 65 % of heat demand is located in climate condition areas E and F, where almost all the existing district heating networks are to be found, which to date cover only a tiny share of national heat demand (2.4 % of the national total).

Table 85 – Heat demand in the residential and service sectors and share covered by district heating in 2013

Area	Number of municipalities	Heat demand in the residential sector (heating + DHW, GWh)	Heat demand in the service sector (GWh)	Share of residential and service sector demand by climate condition area	Energy from district heating in 2013 in the residential sector (GWh)	Energy from district heating in 2013 in the service sector (GWh)	Energy from district heating in 2013 in the industrial sector (GWh)	Total energy from district heating in 2013 (GWh)	Share of residential and service sector demand covered by district heating
A	2	10	4	0 %	-	-	-	-	0.0 %
B	157	4 399	1 469	2 %	0	0	0	0	0.0 %
C	986	28 357	7 891	11 %	0	0	0	0	0.0 %
D	1 582	60 214	15 738	23 %	131	51	40	222	0.2 %
E	4 263	153 489	45 341	59 %	5 223	2 380	575	8 177	3.8 %
F	1 102	11 581	5 808	5 %	817	323	61	1 201	6.6 %
Total	**8 092**	**258 051**	**76 251**	**100 %**	**6 171**	**2 753**	**676**	**9 600**	**2.7 %**

Table 86 – Heat demand in the residential and service sectors and share covered by district heating in 2013 in municipalities served by methane pipelines

Area	Number of municipalities	Heat demand in the residential sector (heating + DHW, GWh)	Heat demand in the service sector (GWh)	Share of residential and service sector demand by climate condition area	Energy from district heating in 2013 in the residential sector (GWh)	Energy from district heating in 2013 in the service sector (GWh)	Energy from district heating in 2013 in the industrial sector (GWh)	Total energy from district heating in 2013 (GWh)	Share of residential and service sector demand covered by district heating
A	1	8	3	0 %	-	-	-	-	0.0 %
B	93	3 980	1 338	2 %	0	0	0	0	0.0 %
C	677	24 166	6 677	10 %	0	0	0	0	0.0 %
D	1 248	57 255	15 189	23 %	130	51	40	221	0.2 %
E	3 978	151 334	44 785	62 %	5 077	2 343	569	7 988	3.8 %
F	595	8 850	4 099	4 %	518	146	29	693	5.1 %
Total	**6 592**	**245 592**	**72 090**	**100 %**	**5 725**	**2 539**	**637**	**8 902**	**2.6 %**

Table 87 – Heat demand in the residential and service sectors and share covered by district heating in 2013 in municipalities not served by methane pipelines

Area	Number of municipalities	Heat demand in the residential sector (heating + DHW, GWh)	Heat demand in the service sector (GWh)	Share of residential and service sector demand by climate condition area	Energy from district heating in 2013 in the residential sector (GWh)	Energy from district heating in 2013 in the service sector (GWh)	Energy from district heating in 2013 in the industrial sector (GWh)	Total energy from district heating in 2013 (GWh)	Share of residential and service sector demand covered by district heating
A	1	3	2	0 %	-	-	-	-	0.0 %
B	64	419	131	3 %	0	0	0	0	0.0 %
C	309	4 191	1 214	33 %	0	0	0	0	0.0 %
D	334	2 960	549	21 %	0	0	0	1	0.0 %
E	285	2 156	556	16 %	146	37	6	189	6.7 %
F	507	2 731	1 709	27 %	299	177	32	508	10.7 %
Total	**1 500**	**12 459**	**4 161**	**100 %**	**445**	**214**	**38**	**697**	**4.0 %**

Area	Number of municipalities	Heat demand in the residential sector (heating + DHW, GWh)	Heat demand in the service sector (GWh)	Share of residential and service sector demand by climate condition area	Energy from district heating in 2013 in the residential sector (GWh)	Energy from district heating in 2013 in the service sector (GWh)	Energy from district heating in 2013 in the industrial sector (GWh)	Total energy from district heating in 2013 (GWh)	Share of residential and service sector demand covered by district heating
A	1	3	2	0 %	-	-	-	-	0.0 %
B	64	419	131	3 %	0	0	0	0	0.0 %
C	309	4 191	1 214	33 %	0	0	0	0	0.0 %
D	334	2 960	549	21 %	0	0	0	1	0.0 %
E	285	2 156	556	16 %	146	37	6	189	6.7 %
F	507	2 731	1 709	27 %	299	177	32	508	10.7 %
Total	**1 500**	**12 459**	**4 161**	**100 %**	**445**	**214**	**38**	**698**	**4.0 %**

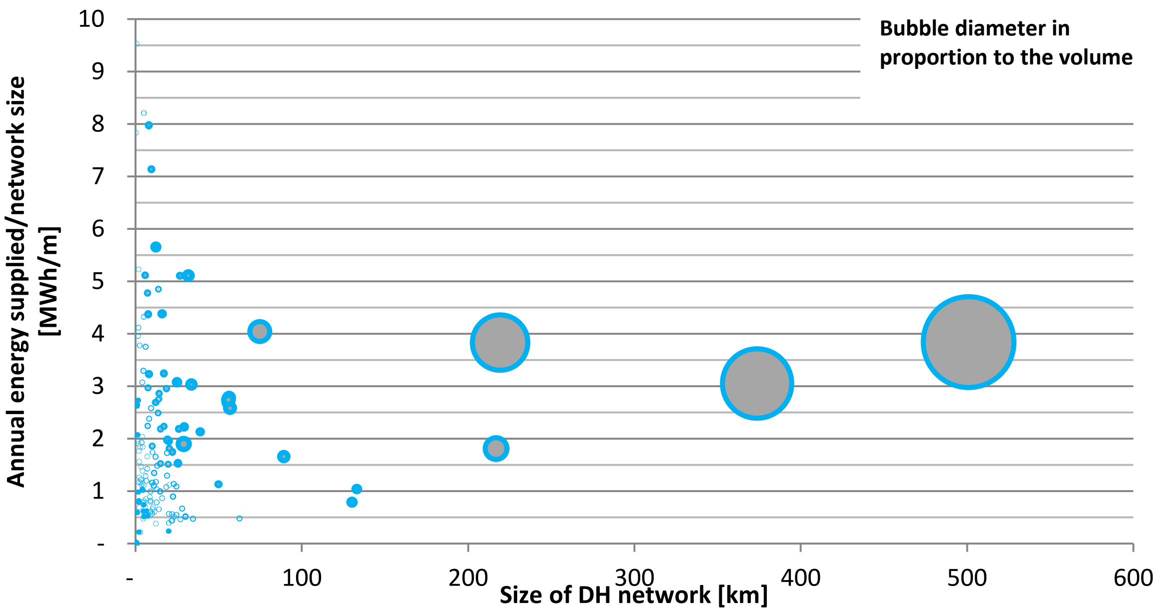
6.2 Technical potential for district heating

The estimate of the development potential for district heating started from identification of gross technical potential for DH, which is considered equal to the heat demand of geographical areas having density characteristics justifying the development of a heat distribution system.

Linear heat density, which is the ratio of the annual heat delivered to the total length of the DH piping and network, is the key driver of distribution costs, which decrease as this parameter increases. Thus linear heat density was used as the key indicator to assess the feasibility of a district heating network.

The European Commission's guidance note on Article 14 of Directive 2012/27 (SWD(2013) 449) states that for a district heating network to be 'directly feasible' its linear heat density should not be less than 2.5 MWh/m. This threshold value is supported by the sector's literature[82], and by the operating data of the main DH networks in Italy. The district heating networks in Italy have an average linear heat density of 2 MWh/m, which rises to 3.7 MWh/m if the average is weighted with the energy supplied. The two average values show synthetically that the best-developed networks in large cities (e.g. Brescia, Turin, Verona, Milan etc.) have linear heat density values well above the threshold value (specifically, between 3.5 and 4 MWh/m), while the many small mountain area networks often have values well below 2 MWh/m.

Figure 70: District heating networks in Italy in 2013. Distribution compared to: network size, linear density and volume heated



[82] Some studies propose higher threshold values, e.g. 3 MWh/m in "Cogeneration and District Heating Best Practices for Municipalities, Energy Charter Protocol on Energy Efficiency and Related Environmental Aspects (PEEREA)", while still others advocate a lower threshold of 2 MWh/m, e.g. "M6 – Energy Distribution: District Heating and Cooling, Intelligent Energy Europe, UP-RES Project".

6.2.1 Technical potential for efficient DH for municipalities served by methane pipelines

The potential for efficient district heating fuelled by natural gas, or with at least 75 % of the heat from CHP has been assessed for all municipalities served by the natural gas network.

Based on these considerations, it was thus decided to take as a threshold value for identifying technical potential the linear heat density value suggested by the European Commission, which is 2.5 MWh/m.

To estimate linear heat density, the calculation method suggested by Persson was used[83]:

$$\frac{Q_S}{L} = e \cdot q \cdot w$$

Where:

$\frac{Q_S}{L}$: linear heat density

e: plot ratio, i.e. the ratio of the useable 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 $w = 61{,}8 \cdot e^{-0{,}15}$

Taking into account the demand already met by the existing district heating networks and some correction factors to calibrate the technical potential for district heating, the incremental technical potential for district heating was calculated using the following formula:

$$P_{INCR-TLR} = \sum_{i=0}^{6592} P_{i\,INCR-TLR} = \sum_{i=0}^{6592} [(F_{RESi} \cdot K_{i\,SAT} \cdot K_{SWITCH} \cdot K_{INCR} \cdot K_{MIN} - E_{i\,TLR}) \cdot K_{i\,MAX}]$$

Where

$\boldsymbol{P_{i\,INCR-TLR}}$: incremental technical potential for district heating in the nth municipality served by methane pipelines

$\boldsymbol{E_{i\,TLR}}$: heat supplied by existing DH in the residential and service sectors in the nth municipality

$\boldsymbol{F_{RESi}}$: residential heating demand for the nth municipality served by methane pipelines

$\boldsymbol{K_{i\,SAT}}$: saturation rate, ratio between the municipal heat demand in those municipal areas (identified by individual census zones) with linear heat density of > 2.5 MWh/m and total demand in the municipality, assuming that all areas can technically be served by district heating. Thus, this assumption fails to consider the presence of physical obstacles to the construction of the networks (roads that are too narrow, difficulties in laying the pipelines due to gradient or soil characteristics, historical centres, etc.) or the possibility that sections with high density of heat demand might be in non-adjoining areas which cannot be served by a single network.

[83] Urban Persson "Realize the Potential! Cost effective and Energy Efficient District Heating in European Urban Areas", 2011

K_{SWITCH}: district heating uptake rate, i.e. the percentage share of potential customers who would connect to the network out of all those with access to it. This factor was assessed at the municipal level as 50 % of central installations, plus 10 % of individual units.

K_{INCR}: incremental rate linked to other customers, or an incremental factor of demand to estimate the contribution linked to acquisition of customers other than residential heating. Considering that nationwide, 30 % of the energy delivered by district heating is for non-process and non-residential thermal use, the incremental factor has been set at 140 % for municipalities that do not currently have district heating, and equal to the ratio of total energy delivered and energy delivered to the residential sector, for municipalities that do already have district heating.

K_{MIN}: rate that introduces a minimum size of network implementation in terms of annual energy supplied of 10 GWh for areas with mains gas

K_{iMAX}: factor establishing the annual growth limit of municipal volume connected to the network. The maximum development thresholds were calculated to take into account the 10-year time horizon over which the potential had to be assessed. Specifically, from the analysis of the time series of volumes connected to existing DH networks, caps on growth were defined of 25 % of the municipal volume for municipalities without district heating in 2013, and 3 Mmc per year for municipalities that already have district heating. In addition, incremental demand for district heating of existing networks was compared with the seasonally adjusted trends of the time series for energy supplied. If the 'theoretical' incremental demand previously calculated was lower than the incremental demand inferred from statistical trends, the latter was used.

Out of a total of 6 592 municipalities served by methane pipelines (with a heating demand in the residential sector estimated at 221 TWh), 2 833 municipalities were identified as having areas characterised by a linear density greater than 2.5 MWh/m (considering both the residential demand and service sector demand), for a relative residential demand of 70 TWh. By applying the acquisition switch rate of demand points for each area, demand is estimated to be 17.1 TWh. This rises to 24.7 TWh if we include the connection of non-residential demand points, or 21 TWh if we exclude smaller initiatives below the theoretical minimum size. Considering that in 2013, 8.2 GWh of heat was supplied by DH in the residential and service sectors, the incremental potential is 14.5 TWh. Looking at the thresholds for the maximum annual growth of volumes that can be connected over a 10-year time horizon, the incremental technical potential for efficient DH is 14.2 TWh. In short, including the 8.9 TWh of heat provided by DH in municipalities served by methane pipelines in all sectors in 2013, DH is calculated to have a technical development potential of 23.1 TWh, for a total of 368 municipalities.

Table 88 Calculation of the technical potential for efficient DH for municipalities served by methane pipelines

Climate condition area	N_c	F_{RESi}	N_c $F_{RESi}*K_{sat}$	$F_{RESi}*K_{sat}$	$F_{RESi}*K_{sat}*K_{switch}$	$F_{RESi}*K_{sat}*K_{switch}*K_{incr}$	$F_{RESi}*K_{sat}*K_{switch}*K_{incr}*K_{min}$
	[Number of municipalities]	[GWh/year]	[Number of municipalities]	[GWh/year]	[GWh/year]	[GWh/year]	[GWh/year]
A	1	0	0	0	0	0	0
B	93	2 693	0	0	0	0	0
C	677	19 318	0	0	0	0	0
D	1 248	51 069	681	20 360	4 219	6 084	5 141
E	3 978	139 427	1 877	47 846	12 459	17 888	15 431
F	595	8 251	275	1 777	454	738	502
Total	**6 592**	**220 757**	**2 833**	**69 984**	**17 132**	**24 710**	**21 075**

Climate condition area	E_{iTLR} (residential and services)	$[F_{RESi}*K_{sat}*K_{switch}*K_{incr}*K_{min}] - E_{iTLR}$	P_{incr}TLR	N_c P_{incr}TLR	EiTLR$_{2013}$ TOT (all sectors)	Potential for DH	N_c Potential for DH
	[GWh/year]	[GWh/year]	[GWh/year]	[Number of municipalities]	[GWh/year]	[GWh/year]	[Number of municipalities]
A	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0
D	181	5 021	3 578	63	221	3 799	78
E	7 420	9 118	10 048	208	7 988	18 037	241
F	664	378	598	43	693	1 291	49
Total	**8 265**	**14 517**	**14 225**	**314**	**8 902**	**23 127**	**368**

6.2.2 Technical potential for efficient DH from waste incineration

The technical potential of district heating supplied by waste was evaluated on the basis of Prime Ministerial Decree of 10 August 2016, containing detailed data on the waste-to-energy plants in operation and to be built[84] in the country (location, authorised treatment capacity, etc.). The data on the thermal output of waste-to-energy plants was then cross-checked against the heating demand of local municipalities.

In 2013, 5.6 million tonnes of waste was sent to 40 waste-to-energy plants, with an estimated input energy content of 15.8 TWh. Of this, 6.8 TWh was used in 11 waste-to-energy plants connected to district heating networks, where 1.5 TWh of the thermal energy recovered by the incineration process was supplied to the network. To assess the role of waste in the growth potential of DH, it is also important to estimate its availability in the near future, since this is quota-based. To this end, analysis of the technical potential of district heating supplied by waste is based on the authorised treatment capacity for existing and planned waste-to-energy plants. This amounts to 8.4 million tonnes of waste, with an estimated input energy content of 25.6 TWh.

Based on the authorised capacity stated in the preliminary report, the following assumptions and calculations have been made so as to estimate the technical potential of thermal energy recoverable from waste incineration:

- For all waste-to-energy plants, it is forecast that the authorised capacity will be saturated under the Prime Ministerial Decree.
- For all waste-to-energy plants, it is technically possible to recover and supply to the network at least 30 % of the input waste energy content in accordance with best practice for the waste DH sector[85].
- The waste-to-energy plant supplies a maximum of 60 % of the heat demand that can technically be covered by district heating. This percentage was derived from the analysis of waste-to-energy plants currently in operation and connected to DH networks where they are typically used for baseload coverage.
- The demand for heat that can technically be met by district heating is considered equal to the incremental technical potential[86] of the municipality where the incineration plant is situated and the surrounding municipalities (if they are located within a radius of about 10 km and have significant population centres). The demand that can technically be met by district heating networks in municipalities located in climate condition areas A, B and C is considered negligible, as is that of plants planned and not yet built, since all of these are planned for central and southern regions of the country.
- The resulting technical potential is therefore between 30 % of the energy content of authorised waste and 60 % of the incremental technical potential of municipalities that can be served by the waste-to-energy plant.

[84] Including plants with authorisation but not yet in operation and new plants awaiting authorisation in specific regions.

[85] In some cases (Brescia, Cremona), the recovery is estimated at more than 30 % (38 % and 31 %, respectively), in line with the current operating results reported by AIRU. For plants that do not have this recovery level currently (9 out of 11), it is assumed that they can increase their thermal efficiency in line with industry best practice if there is sufficient heat demand to be met.

[86] In other words, the demand for heat of the residential and service sectors in areas with a linear density greater than 2.5 MWh/m (since all of the plants but one are in municipalities served by methane pipelines), less the appropriate switch rates and heat already provided by existing networks.

Table 89 Technical potential of DH from waste [GWh]

	2013	Technical potential
Abruzzo	-	-
Basilicata	-	-
Calabria	-	-
Campania	-	-
Emilia-Romagna	110	515
Friuli-Venezia Giulia	-	128
Lazio	-	119
Liguria	-	-
Lombardy	1 111	1 604
Marche	-	-
Molise	-	-
Piedmont	-	343
Apulia	-	-
Sardinia	-	11
Sicily	-	-
Tuscany	-	258
Autonomous Province of Bolzano	20	131
Autonomous Province of Trento	-	-
Umbria	-	-
Valle d'Aosta	-	-
Veneto	-	124
Italy	1 240	3 234

6.2.3 Technical potential of efficient DH for municipalities not served by methane pipelines

The potential for efficient district heating fuelled by biomass was assessed for all the municipalities not reached by the natural gas network.

The analysis adopted the same method described for areas served by methane pipelines in section 6.2.1. However, the threshold value of the linear thermal density of census zones suitable for the development of DH was decreased to 1.5 MWh/m, while the minimum size of the initiatives was reduced to 2 GWh of heat supplied per annum. The following formula was used:

$$P_{INCR-TLR} = \sum_{i=0}^{1500} P_{i\,INCR-TLR} = \sum_{i=0}^{1500} [(F_{RESi} \cdot K_{i\,SAT} \cdot K_{SWITCH} \cdot K_{INCR} \cdot K_{MIN}) - E_{i\,TLR}] \cdot K_{i\,MAX}$$

where

$\boldsymbol{P_{i\,INCR-TLR}}$: incremental technical potential of district heating in the nth municipality not served by methane pipelines

$\boldsymbol{E_{i\,TLR}}$: heat supplied by existing DH in the residential and service sectors in the nth municipality

$\boldsymbol{F_{RESi}}$: residential heating demand for the nth municipality not served by methane pipelines

$\boldsymbol{K_{i\,SAT}}$: saturation rate, ratio between the municipal heat demand in those municipal areas (identified by individual census zones) with linear heat density of > 1.5 MWh/m and total demand in the municipality, assuming that all areas can technically be served by district heating. Thus, this assumption fails to consider the presence of physical obstacles to the construction of the networks (roads that are too narrow, difficulties in laying the pipelines due to gradient or soil characteristics, historical centres, etc.) or the possibility that sections with high density of heat demand might be in non-adjoining areas which cannot be served by a single network.

$\boldsymbol{K_{SWITCH}}$: district heating uptake rate, i.e. the percentage share of potential customers who would connect to the network out of all those with access to it. This factor was assessed at the municipal level as 50 % of central installations, plus 10 % of individual units.

$\boldsymbol{K_{INCR}}$: incremental rate linked to other customers, or an incremental factor of demand to estimate the contribution linked to acquisition of customers other than residential heating. Considering that nationwide, 30 % of the energy delivered by district heating is for non-process and non-residential thermal use, the incremental factor has been set at 140 % for municipalities that do not currently have district heating, and equal to the ratio of total energy delivered and energy delivered to the residential sector, for municipalities that do already have district heating.

$\boldsymbol{K_{MIN}}$: rate that introduces a minimum size of network implementation in terms of annual energy supplied of 2 GWh for areas without mains gas.

$\boldsymbol{K_{iMAX}}$: factor establishing the annual growth limit of municipal volume connected to the network. The maximum development thresholds were calculated to take into account the 10-year time horizon over which the potential had to be assessed. Specifically, from the analysis of the time series of volumes connected to existing DH networks, caps on growth were defined of 25 % of the municipal volume for municipalities without district heating in 2013, and 3 Mmc per year for municipalities that already have district heating. In addition, incremental demand for district heating of existing networks was compared with the seasonally adjusted trends of the time series for energy supplied. If the ‘theoretical’ incremental demand previously calculated was lower than the incremental demand inferred from statistical trends, the latter was used.

Out of a total of 1 500 municipalities served by methane pipelines (with a heating demand in the residential sector estimated at 10.9 TWh), 674 municipalities were identified as having areas characterised by a linear density greater than 1.5 MWh/m (considering both the residential demand and service sector demand), for a relative residential demand of 2.8 TWh. By applying the acquisition switch rate of demand points for each area, demand is estimated to be 2 TWh. This rises to 2.8 TWh if we include the connection of non-residential demand points, or 2.5 TWh if we exclude smaller initiatives below the theoretical minimum size. Considering that in 2013, 0.7 TWh of heat was supplied by DH in the residential and service sectors, the incremental potential is 2.2 TWh. Looking at the thresholds for the maximum annual growth of volumes that can be connected over a 10-year time horizon, the incremental technical potential for efficient DH is 1.5 TWh. In short, including the 0.7 TWh of heat provided by DH in municipalities not served by methane pipelines in all sectors in 2013, DH is calculated to have a technical development potential of 2.2 TWh, for a total of 372 municipalities.

Table 90 Calculation of the incremental technical potential for efficient DH for municipalities not served by methane pipelines

Climate condition area	N_c	F_{RESi}	N_c $F_{RESi}*K_{sat}$	$F_{RESi}*K_{sat}$	$F_{RESi}*$ $K_{sat}*K_{switch}$	$F_{RESi}*K_{sat}*$ $K_{switch}*K_{incr}$	$F_{RESi}*K_{sat}*$ $K_{switch}*K_{incr}*K_{min}$
	[Number of municipalities]	[GWh/year]	[Number of municipalities]	[GWh/year]	[GWh/year]	[GWh/year]	[GWh/year]
A	1	-	-	-	-	-	-
B	64	292	-	-	-	-	-
C	309	3 412	-	-	-	-	-
D	334	2 673	186	1 015	710	995	913
E	285	2 006	161	860	602	844	782
F	507	2 540	327	922	647	956	815
Total	**1 500**	**10 923**	**674**	**2 797**	**1 960**	**2 795**	**2 510**

Climate condition area	E_{iTLR} (residential and services)	$[F_{RESi}*K_{sat}*$ $K_{switch}*K_{incr}*K_{min}]$ $- E_{iTLR}$	Potenziale$_{incr}$ TLR	N_c $P_{incr}TLR$	$EiTLR_{2013\ TOT}$ (all sectors)	Potential for DH	N_c Potential for DH
	[GWh/year]	[GWh/year]	[GWh/year]	[Number of municipalities]	[GWh/year]	[GWh/year]	[Number of municipalities]
A	-	-	-	-	-	-	-
B	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-
D	1	913	510	118	1	511	118
E	183	655	413	89	189	602	91
F	476	615	549	153	508	1 057	163
Total	**659**	**2 183**	**1 472**	**360**	**698**	**2 169**	**372**

6.3 Network sizing and costs

To establish the costs of district heating, overall sizing of the infrastructure was performed to establish the magnitude of the minimum technical parameters to which network investment and operating costs are linked.

For each municipality, the network infrastructure was sized on the basis of the incremental technical potential relating to the aggregate municipal network areas where the linear heat density index was greater than 2.5 MWh/m[87].

Overall network length was thus determined through the ratio of incremental technical potential to aggregate linear heat density of the area identified.

The specific network development cost (€/km) is closely dependent on the diameter of the pipes to be installed. In light of the lack of detailed data on the diameter of the existing networks, and since it was not possible to design in detail the layout of each proposed network to obtain its size, network costs were estimated on the basis of average unit costs (€/km) taken from market surveys carried out by the Italian Competition Authority (AGCM)[88], as shown below:

Table 91 Linear pipeline cost

Pipeline costs (minor networks)	200 €/m
Pipeline costs (mountain area networks)	500 €/m
Pipeline costs (urban area networks)	500 €/m

The demand point substations were sized by multiplying the average specific capacity[89] by the incremental volumes that can be heated by district heating, calculated for each municipality:

Table 92 Demand point substations: average specific capacity

Climate condition area D	23. 3 W/m3
Climate condition area E	29.0 W/m3
Climate condition area F	35.6 W/m3

The specific cost of the demand point substations was obtained through parametric estimates obtained from review of the literature. Ancillary costs (inclusive of connecting pipework, special components such as inspection pits, connections, etc.) and design costs have been estimated to make up 30 % of total network investment costs.

87 For networks fuelled by biomass this index was considered to be 1.5.

88 AGCM 'Indagine conoscitiva sul settore del teleriscaldamento' 2013

89 Obtained for climate condition area E from the data on the Province of Turin and then extrapolated by GSE for the other climate condition areas on the basis of average degree days.

Consumption for pumping has been drawn from the electricity consumption of the district heating networks in operation, setting a reference benchmark of 80 MWh/km to which electricity prices of 8 €/MWh have been applied, obtained from Eurostat statistics[90].

Network operating costs were taken from the JRC guidelines[91] which state costs of:

- 250 €/TJ for the part on network operation and maintenance;
- €/kW for the part on substation operation and maintenance.

Useful life was considered to be of 30 years for networks and 20 years for demand point 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 93 Components of specific distribution cost (€/MWh)

Specific cost for pipelines	Specific cost for demand point substations	Specific costs for accessories	Operating cost for pumping	Network O&M costs	**Total distribution cost**
5.4	6.6	5.2	1.6	1.9	20.8

[90] Prices of electricity net of VAT and other recoverable charges, billed in 2014 to industries with consumption between 70 and 150 GWh

[91] JRC "Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level", 2015

6.4 Plant sizing and costs

The heat production on the basis of which plant capacity was sized considers 15 % of network losses[92], which are added to the incremental demand.

The size of the plants that supply heat to the network was set on the basis of analysis of the capacity of heat generating plant supplying the existing district heating networks.

6.4.1 Plants fuelled by natural gas

To size the plants fuelled by natural gas, the following parameters were calculated for the main existing networks: K_{base} which is the ratio of the capacity of baseload plants (e.g. CHP, RES and waste plants) to average heating capacity, and K_{peak} which is the ratio of backup plants (e.g. boilers using fossil fuels) to average heating capacity[93], obtaining average values of:

Table 94 K_{base} and K_{peak} parameters

K_{base}	1
K_{peak}	1.3

Average capacity was estimated for each municipality served by methane pipelines. The capacity of the baseload systems and peak systems could then be obtained through the parameters K_{base} and K_{peak}.

The choice of technology for the baseload systems fell on ICE CHP systems using natural gas, since this is a modular technology, well suited to the typically gradual expansion of district heating networks.

The technical parameters on plant performance, derived from operating data of the HE CHP plants supplying heat to some of the main DH networks, are set out in the following table:

Table 95 Technical parameters of ICE CHP systems

	(H/E)max	Fuel/E EE only	Fuel/E CHP	E CHP/E	SAVING/E	PES
Large ICE	0.87	2.20	2.20	1.00	0.92	22
Small ICE	1.05	2.50	2.47	1.00	0.87	20

[92] Value in line with the current average losses of Italian DH networks of 16 %, and with the main studies in the sector's literature, which place it in the range 10 % to 20 %.

[93] Estimated by the ratio between energy supplied by the network and heating hours for each climate condition area under Presidential Decree No 412/93.

To fulfil the efficiency requirements of district heating networks, 80% of the heat is assumed to come from CHP and the remaining 20 % to be generated by the backup boilers. Electricity production was defined on the basis of the specific H/E ratio of the technology, set out in the previous table.

As to operation outside the heating season, the plant has been assumed to operate in non-CHP mode with equivalent hours estimated on the basis of the hours in which the prices recorded on the day-ahead market (in the northern zone, outside the heating season in 2014) exceeded marginal production costs.

Table 96 Equivalent operating hours adopted

Climate condition area	heq CHP winter	heq Electricity only summer
D	1 594	424
E	2 050	424
F	2 714	424

To calculate the system investment and operating costs and the associated revenues from the sale of electricity and heat, the following cost (C) and revenue (R) parameters were used:

Table 97 Economic parameters of plants

	C_{inv}	$C_{o\&m}$	$C_{o\&m}$	C_{fuel}	R_{heat}	$R_{ele\ chp}$ Winter	R_{ele} only summer ele
	€/KW	€/KWyear	€/MWh	€/KWh	€/MWh	€/MWh	€/MWh
Large ICE	650	52		0.027	94.8	57	78
Small ICE	1000	40		0.027	94.8	57	78
Gas boiler	100		3	0.028	94.8	57	78

The costs of plants and the prices of the commodities gas, biomass, electricity and heat used have been priced on the basis of calculations on market data from several different sources, listed below.

Table 98 Data sources on economic parameters

	C_{inv}	$C_{o\&m}$	$C_{o\&m}$	C_{fuel}	R_{heat}	$R_{ele\ chp}$ Winter	R_{ele} only summer ele
Large ICE	Torvergata University 2015	Torvergata University 2015	Torvergata University 2015	GSE based on PSV data	Equivalence gas-DH on price recorded by Eurostat in 2014	GSE based on MPG data 2014	GSE based on MPG data 2014
Small ICE	Torvergata University 2015	Torvergata University 2015	Torvergata University 2015	GSE based on PSV data	Equivalence gas-DH on price recorded by Eurostat in	GSE based on MPG data 2014	GSE based on MPG data 2014

					2015		
Gas boiler	AGCM 2013	AGCM 2013	AGCM 2013	GSE based on PSV data	Equivalence gas-DH on price recorded by Eurostat in 2016	GSE based on MPG data 2014	GSE based on MPG data 2014

Thus, the annualised costs of heat and power generation have been calculated (respectively Levelized cost of electricity LCOE and Levelized cost of Heat LCOH) considering, in the case of heat generation costs, the revenues from the sales of electricity and, in the case of electricity the revenues from the sale of heat.

Table 99 Average values of generation costs of the networks included in economic potential

LCOE	LCOH
€/MWh	€/MWh
51	71

6.4.2 Plants fuelled by biomass

District heating plants using woody biomass were sized by analogy with the data from networks in areas not served by methane pipelines, assuming the coupling of heat generation via biomass boiler and CHP generation using an Organic Rankine Cycle (ORC) plant.

In particular, the system was sized setting the average values concerning the characteristics observed, such as:

- $K_{H/CHP}$: the ratio of the boiler's rated heat output to that of the cogenerator, assessed to be 2.9
- H/E_{CHP}: the heat to power ratio of the CHP system, set at 4.6

Table 100 K_{base} and K_{peak} parameters

$K_{H/CHP}$	2.9
H/E_{CHP}	4.6

The technical efficiency parameters for CHP plants are listed below:

Table 101 Technical parameters for cogeneration plants

	(H/E)max	Fuel/E - EE only	E CHP/E
ORC	4.63	8.94	1.00

Based on heat demand and the ratios $K_{H/CHP}$ and H/E_{CHP}, the systems have been sized according to the following hours of ORC operation:

Table 102 Equivalent operating hours adopted for ORC

Climate condition area	heq CHP winter
D	1 594
E	2 050
F	2 714

To calculate the system investment and operating costs and the associated revenues from the sale of electricity and heat the following parameters were used:

Table 103 Economic parameters of plants

	C_{inv}	$C_{o\&m}$	$C_{o\&m}$	C_{fuel}	R_{heat}	$R_{ele\ ch}$	EEC
	€/KW	€/KW year	€/MWh	€/KWh	€/MWh	€/MWh	€/EEC
ORC	6 500	468		0.020	140	115	-
Wood chips	170		5,1	0.020	140	-	100

The costs of plants and the prices of the commodities gas, biomass, electricity and heat used have been priced on the basis of calculations on the market data and studies mentioned earlier. In particular the cost of biomass refers to the average annual value recorded in 2014 by the Chamber of Commerce of Milan for virgin wood chips with bark for industrial use, from forest management (moisture in the product at source 45 %; Lower Heating Value (LHV): 2.5 MWh/t).

6.5 Economic potential for DH

After characterising the technical and economic parameters for development of efficient district heating infrastructure, the analysis turned to assessment of the cost-effectiveness of the proposed projects.

The analysis covered each of the municipalities included in calculation of the technical potential for DH, and verified the economic feasibility of the investments, assessing the costs and revenues associated with the development and operation of the network and systems by a potential investor, assuming that the sales price to the end customer would be competitive with respect to the price of the replaced fuel (gas or LPG in non-methane-served areas).

The cost-effectiveness of the initiatives was analysed on the basis of the Net Present Value (NPV) of each network, considering a 30-year valuation period.

To calculate NPV, a weighted average cost of capital (WACC) of 5 % was considered. The economic potential was derived by considering only the technical potential of projects with positive NPV. Moreover, a cost-effectiveness percentage 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. The hurdle rate was set at 5 % in the event of extension of an existing district heating network, and at 7 % in the case of development of an entirely new infrastructure.

In cases with 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 reference prices of heat in the residential sector with conventional solutions (using suitable equivalence formulas), the estimated cost-effectiveness for investors can be used at least partly to assess the cost-effectiveness for final users[94].

The results of the analysis must be interpreted as providing an overall view and are useful to characterise the most cost effective initiative through comparative assessment. Clearly, the assessment of individual investments requires specific feasibility assessments that factor in the features of each investment and site-specific aspects which cannot be adequately considered by large-scale analysis.

Assessment of the economic potential for DH was accompanied by assessment of environmental benefits, such as savings on GHG emissions and the primary energy savings linked to DH development.

[94] This approach provides however a partial view, since district heating has not been contrasted with all efficient heat supply technologies but only with conventional technologies.

6.5.1 Economic potential for efficient DH from natural gas

The cost-effectiveness of efficient district heating infrastructure is very sensitive, not only to urban characteristics and the local heat demand intensity, but also to the wholesale and retail prices of the different fuels.

Regarding municipalities served by methane pipelines, the average value of the annualised cost of heat generation, supplied by cost effective networks, is 71 €/MWh, compared with an estimated average sales price of 94.8 €/MWh[95]. This margin, which includes capital expenditure, operating costs and financial charges, is strongly influenced not only by the gas prices charged to domestic customers, but also by the different tax rates (a reduced VAT of 10 % is applied to DH from high-efficiency CHP and renewable sources for residential customers) and excise duties (the excise duty on industrial use applied to DH is lower than the excise duty on civil use charged to residential gas customers).

Table 104 Reference prices considered for the economic analysis of municipalities served by methane pipelines (prices before VAT)

Price of gas for CHP	26.9	€/MWh
Price of industrial gas	28.2	€/MWh
Price of retail gas	73.9	€/MWh
Price of CHP electricity	57.0	€/MWh
Price of electricity in summer	67.3	€/MWh
Wholesale price of heat	33.2	€/MWh
Sales price DH	94.8	€/MWh
Price of white certificates	116	€/EEC

It is important to stress, in view of the long useful life considered for this type of infrastructure, the strong correlation between cost-effectiveness and the retail price of natural gas, with which DH competes, and the evolution in the volumes of consumption by connected customers. Add furthermore that the potential identified does not consider possible alternative methods of meeting heat demand (e.g. heat pumps or heating systems using RES) which might be more cost effective than district heating.

Applying the reference prices in 2014, the economic potential for DH fed by HE CHP amounts to a potential increase of 1.2 TWh of heat supplied to customers per year. This involves an increase in network length of 246 km and 30 million m3 of heated space.

[95] This price was calculated, on the basis of the reference prices considered, through the following equivalence formula with the retail price of gas for residential customers:

$$P_{TLR} = [P_{CH4}/(9{,}6 \times rend)] \times (1{,}22/1{,}1) + IVA\ 10\ \%$$

P_{TLR}: DH sales price

P_{CH4}: sales price of methane for residential heating, before VAT

9,6: LHV of methane (KWh/m3)

eff = average seasonal energy efficiency of traditional boilers

$(1{,}22/1{,}1)$ = VAT difference between methane and residential DH from HE CHP or renewable sources.

Table 105 Incremental economic potential of district heating for municipalities served by methane pipelines (based on consumption in 2013)

Climate condition area	D	E	F	Grand total
Incremental economic potential [GWh]	14	1 057	155	**1 225**
Incremental length of networks [km]	2	209	35	**246**
Incremental heated space [million m3]	0	26	3	**30**
Incr. thermal potential HE CHP [MWt]	8	485	54	**547**
Incremental supplemental thermal capacity [MWt]	11	631	70	**711**
Incr. thermal energy HE CHP supplied [GWh]	11	845	124	**980**
Incremental supplemental heat output [MWt]	3	211	31	**245**
Incr. electrical potential HE CHP [MWel]	10	552	59	**621**
Incr. electricity HE CHP produced [GWh]	15	1 132	160	**1 307**
Incremental non-HE CHP electricity produced [GWh]	4	234	25	**263**
LCOH [€/MWh]	94	70	64	**68**
Saved emissions [ton CO2eq]	3 447	257 238	37 074	**297 759**
Primary energy savings [toe]	762	57 163	8 390	**66 315**

According to the ENEA scenarios simulated using the Times model, the final consumption of the residential sector should decrease by about 6 % over the next 10 years, mainly as a result of energy efficiency improvements, especially as concerns thermal energy. Under this consumption scenario, the economic potential for DH fuelled by HE CHP would amount to an increase of just 0.9 TWh of heat supplied to customers per year. This result highlights the problems linked to the very long lead times for development and return on investment of DH infrastructure, which on the other hand seem ready to grasp the opportunities offered by the availability of local process heat, heat from waste incineration and heat from biomass.

Table 106 Economic potential of district heating for municipalities served by methane pipelines (based on consumption in 2023)

Climate condition area	D	E	F	Grand total
Incremental economic potential [GWh]	14	792	110	**916**
Incremental length of networks [km]	2	164	27	**193**
Incremental heated space [million m3]	0	21	2	**24**
Incr. thermal potential HE CHP [MWt]	8	364	38	**409**
Incremental supplemental thermal capacity [MWt]	11	473	49	**532**
Incr. thermal energy HE CHP supplied [GWh]	11	634	89	**733**
Incremental supplemental heat output [MWt]	3	159	22	**183**
Incr. electrical potential HE CHP [MWel]	9	414	41	**464**
Incr. electricity HE CHP produced [GWh]	16	848	112	**976**
Incremental non-HE CHP electricity produced [GWh]	4	175	17	**196**
LCOH [€/MWh]	-69	71	67	**69**
Saved emissions [ton CO2eq]	3 561	192 773	26 092	**222 426**
Primary energy savings [toe]	799	42 839	5 899	**49 537**

6.5.2 Economic potential for efficient DH from waste incineration

To estimate the economic potential, the infrastructure development costs for the transmission and distribution of heat were analysed and measured[96], taking into account the costs of waste-to-energy plants (costs of building, upgrading and operating plants) for the waste management sector. By comparing the sales prices for heat charged to district heating customers[97] with the specific cost of heat generated from waste, it emerged that, where the technical potential for waste-to-energy existed, it was also found to be cost effective. This analysis still applies, therefore the technical potential is equal to the economic potential.

Table 107 Economic potential of efficient DH from waste incineration [GWh]

	2013	Technical potential	Economic potential
Abruzzo	-	-	-
Basilicata	-	-	-
Calabria	-	-	-
Campania	-	-	-
Emilia-Romagna	110	515	515
Friuli-Venezia Giulia	-	128	128
Lazio	-	119	119
Liguria	-	-	-
Lombardy	1 111	1 604	1 604
Marche	-	-	-
Molise	-	-	-
Piedmont	-	343	343
Apulia	-	-	-
Sardinia	-	11	11
Sicily	-	-	-
Tuscany	-	258	258
Autonomous Province of Bolzano	20	131	131
Autonomous Province of Trento	-	-	-
Umbria	-	-	-
Valle d'Aosta	-	-	-
Veneto	-	124	124
Italy	**1 240**	**3 234**	**3 234**

Utilising the heat and electricity generated saves 210 ktoe in primary energy (fossil fuels) and avoids 124 kton of CO2eq in emissions.

[96] The heat transmission infrastructure refers to the connection between the waste-to-energy plant (almost always located outside urban areas) and the municipal boundary for which its length and diameter were sized. The distribution infrastructure refers to the urban DH network economically assessed and sized according to the criteria listed in section 6.3 of the report.

[97] Equal to 94.8 €/MWh, estimated according to the method described in section 6.5.1 of the study.

6.5.3 Economic potential for efficient DH from biomass

As for networks located in municipalities not served by methane pipelines, which use biomass and have been determined to be cost effective, the average value of the annualised cost of heat supply to customers was calculated to be 103 €/MWh, against an average sales price of the heat supplied of 140.1 €/MWh[98]. This margin, which includes both investment and operating costs and financial charges, is strongly influenced by the sales price of LPG for heating and by the lower cost linked to use of biomass and the different tax rates (reduced 10 % VAT for DH from HE CHP and renewable sources for residential customers).

Table 108 Reference prices considered for the economic analysis of efficient DH using biomass (prices before VAT)

Retail price of LPG	109.2	€/MWh
Price of wood chips	20	€/MWh
Price of CHP electricity[99]	115	€/MWh
Wholesale price of heat	33.2	€/MWh
Sales price DH	140.1	€/MWh
Price of white certificates	116	€/EEC

It is important to stress the strong correlation between economic feasibility, the availability of local, inexpensive biomass and, in light of the long useful life of the infrastructure, the evolution of consumption volumes by the connected customers. Add furthermore that the potential identified does not consider possible alternative methods of meeting heat demand (e.g. heat pumps or heating systems using RES) which might be more cost effective than district heating.

The cost of biomass applied is based on the average annual value recorded in 2014 by the Chamber of Commerce of Milan for virgin wood chips with bark for industrial use, from forest management (moisture in the product at source 45 %; Lower Heating Value (LHV): 2.5 MWh/t).

Applying the reference prices in 2014, the economic potential for DH fed by biomass amounts to a potential increase of 0.7 TWh of heat supplied to customers per year. This involves an increase in network length of 253 km and 14 million m3 of heated space.

[98] This price was calculated, on the basis of the reference prices considered, through the following equivalence formula with the retail price of LPG for residential customers

$$P_{TLR} = [P_{GPL}/(rend)] \times (1{,}22/1{,}1) + IVA\ 10\ \%$$

P_{TLR}: DH sales price

P_{GPL}: sales price of LPG for residential heating, before VAT

eff = average seasonal efficiency of boilers

$(1{,}22/1{,}1)$ = VAT difference between LPG and residential DH from HE CHP or renewable sources.

[99] Based on the preliminary value for wood chips from forest maintenance set out in the draft for 2015 of the Ministerial Decree on incentives to renewable sources other than PV.

Table 109 – Incremental economic potential of efficient DH using biomass (based on consumption in 2013)

Climate condition area	D	E	F	Grand total
Incremental economic potential [GWh]	78	307	310	**696**
Incremental length of networks [km]	29	101	123	**253**
Incremental heated space [million m3]	2	6	6	**14**
Incr. thermal potential HE CHP [MWt]	20	62	48	**131**
Incremental supplemental thermal capacity [MWt]	59	181	138	**378**
Incr. thermal energy HE CHP supplied [GWh]	35	136	137	**308**
Incremental supplemental heat output [MWt]	44	171	173	**388**
Incr. electrical potential HE CHP [MWel]	4	13	10	**28**
Incr. electricity HE CHP produced [GWh]	9	35	35	**78**
Incremental non-HE CHP electricity produced [GWh]	-	-	-	**-**
LCOH [€/MWh]	120	102	103	**108**
Saved emissions [ton CO2eq]	4 481	17 577	17 741	**39 799**
Primary energy savings [toe]	8 970	35 182	35 511	**79 663**

According to the ENEA scenarios simulated using the Times model, the final consumption of the residential sector should decrease by about 6 % over the next 10 years. Under this consumption scenario, the economic potential for DH fuelled by biomass would amount to an increase of 0.6 TWh of heat supplied to customers per year.

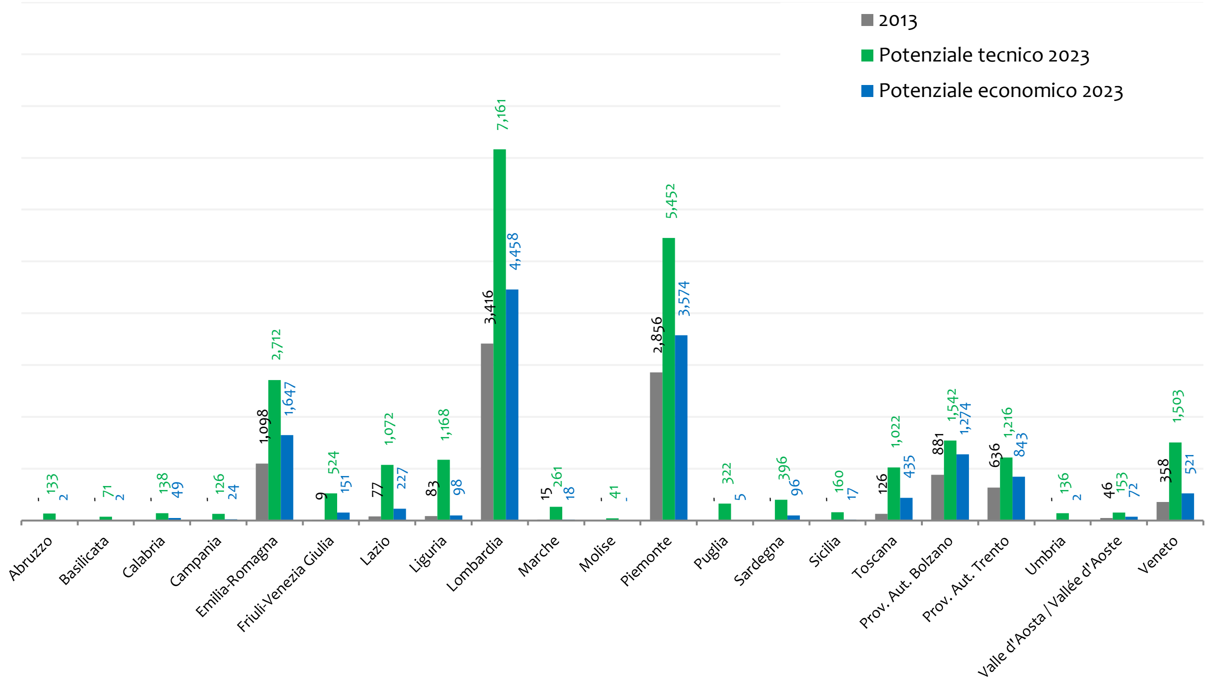
Table 110 Economic potential of efficient DH using biomass (based on consumption in 2023)

Climate condition area	D	E	F	Grand total
Incremental economic potential [GWh]	75	277	271	**625**
Incremental length of networks [km]	28	95	110	**234**
Incremental heated space [million m3]	2	6	5	**13**
Incr. thermal potential HE CHP [MWt]	19	57	42	**118**
Incremental supplemental thermal capacity [MWt]	57	163	121	**341**
Incr. thermal energy HE CHP supplied [GWh]	33	123	120	**277**
Incremental supplemental heat output [MWt]	42	155	151	**348**
Incr. electrical potential HE CHP [MWel]	4	12	9	**26**
Incr. electricity HE CHP produced [GWh]	8	31	30	**70**
Incremental non-HE CHP electricity produced [GWh]	-	-	-	**-**
LCOH [€/MWh]	120	102	103	**109**
Saved emissions [ton CO2eq]	4 290	15 880	15 536	**35 756**
Primary energy savings [toe]	8 587	31 786	31 098	**71 571**

6.6 Results of regional DH potential

This section contains a summary of aggregated results by region. Specifically, the contribution from the different sources covered (natural gas, waste and biomass) is analysed at the regional level. This analysis, while consistent with the total national technical potential, differs significantly from the results contained in section 6.2, where the technical potential was calculated both for areas with a mains gas supply and those without.

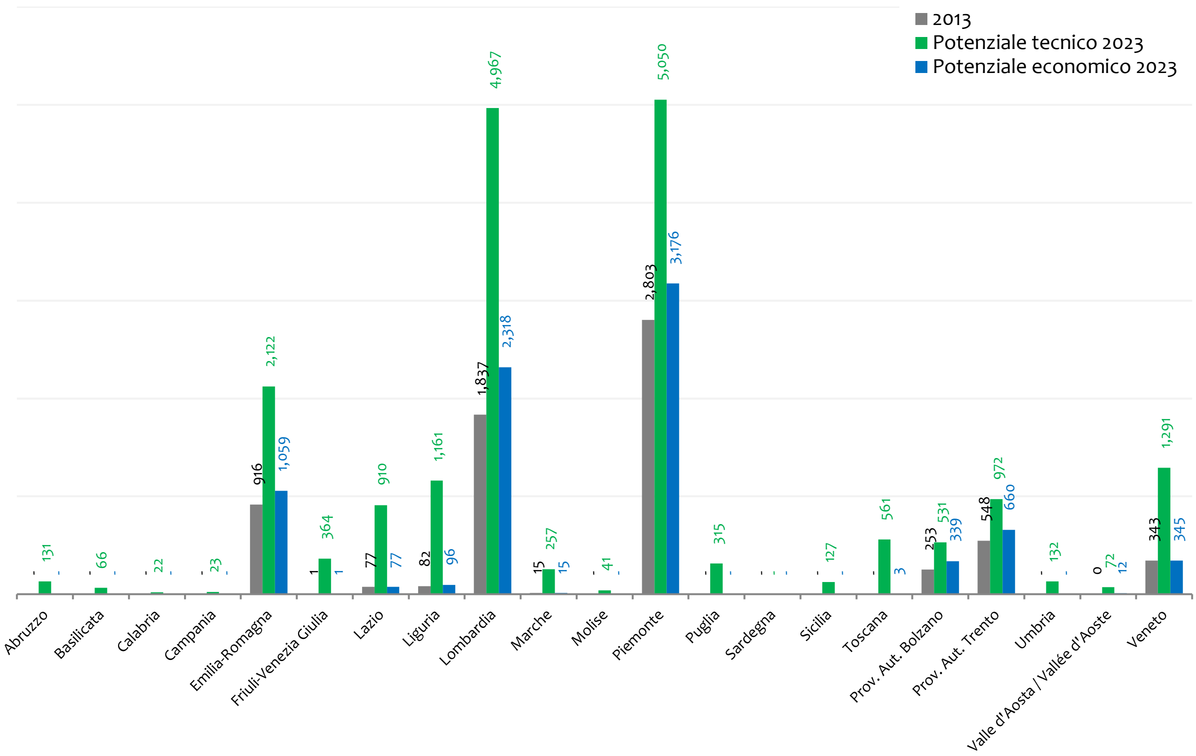
Figure 71 National DH potential by region [GWh]



Potenziale tecnico	Technical potential
Potenziale economico	Economic potential

	2013	Technical potential	Economic potential
Abruzzo	-	133	2
Basilicata	-	71	2
Calabria	-	138	49
Campania	-	126	24
Emilia-Romagna	1 098	2 712	1 647
Friuli-Venezia Giulia	9	524	151
Lazio	77	1 072	227
Liguria	83	1 168	98
Lombardy	3 416	7 161	4 458
Marche	15	261	18
Molise	-	41	-
Piedmont	2 856	5 452	3 574
Apulia	-	322	5
Sardinia	-	396	96
Sicily	-	160	17
Tuscany	126	1 022	435
Autonomous Province of Bolzano	881	1 542	1 274
Autonomous Province of Trento	636	1 216	843
Umbria	-	136	2
Valle d'Aosta	46	153	72
Veneto	358	1 503	521
Italy	9 600	25 308	13 516

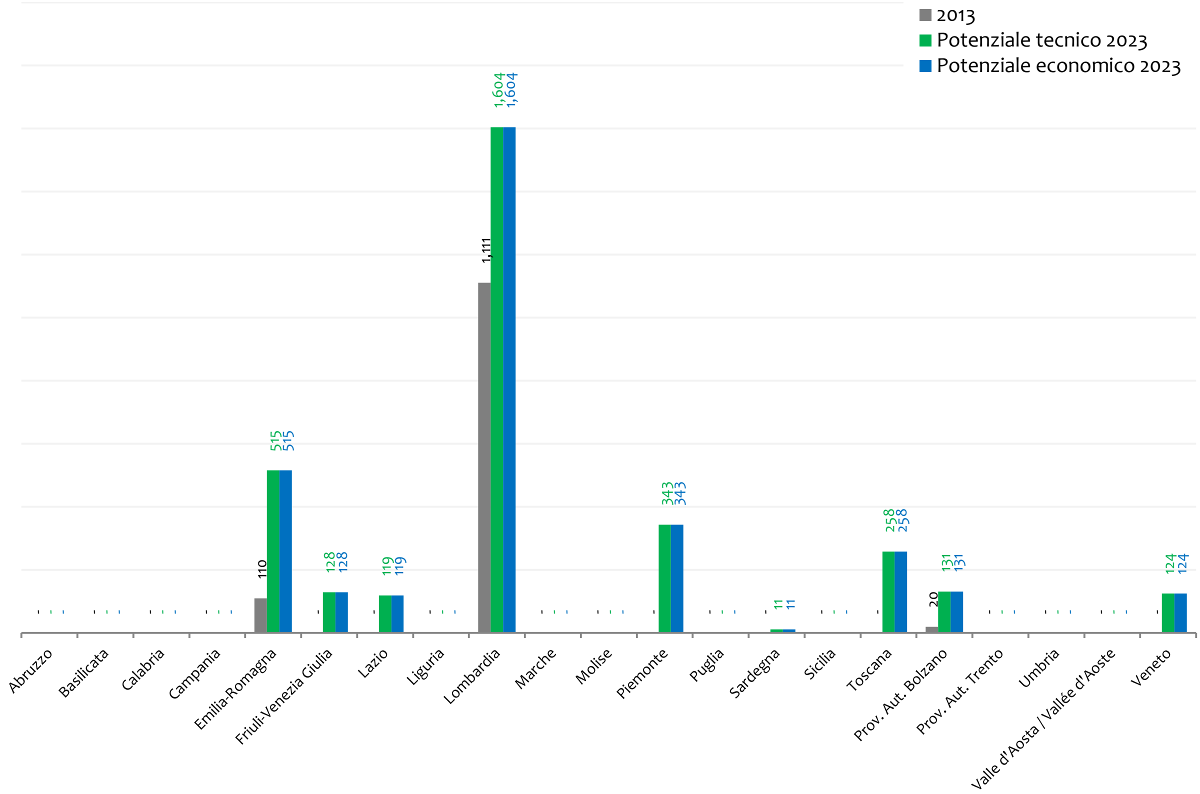
Figure 72 Technical potential and economic potential of DH from gas cogeneration [GWh]



Potenziale tecnico	Technical potential
Potenziale economico	Economic potential

	2013	Technical potential	Economic potential
Abruzzo	-	131	-
Basilicata	-	66	-
Calabria	-	22	-
Campania	-	23	-
Emilia-Romagna	916	2 122	1 059
Friuli-Venezia Giulia	1	364	1
Lazio	77	910	77
Liguria	82	1 161	96
Lombardy	1 837	4 967	2 318
Marche	15	257	15
Molise	-	41	-
Piedmont	2 803	5 050	3 176
Apulia	-	315	-
Sardinia	-	-	-
Sicily	-	127	-
Tuscany	-	561	3
Autonomous Province of Bolzano	253	531	339
Autonomous Province of Trento	548	972	660
Umbria	-	132	-
Valle d'Aosta	0	72	12
Veneto	343	1 291	345
Italy	6 873	19 115	8 098

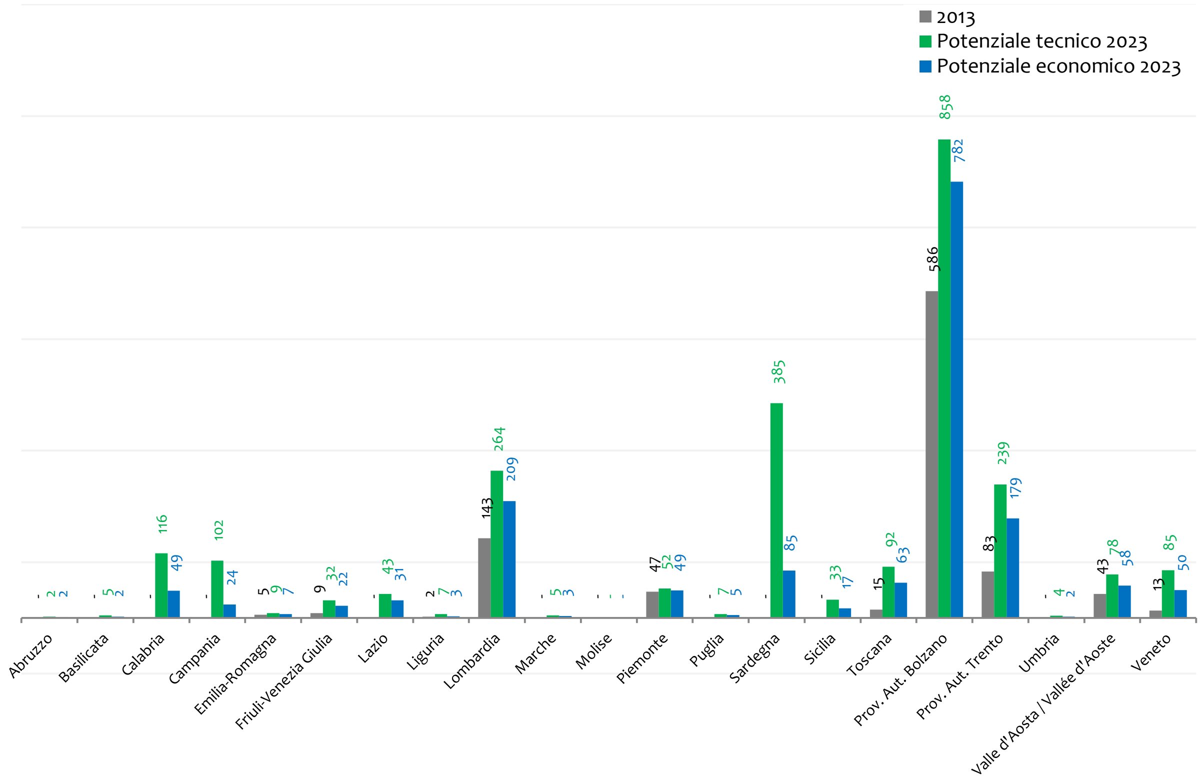
Figure 73 Technical potential and economic potential of DH from waste cogeneration [GWh]



Potenziale tecnico	Technical potential
Potenziale economico	Economic potential

	2013	Technical potential	Economic potential
Abruzzo	-	-	-
Basilicata	-	-	-
Calabria	-	-	-
Campania	-	-	-
Emilia-Romagna	110	515	515
Friuli-Venezia Giulia	-	128	128
Lazio	-	119	119
Liguria	-	-	-
Lombardy	1 111	1 604	1 604
Marche	-	-	-
Molise	-	-	-
Piedmont	-	343	343
Apulia	-	-	-
Sardinia	-	11	11
Sicily	-	-	-
Tuscany	-	258	258
Autonomous Province of Bolzano	20	131	131
Autonomous Province of Trento	-	-	-
Umbria	-	-	-
Valle d'Aosta	-	-	-
Veneto	-	124	124
Italy	1 240	3 234	3 234

Figure 74 Technical potential and economic potential of DH from biomass [GWh]



Potenziale tecnico	Technical potential
Potenziale economico	Economic potential

	2013	Technical potential	Economic potential
Abruzzo	-	2	2
Basilicata	-	5	2
Calabria	-	116	49
Campania	-	102	24
Emilia-Romagna	5	9	7
Friuli-Venezia Giulia	9	32	22
Lazio	-	43	31
Liguria	2	7	3
Lombardy	143	264	209
Marche	-	5	3
Molise	-	-	-
Piedmont	47	52	49
Apulia	-	7	5
Sardinia	-	385	85
Sicily	-	33	17
Tuscany	15	92	63
Autonomous Province of Bolzano	586	858	782
Autonomous Province of Trento	83	239	179
Umbria	-	4	2
Valle d’Aosta	43	78	58
Veneto	13	85	50
Italy	945	2 417	1 641

6.7 Potential increase in the efficiency of existing district heating networks

During 2013 heat losses during heat distribution by district heating networks amounted to 1.77 TWh, or 16 % of the heat supplied to the networks.

In theory, if each network were upgraded to the best heat distribution efficiency in accordance with the European Commission's guidelines, network losses could theoretically be limited to 10 %. The reduction of losses in existing networks would yield a saving of 684 GWh of heat supplied to the network.

Table 111 Potential increase in the efficiency of existing DH networks

Municipality	Heat supplied [MWh]	Heat losses in the DH network [MWh]	Heat supplied to the network [MWh]	Losses [%]	Potential for efficiency improvement [MWh]
Grand total	**9 600 340**	**1 774 276**	**11 374 616**	**16 %**	**683 703**
Turin	1 923 064	389 175	2 312 239	17 %	157 951
Brescia	1 139 691	240 596	1 380 287	17 %	102 567
Milan	891 034	98 233	989 267	10 %	-
Riva del Garda	395 359	9 270	404 629	2 %	-
Reggio nell'Emilia	391 666	66 145	457 811	14 %	20 364
Verona	301 470	45 012	346 482	13 %	10 364
San Donato Milanese	162 108	21 421	183 529	12 %	3 068
Bergamo	158 042	20 366	178 408	11 %	2 525
Mantua	155 937	32 770	188 707	17 %	13 899
Ferrara	153 073	29 231	182 304	16 %	11 001
Rivoli	151 640	24 624	176 264	14 %	6 998
Parma	147 599	26 047	173 646	15 %	8 682
Cremona	146 786	26 312	173 098	15 %	9 002
Rovereto	142 197	26 016	168 213	15 %	9 195
Bologna	138 414	17 991	156 405	12 %	2 351
Brunico	137 926	25 744	163 670	16 %	9 377
Bressanone - Varna	109 202	19 061	128 263	15 %	6 234
Imola	102 286	22 456	124 742	18 %	9 982
Alba	101 607	29 413	131 020	22 %	16 311
Merano	83 416	8 221	91 637	9 %	-
Settimo Torinese	82 808	16 223	99 031	16 %	6 320
Monza	82 639	11 882	94 521	13 %	2 430
Rho	82 580	15 618	98 198	16 %	5 798
Rome	76 573	19 687	96 260	20 %	10 061
Varese	70 040	6 334	76 374	8 %	-
Genoa	69 096	1 821	70 917	3 %	-
Bardonecchia	67 797	9 599	77 396	12 %	1 859
Sestriere	66 506	5 401	71 907	8 %	-
Legnano	64 859	12 960	77 819	17 %	5 178
Val di Vizze	57 541	21 517	79 059	27 %	13 611
Dobbiaco	56 754	14 160	70 914	20 %	7 069
Chieri	55 447	8 601	64 048	13 %	2 196
Cinisello Balsamo	55 108	6 462	61 570	10 %	305
Bolzano	54 954	5 285	60 239	9 %	-
Pomarance	49 169	2 546	51 715	5 %	-
Mondovì	45 000	7 000	52 000	13 %	1 800
Vicenza	43 535	8 059	51 594	16 %	2 900
Savigliano	42 000	5 000	47 000	11 %	300
Seregno	39 394	10 719	50 113	21 %	5 708
Morbegno	38 994	15 210	54 204	28 %	9 790
Tirano	38 877	10 714	49 591	22 %	5 755
Como	38 733	13 779	52 512	26 %	8 528
Desio	38 574	10 901	49 475	22 %	5 954
Saluzzo	37 024	7 286	44 310	16 %	2 855

Fossano	36 698	10 520	47 218	22 %	5 798
Biella	33 605	3 892	37 497	10 %	142
Acqui Terme	32 920	5 010	37 930	13 %	1 217
Lodi	32 712	4 638	37 350	12 %	903
Modena	32 298	5 830	38 128	15 %	2 017
Castelnuovo di Val di Cecina	32 042	9 006	41 048	22 %	4 901
Cesena	30 833	5 431	36 264	15 %	1 805
Piacenza	29 670	5 236	34 906	15 %	1 745
Silandro	26 656	6 447	33 103	19 %	3 137
Cavalese	26 090	14 663	40 753	36 %	10 588
Voghera	26 012	3 020	29 032	10 %	117
Casalecchio di Reno	25 396	7 898	33 294	24 %	4 569
Cassano d'Adda	24 567	2 136	26 703	8 %	-
Siror	22 807	2 394	25 201	10 %	-
Santa Fiora	22 588	5 825	28 413	21 %	2 984
Casale Monferrato	22 429	2 545	24 974	10 %	48
Cesana Torinese	21 122	2 451	23 573	10 %	94
Valdaora	20 795	3 940	24 735	16 %	1 467
Temù	20 097	5 403	25 500	21 %	2 853
La Thuile	20 067	3 883	23 950	16 %	1 488
Sesto	19 946	3 951	23 897	17 %	1 561
Borgaro Torinese	19 264	1 759	21 023	8 %	-
Busto Arsizio	19 159	2 780	21 939	13 %	586
Monguelfo-Tesido	19 015	2 871	21 887	13 %	683
Valle Aurina	17 695	6 038	23 733	25 %	3 665
Laces	17 279	6 164	23 443	26 %	3 820
Carmagnola	16 299	2 502	18 801	13 %	622
Sluderno	15 754	10 032	25 786	39 %	7 453
Mezzano	15 418	7 624	23 042	33 %	5 320
Madesimo	15 242	3 917	19 159	20 %	2 001
Sondalo	15 084	4 980	20 064	25 %	2 974
Chiusa	15 056	3 373	18 429	18 %	1 530
Rasun Anterselva	15 005	7 861	22 867	34 %	5 574
Osimo	14 702	5 600	20 302	28 %	3 570
Leinì	14 279	3 275	17 554	19 %	1 520
Edolo	14 063	6 946	21 009	33 %	4 845
Badia	13 950	4 957	18 907	26 %	3 066
Malles Venosta	13 689	4 104	17 793	23 %	2 325
Lasa	12 807	4 727	17 535	27 %	2 974
Prato allo Stelvio	12 618	4 749	17 366	27 %	3 012
Campo Tures	12 552	4 934	17 486	28 %	3 185
Cairo Montenotte	12 405	1 552	13 957	11 %	156
Castellamonte	11 946	3 400	15 346	22 %	1 866
Renon	11 861	6 370	18 231	35 %	4 547
Pragelato	11 642	2 522	14 164	18 %	1 106
Morgex	11 569	5 845	17 414	34 %	4 104
Stelvio	10 533	2 230	12 763	17 %	954
Prè-Saint-Didier	9 977	1 819	11 796	15 %	639
Sarentino	9 961	4 041	14 003	29 %	2 641
Forlì	9 764	3 998	13 762	29 %	2 622
Pinerolo	9 404	973	10 377	9 %	-
Predazzo	9 373	3 370	12 743	26 %	2 096
Racines	9 321	711	10 031	7 %	-
Curon Venosta	9 319	2 185	11 504	19 %	1 035
Piossasco	9 240	528	9 768	5 %	-
Ultimo	8 384	2 799	11 183	25 %	1 680
Cesano Boscone	8 148	3 492	11 640	30 %	2 328
Verzuolo	7 906	1 489	9 395	16 %	550
Vandoies	7 843	2 586	10 429	25 %	1 543
Villa Guardia	7 840	2 974	10 814	28 %	1 893
Asiago	7 825	2 199	10 024	22 %	1 197
Monterotondo Marittimo	7 819	2 198	10 017	22 %	1 196
Rio di Pusteria	7 734	2 182	9 916	22 %	1 190
Rimini	7 729	2 947	10 676	28 %	1 879

Brennero	7 593	1 823	9 416	19 %	882
Valfurva	7 031	3 775	10 806	35 %	2 695
Sellero	6 717	2 784	9 501	29 %	1 834
Funes	6 349	2 174	8 523	26 %	1 322
Fondo	5 684	2 896	8 580	34 %	2 038
Peio	5 556	1 259	6 815	18 %	578
Collio	5 473	2 719	8 192	33 %	1 900
Bagno di Romagna	5 400	2 390	7 790	31 %	1 611
Nova Ponente	5 320	1 225	6 546	19 %	571
Ormea	5 249	2 713	7 962	34 %	1 917
Arta Terme	5 242	2 413	7 655	32 %	1 648
Vico Canavese	5 152	1 448	6 600	22 %	788
Nizza Monferrato	5 013	787	5 800	14 %	207
Laion	4 958	1 499	6 457	23 %	853
Falzes	4 932	1 874	6 806	28 %	1 193
Lizzano in Belvedere	4 655	2 315	6 970	33 %	1 618
Racconigi	4 610	710	5 320	13 %	178
Mirandola	4 481	1 295	5 776	22 %	717
Terenten	4 461	505	4 966	10 %	8
Bomporto	4 143	2 984	7 127	42 %	2 271
Velturno	4 106	1 299	5 405	24 %	758
Castel Maggiore	4 068	1 743	5 811	30 %	1 162
Pollein	3 905	1 812	5 717	32 %	1 240
San Candido	3 725	452	4 177	11 %	35
Naz-Sciaves	3 573	1 240	4 813	26 %	759
Canale	3 500	1 238	4 738	26 %	764
Luson	3 432	859	4 291	20 %	430
Trento	3 418	661	4 079	16 %	253
Selva dei Molini	3 404	570	3 974	14 %	172
Forni di Sopra	3 128	272	3 399	8 %	-
Naturno	3 028	657	3 685	18 %	289
Sedrina	2 964	1 429	4 393	33 %	989
Castegnato	2 893	1 949	4 842	40 %	1 465
Coredo	2 814	727	3 541	21 %	373
Casalmaggiore	2 665	200	2 865	7 %	-
Terlano	2 608	570	3 178	18 %	252
Bra	2 600	481	3 081	16 %	173
Santo Stefano di Cadore	2 427	135	2 562	5 %	-
San Felice sul Panaro	2 378	1 192	3 570	33 %	835
Castel Bolognese	2 194	482	2 676	18 %	214
Tires	2 134	518	2 652	20 %	253
San Pancrazio	2 128	454	2 582	18 %	196
Rosà	2 115	595	2 710	22 %	324
Verano	2 029	598	2 627	23 %	335
Cortemilia	1 946	76	2 022	4 %	-
Castelrotto	1 850	568	2 418	24 %	327
Stazzema	1 824	513	2 337	22 %	279
Moso in Passiria	1 754	475	2 229	21 %	252
Chivasso	1 708	112	1 820	6 %	-
Cloz	1 594	448	2 042	22 %	244
Vinovo	1 556	204	1 760	12 %	28
Piazza al Serchio	1 519	427	1 946	22 %	232
Cornedo all’Isarco	1 474	187	1 662	11 %	21
Rodengo	1 442	603	2 044	29 %	398
San Martino in Badia	1 396	384	1 780	22 %	206
Pellizzano	1 373	536	1 909	28 %	345
Rossiglione	1 317	370	1 688	22 %	201
Camporgiano	1 250	351	1 602	22 %	191
Vallarsa	1 238	348	1 586	22 %	189
Marchirolo	1 215	214	1 430	15 %	71
Perosa Argentina	1 174	247	1 421	17 %	105
San Romano in Garfagnana	1 126	1 226	2 352	52 %	991
Serravalle Scrivia	912	256	1 168	22 %	139
Tres	867	244	1 111	22 %	133

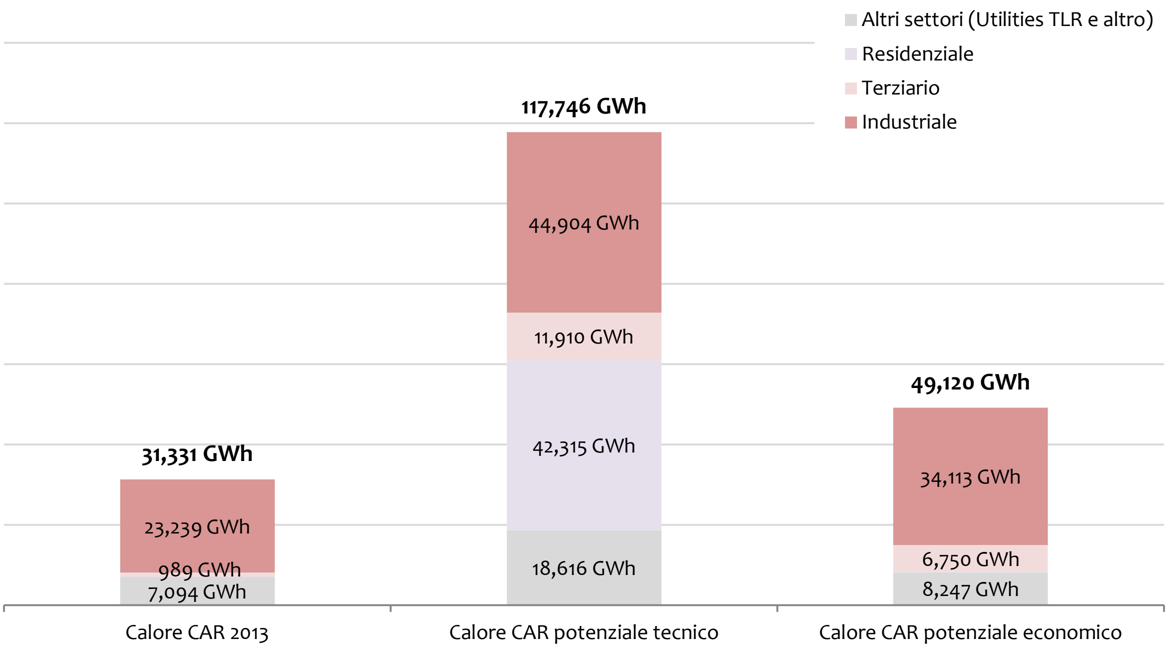
Reggello	866	96	962	10 %	-
Vicchio	846	238	1 083	22 %	129
Monterenzio	836	136	972	14 %	39
Malosco	835	239	1 074	22 %	132
Ledro	773	232	1 005	23 %	131
Rufina	770	289	1 059	27 %	183
Zubiena	752	211	963	22 %	115
Sestola	752	211	963	22 %	115
Loro Ciuffenna	746	210	956	22 %	114
San Godenzo	710	290	1 000	29 %	190
Bresimo	705	198	903	22 %	108
Occhieppo superiore	703	198	901	22 %	108
Polverara	682	192	873	22 %	104
Campo Ligure	660	185	845	22 %	101
Arquata Scrivia	635	178	813	22 %	97
Monticiano	628	176	804	22 %	96
Montaione	622	16	637	2 %	-
Martello	569	160	729	22 %	87
Pistoia	549	441	990	45 %	342
Minucciano	500	300	800	38 %	220
Treppo Carnico	479	355	834	43 %	272
Campo di Trens	466	117	583	20 %	59
Careggine	463	130	593	22 %	71
Cantagallo	453	127	580	22 %	69
Piobesi Torinese	428	112	540	21 %	58
Vigevano	413	50	463	11 %	4
Grumes	394	118	512	23 %	67
Castel Focognano	325	91	416	22 %	50
San Gimignano	321	90	411	22 %	49
Perca	286	80	366	22 %	44
Pradleves	249	70	319	22 %	38
Chiusdino	223	63	285	22 %	34
Fivizzano	221	62	283	22 %	34
Barberino Val d'Elsa	220	185	405	46 %	144
San Casciano in Val di Pesa	218	27	245	11 %	2
Londa	173	58	231	25 %	35
Lauco	170	73	244	30 %	49
Riolunato	169	17	186	9 %	-
Villa Collemandina	167	45	213	21 %	24
Verzegnis	130	64	194	33 %	45
Marmentino	99	49	148	33 %	34

7 Summary of results

The economic potential of high-efficiency CHP was found to be, given the current market and regulatory conditions, 49.1 TWh (4 224 ktoe) of useful heat. Compared with the overall production of useful heat from high-efficiency CHP in 2013, equivalent to 31.3 TWh (2 694 ktoe), the potential increase is 17.8 TWh (1 529 ktoe).

Of this increase in useful heat from high-efficiency CHP, 61 % is linked to self-producing high-efficiency CHP plants in the industrial sector (10.8 TWh), 32 % from high-efficiency CHP plants in the service sector (5.8 TWh), and 6 % (1.2 TWh) from high-efficiency CHP plants operated by energy utilities involved in district heating. The residential sector has no economic potential under the current market conditions and cost of the technologies.

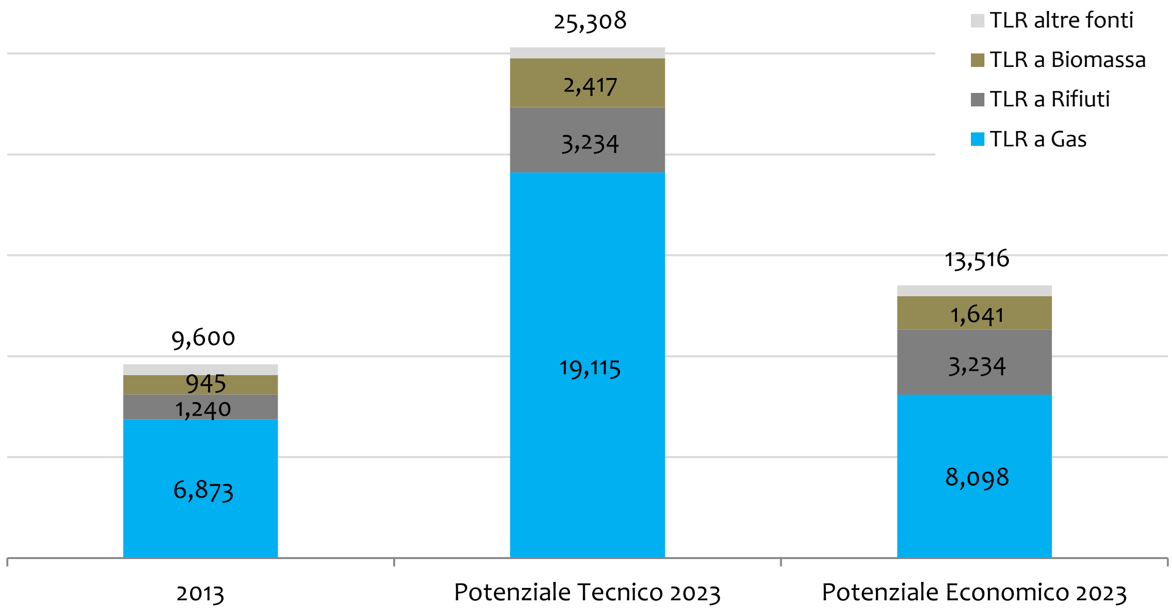
Figure 75 Comparison of the current level of useful heat production from HE CHP (2013) and its technical and economic potential by use sector



Altri settori (Utilities TLR e altro)	Other sectors (DH Utilities and other)
Residenziale	Residential
Terziario	Services
Industriale	Industrial
Calore CAR 2013	HE CHP heat 2013
Calore CAR potenziale tecnico	Technical potential for HE CHP heat
Calore CAR potenziale economico	Economic potential for HE CHP heat

In the district heating sector, the economic potential was determined to be 13.5 TWh (1 160 ktoe). Compared with the heat supplied by DH in 2013, which amounted to 825 ktoe, the potential increase through efficient district heating is estimated to be 335 ktoe. This potential increase in energy from district heating is based on the production of heat from natural gas, which contributes 1 225 GWh (or 105 ktoe, of which 84 ktoe from cogeneration), biomass exploitation, which contributes 696 GWh (60 ktoe), and waste-to-energy, which contributes a further 1 994 GWh (171 ktoe).

Figure 76 Comparison between the current level of energy supplied by DH (2013) and its technical and economic potential by source [GWh]



TLR altre fonti	Other sources DH
TLR a Biomassa	Biomass DH
TLR a Rifiuti	Waste DH
TLR a Gas	Gas DH
Potenziale tecnico	Technical potential
Potenziale economico	Economic potential

Table 112 Summary of results on CHP and DH potential

Sector	Measurement	Unit of measurement	Current situation	Technical potential	Economic potential
Residential HE CHP	Electrical capacity	MWe	5	4 526	5
	HE CHP electrical production	GWh el	6	10 560	6
	Thermal production	GWh t	10	42 315	10
		ktoe	1	3 638	1
Services HE CHP	Electrical capacity	MWe	287	2 237	1 426
	HE CHP electrical production	GWh el	989	7 369	5 050
	Thermal production	GWh t	989	11 910	6 750
		ktoe	85	1 024	580
HE CHP industrial sector	Electrical capacity	MWe	8 773	15 415	11 041
	HE CHP electrical production	GWh el	18 327	34 908	26 719
	Thermal production	GWh t	23 239	44 904	34 113
		ktoe	1 998	3 861	2 933
HE CHP other sectors (Utilities DH and other)	Electrical capacity	MWe	4 022	10 735	4 645
	HE CHP electrical production	GWh el	6 956	19 868	8 265
	Thermal production	GWh t	7 094	18 616	8 247
		ktoe	610	1 601	709
Total HE CHP Italy	Electrical capacity	MWe	13 087	32 912	17 117
	HE CHP electrical production	GWh el	26 279	72 705	40 040
	Thermal production	**GWh t**	**31 331**	**117 746**	**49 120**
		ktoe	**2 694**	**10 124**	**4 224**
DH	Volumes heated	MMC	316	721	404
	Km of network		4 088	8 888	4 969
	Heat supplied	**GWh t**	**9 600**	**25 308**	**13 516**
		ktoe	**825**	**2 176**	**1 162**
	of which gas (*)	*GWh t*	*6 873*	*19 115*	*8 098*
	of which from waste	*GWh t*	*1 240*	*3 234*	*3 234*
	of which from biomass	*GWh t*	*945*	*2 417*	*1 641*
	of which other	*GWh t*	*542*	*542*	*542*

(*) HE CHP share equal to 80 %

8 Appendix

8.1 High-efficiency cogeneration and district heating: policies and objectives

Directive 2012/27/EU gives to high-efficiency cogeneration (HE CHP) and efficient district heating and cooling (DHC) a key role in the pursuit of energy saving and GHG emission reduction targets.

The recitals to the Directive point out that high-efficiency cogeneration and district heating and cooling have significant potential for saving primary energy, which is largely untapped in the Union. Therefore, the Directive requires Member States to carry out a comprehensive assessment of the technical and economic potential of those technologies, with a view to promoting their deployment based on criteria of effectiveness and efficiency.

Legislative Decree No 102/2014, which transposed Directive 2012/27/EU, confirmed the major role of HE CHP and efficient district heating and cooling in achieving the indicative national target for energy saving which consists in reducing by the year 2020 the consumption of primary energy by 20 million toe (equal to 15.5 million toe of final energy) with respect to the quantities in 2010.

This target has been set in line with the National Energy Strategy (NES) of March 2013, which identifies development of HE CHP and DH as a major contributor to energy efficiency in Italy.

In the sector of high-efficiency cogeneration, in line with the provisions of Directive 2012/27/EU, the NES recommends the adoption of regulations supplementing the current incentive system, in order to favour the spread of this technology. The NES highlights the fact that HE CHP is already well-developed in Italy in certain specific industrial processes, especially with medium-large systems. Thus the NES points out that public support should target not only the development of new installations, in particular small-sized ones, but especially the replacement or remaking of existing plants, focused on higher-performance technologies and designs.

As concerns the potential offered by district heating and cooling, the NES states that this is not fully exploited. This is why actions are necessary to encourage deployment of these technologies.

In general, the NES highlights the development of renewable thermal energy – biomass boilers, heat pumps, thermal solar, etc. The overarching goal is to ‘exceed the EU 20-20-20 targets, via better balancing of the various renewable sources (in particular, focusing greater attention on thermal renewable sources)’. The target for thermal renewables is to ‘develop the production of renewables to reach 20 % of final consumption by 2020 (the 20-20-20 target is 17 %), or about 11 Mtoe/year’.

In particular, the NES plans to achieve the target also through the development or enlargement, where cost effective, of network infrastructure for the supply of renewable heat, through establishment of a guarantee fund.

8.2 Current incentives

8.2.1 Combined heat and power production

In order to promote energy efficiency in cogeneration, Legislative Decree No 20/2007, implementing Directive 2004/8/EC, makes provision for financial support to technology projects that meet specific requirements in terms of primary energy savings (PES index) and can therefore be considered to operate in high-efficiency cogeneration (HE CHP) mode.

The Ministerial Decree of 4 August 2011 completed transposition of the Directive by laying down the criteria for assessing the HE CHP condition.

On the basis of the principles of Legislative Decree No 20/2007, the Ministerial Decree of 5 September 2011 introduced access to type-II white certificates (HE CHP white certificates) for technology projects regarding cogeneration units, according to the following criteria:

a. for newly-built cogeneration units commissioned from 7 March 2007 the entitlement to HE CHP white certificates applies for a period of 10 calendar years in variable number for each reporting year on the basis of the primary energy savings achieved and of a harmonisation coefficient 'K' ranging between 1 and 1.4 according to mean electricity generation capacity in HE CHP mode. The incentive period is extended to 15 calendar years for units coupled with district heating networks if the new construction project also includes the network;

b. for cogeneration units which from 7 March 2007 undergo 'major renovation' (replacement of at least two major components with new components in units in operation for at least 12 years), the entitlement to HE CHP White Certificates applies for 10 calendar years in variable number 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 for units coupled with a district heating network, if the major renovation project included additional transport capacity in the network expressed in toe/y of not less than 30 % of the nominal transport capacity prior to the project;

c. installations commissioned between 1 April 1999 and 6 March 2007, recognised as CHP installations under the rules in force on their commissioning date, transposing Legislative Decree No 28/2011, are entitled to issue HE CHP White Certificates for a period of five calendar years; the number of these WCs is 30 % of the certificates granted to the units listed in the preceding subsections.

White Certificates can be used to fulfil the obligation, imposed on electricity and natural gas distributors, to achieve specific annual primary energy savings targets, expressed in tonnes of oil equivalent saved, pursuant to the Ministerial Decree of 20 July 2004, or can be exchanged and traded on the electronic market managed by GME (the Energy Market Operator).

Alternatively, the operator can ask GSE to withdraw the White Certificates it is entitled to. The withdrawal price is the price in force at the time of the unit's commissioning and is constant throughout the incentive period. Only for the units commissioned before the Ministerial Decree of 5 September 2011 the withdrawal price is that in force at the date the Decree entered into force.

The electricity produced by the cogeneration units recognised as being HE CHP units pursuant to the Ministerial Decree of 4 August 2011 is entitled to the following additional benefits:

- exemption from the obligation to purchase green certificates, which applies to electricity producers and importers whose annual production or imports from non-renewable sources exceed 100 GWh;
- priority in dispatching the electricity produced by mainly HE CHP units (i.e. units producing 50 % or more of their total electricity output in HE CHP mode;
- for the share of net electricity produced by the HE CHP unit and fed into the grid from plants using biomass, biogas and sustainable bioliquids, an increase - differing according to type of fuel - is granted to the baseline incentive tariff set out in the Ministerial Decree of 6 July 2012;
- for the net electricity produced by the HE CHP unit and fed into the grid from biomethane power plants, eligibility, under the Ministerial Decree of 5 December 2013, for the tariff applying to electricity from biogas as laid down in the Ministerial Decree of 6 July 2012;
- part-exemption from payment of general system charges, if the other requirements set out in Legislative Decree No 115/2008, as amended by Legislative Decree No 56/2010 are met, for the purpose of classification as 'efficient demand point system and equivalent systems (SEU and SEESEU)'.

The Ministerial Decree of 24 October 2005 governs access to Green Certificates (District Heating Green Certificates) for units already qualified as 'cogeneration plants coupled with a district heating network', recognised as cogeneration plants pursuant to AEEG Decision No 42/02 as amended and supplemented. The District Heating GCs are granted for a period of eight calendar years in variable number for each reporting year on the basis of the cogenerated heat supplied to the network.

Article 14(11) of Directive 2012/27/EU on energy efficiency provides 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'.

Lastly, the natural gas used to generate electricity is subject to a particular excise duty regime (variable according to consumption and final use), i.e.: excise duty of 0.000449 €/m^3 for gas with a specific consumption of up to 0.220 m^3/kWh, and excise duty of between 0.007499 €/m^3 and 0.044 €/m^3 (according to final use) for gas consumption exceeding that threshold. If the electricity is self-consumed, the excise duty is reduced by 30 %.

Gas methane supplies used to generate electricity (including via cogeneration) are subject to reduced 10 % VAT, while gas used in boilers is charged standard VAT at 22 %.

8.2.2 District heating

In Italy, the development of district heating was spurred on the one hand by the need to achieve national and EU targets of environmental protection and energy efficiency, which led to various support schemes promoting development of the sector. On the other hand, DH has been often regulated by local authorities and deployed by the same authorities' public companies, which have developed many of the existing networks.

Over the years, various incentives have promoted the deployment of DH: obligations, capital and interest subsidies, operating subsidies.

As to obligations, Legislative Decree No 311/2006 requires all new buildings located at no more than 1 km from a DH network to be fitted so as to enable connection to the network.

This provision has been strengthened by Article 22(1) of Legislative Decree No 28/2011, which provides that infrastructure for the installation of district heating and cooling networks using renewable sources are classed for all intents and purposes as primary urban infrastructure works. This means that including this infrastructure may be mandatory in new residential development, as a condition for obtaining the building permit. The connection obligation exists de facto in public housing schemes developed by the competent public bodies.

Article 11 of Legislative Decree No 28/2011 also introduced (from 2012, for a share which will progressively be raised to 50 % of the building's overall heat demand) the requirement to include renewable sources in the fuel mix for heating and cooling in new buildings and in buildings undergoing major renovation. This is also a condition of the planning permission. This obligation, laid down in section 5, does not apply if the building is connected to a district heating network covering the entire demand for heat for space heating and the domestic hot water production.

As to capital incentives, in the 1980s and 1990s projects for DH systems and networks benefited from some investment subsidies designed to pursue the national policies for energy saving and use of RES. These schemes are no longer in force. However, they are recapped briefly below in view of their significant role in supporting development of the sector.

Law No 308/82 considered the use of RES as being 'of public interest and public utility'. This includes 'the processing of organic and inorganic wastes or vegetable products and the heat recoverable from electrical installations, waste gases, thermal plants and industrial processes, and other forms of energy recoverable from processes or installations'.

In this context, Article 4 of Law No 308/82 removed ENEL's monopoly on the production of electricity in cogeneration mode and from renewable sources in plants having a capacity of less than 3 MWe. This law also made an important exception for public companies owned by the municipalities: 'If the plants are operated by municipalities, provinces or their consortia or municipal companies, individually or in consortia, or by consortia of public and private companies, the capacity limits are determined by heat production demands'. The excess electricity generated by those plants was purchased by ENEL at prices regulated by the Interministerial Pricing Committee (Comitato Interministeriale Prezzi).

To incentivise development of production from renewables or from cogeneration, non-returnable grants were provided for feasibility studies and executive designs, and a fund of no less than ITL 415 billion was established providing capital contributions to the same entities that build or developed RES plants or CHP plants, covering up to 30 % of total budgeted cost.

These grants were used to develop some of the early networks, such as those of Brescia, Turin, Brunico, Rovereto and Verona, in particular to purchase the heat-generation plants.

Law No 10/91 repealed Law No 308/82 but confirmed and expanded the incentives to DH. In particular, Article 11 provided that the same beneficiaries could receive, for the same aims set out in Article 10 of Law No 308/82 capital contributions of up to 50 % of the budgeted eligible expenditure up to a maximum of ITL 50 million for technical-economic feasibility studies and ITL 300 million for executive designs. The same article also introduced a capital contribution of 40 % of documented expenditure for DH networks.

Section 7 of Article 7 also introduced a specific provision for DH, to the effect that the 'development of district heating systems by companies owned by the municipalities, public authorities, consortia between public authorities, between public authorities and private enterprises or between private enterprises which use the process heat from thermoelectric power plants or from industrial processes are eligible for capital contributions up to 50 % of the costs incurred'.

Article 6 required the Regions and the Autonomous provinces of Trento and Bolzano to identify areas suitable for the construction of plants and district heating networks and required public authorities and entities having buildings in those areas to give priority to connection to DH networks.

Article 8 also provided for capital contributions, for an amount between 20 % and 40 % of documented expenditure, for projects to improve the energy efficiency of buildings, prioritizing connection of the buildings to the DH networks.

Law No 10/91 was not refinanced in 1995 and thus ceased being effective.

Some regions, such as Lombardy, Piedmont and Emilia Romagna and the Autonomous Provinces of Trento and Bolzano, have provided incentives for the construction of DH networks through the granting of capital contributions, used mainly to construct heat distribution networks.

Article 22(4) of Legislative Decree No 28/2011 has set up a guarantee fund supporting the construction of district heating networks. Money for the fund comes from a levy on methane consumption, charged to end users, of 0.05 c€/Nm3. However, the interministerial decrees laying down the criteria for access to the fund have not yet been issued.

Legislative Decree No 102/2014, in its Article 5(12), superseded the fund, by establishing that the resources earmarked for it must be paid into the State budget, for an amount of EUR 5 million in 2014 and EUR 25 million in 2015, and then be reassigned to implementation of the programme of actions for improvement of the energy efficiency of buildings of the central public administration.

Article 15 of Legislative Decree No 102/2014 established the national revolving fund for energy efficiency, intended to support the financing of measures consistent with the achievement of national targets for energy efficiency. This encouraged the involvement of national and EU financial institutions and private investors on the basis of appropriate risk-sharing, particularly with regard to the following: a) measures for improving the energy efficiency of government-owned buildings; b) construction of networks for district heating and cooling; c) energy efficiency of public services and infrastructure, including public lighting; d) energy efficiency of entire buildings intended for residential use, including social housing; e) energy efficiency and reduction in energy consumption in the industrial and service sectors.

As to interest rate subsidies, a major driver of development of the sector is the low interest rate loans granted by the European Investment Bank. The planned expansion of the DH network in Milan will be financed by one such loan, with a maturity of 15 years.

Again to pursue energy efficiency targets, DH networks have benefited and will continue to benefit, directly and indirectly, from several operating expense subsidies.

DH networks are eligible for the White Certificate scheme (also known as Energy Efficiency Certificates - EEC). The certificates available to DH networks linked to HE CHP installations are calculated in the manner set out in the Ministerial Decree of 5/9/2011 which establishes the support scheme for high-efficiency cogeneration. As to the White Certificates available to DH networks linked to non-CHP plants or to plants not considered in the Ministerial Decree, the applicable rules are those of Technical Sheet 22T: 'Application in the civil sector of district heating systems for space conditioning and domestic hot water production'.

Pursuant to Article 2(3)(a) of the Decree of the Minister for Production Activities of 24 October 2005, CHP plants supplying a DH network are eligible for the Green Certificate Scheme (GC-DH) in proportion to the quantity of heat supplied to the DH network and the generation technology used, even when not employing renewable sources.

The Ministerial Decree of 6 July 2012 on incentives for energy from non-PV renewable electricity sources provided for the gradual phasing-out of the Green Certificate scheme. Specifically, starting in 2016, the production of energy by CHP plants connected to district heating commissioned by 31 December 2012 will be entitled to an incentive on their net output, calculated in the manner set out in the Decree, in addition to the revenues from the sale of energy.

The Ministerial Decree of 6 July 2012 also provides that the tariff applying to biomass systems using specific types of by-products, listed in the Decree, is to be increased by a premium of EUR 40/MWh if the cogenerated heat is used for district heating.

Green Certificates, as well as the premium for cogeneration associated with district heating, cannot be cumulated with incentives for energy efficiency and heat production (e.g. the White Certificates).

Again as concerns incentives towards operating costs, some CHP installations have received the contribution per kWh produced set out in the measures of the Interministerial Price Committee Nos 15/89 and 34/90, up to about 2000. Other plants have received the CIP 6/92 contributions.

The electricity produced by CHP plants serving DH networks enjoys priority dispatching onto the national transmission grid.

Lastly, DH enjoys some tax relief compared with the production of heat at the premises of civil end-users. The consumption of the fuel used in cogeneration units and in the backup boilers directly linked to the same district heating network are entitled to the reduced excise duty for industrial uses (and to the associated reduced rate of duty for electrical uses), provided they meet certain conditions (high-efficiency cogeneration and electricity/heat ratio > 10 %). If these requirements are not met, this consumption is charged the excise duty rate for civil uses.

8.3 HE CHP and DH in Regional Energy Plans (PEAR) and other regional measures

The measures taken by the various regions – mainly the Regional Energy and Environmental Plans (Piani Energetici Ambientali Regionali – PEAR) some of which have received the final approval from the Regional Assemblies, while others have been approved by the Regional Executive and opened for public consultation – show a broad distinction between those regions that in recent years have pushed forward significantly the theme of cogeneration and district heating and those that have given a more marginal role to development scenarios for those technologies or have outright failed to issue specific measures and guidelines on this issue.

Figure 77 – Regions whose official documents include assessment of the potential for HE CHP

Figure 78 – Regions whose official documents include assessment of the potential for DH

In particular, mapping of the main regional data concerning this benchmark shows a clear propensity of northern regions to see HE CHP and especially DH as useful contributors to diversification of energy supply, in particular in the residential and industrial sectors. This is clearly due to the specific climatic and socio-economic characteristics of the northern regions, including the demand for space heating and the existence of particular energy districts and poles, coupled with availability of the fuels used.

The following table lists those regions which provide in their Energy and Environmental plans (PEAR) – and in other documents – assessments on the potential for development of **cogeneration**, followed by brief descriptions, region by region, of the main data found in regulatory measures on assessment of the potential for cogeneration.

Table 113 – HE CHP: Regions which provide assessment of potential in their energy plans (PEAR) or in other documents

REGION	Potential for HE CHP	Source consulted	Year of source
Piedmont		Draft document for the new PEAR	2015
Valle d'Aosta		PEAR	2014
Lombardy		PEAR integrated with SEA	2015
Bolzano		Climate and energy plan of Alto Adige 2050	2011
Trento		PEAP	2013
Veneto		PEAR – Proposal for the Regional Assembly	2014
Friuli Venezia Giulia		PER	2015
Emilia Romagna		PER – II Implementing plan 2011-2013	2011
Liguria		PEAR proposal	2014
Tuscany		PAER	2015
Umbria		SEAR	2016
Marche		PEAR	2005
Lazio		Policy Document – New Energy Plan of Lazio	2015
Abruzzo		PER	2009
Molise		Draft document for the new PEAR 2015	2015
Campania		Draft PEAR and launch of SEA	2009
Apulia		Adoption of the updated PEAR and launch of consultation for SEA	2015
Basilicata		PIEAR	2010
Calabria		PEAR	2005
Sicily		PEARS	2009
Sardinia		Draft PEAR and launch of consultation	2014

One of the regional authorities that assessed the potential for development of HE CHP in their territories is the **Autonomous Province of Bolzano**, which in its Climate and Energy Plan for Alto Adige 2050, approved in 2011, stated that the number of CHP plants in the industrial and craft sectors in the province would be expanded further, taking into account heat demand in residential areas. The plan also provided that to increase the number of cogeneration plants in the industrial and commercial sector of the province, by 2013 the existing potential would be surveyed in cooperation with industry associations.

The **Autonomous Province of Trento** set out in its PEAP approved in 2013 its increase scenarios for biomass-fuelled CHP systems and district heating networks. Two scenarios to 2020 have been considered: the low scenario predicts construction of just 50 % of the plants currently in the final design stage, 80 % of those in the executive design stage and 100 % of those under construction; the high scenario assumes that all the plants will be constructed.

The **Region of Valle d'Aosta**, in its PEAR Plan approved in 2014, sets out a scenario including installation, by 2020, of CHP installations with the following fuels: 2 MWt natural gas, 4 MWt diesel and 4 MWt other CHP installations fuelled by biomass. These estimates also include mini and micro-CHP plants.

In the **Region of Veneto**, the section 'Potential for energy saving in the industrial sector' of the draft Regional Energy Plan, prepared in 2014 for approval by the Regional Assembly, envisaged actions in 2016 to improve energy efficiency in the industrial sector – through HE CHP – for 6 280 GWh/year. This follows the 2 493 GWh already achieved in 2010, again through energy-saving actions. Adding together the actual and feasible heat and power savings (the heat produced by cogeneration is assumed to be used in the production process or in tri-generation), achieved through adoption of the technologies, at regional level the energy saving in the baseline scenario by 2020 (calculated at the lower penetration rate of the technology) is in the order of 266 ktoe, of which 134 of power and 132 of heat.

The **Region of Friuli Venezia Giulia**, in its Regional Energy Plan adopted in late 2015, also included a survey on the existing regional cogeneration facilities. This focuses on the growth of HE CHP, including via specific regional measures which provide, for instance, for the creation of revolving funds and/or guarantee funds helping SMEs to invest in this technology for more efficient use of energy output (heat, power and cooling). An allied goal is to promote, including through interest rate facilities, the development of small CHP installations to maximise resource of local resources (biomass) and plant efficiency through the recovery of process heat.

The **Region of Lombardy**, in its draft PEAR of 2015, provides detailed information on the role of HE CHP in the various sectors (residential, industrial) and on future developments. These could involve bioenergy, and specifically solid biomass from wood and residues in the civil sector for single-dwelling heating and in the units serving district heating networks, including in combined heat and power generation mode; biogas in power generation, including in combined heat and power generation; liquid biofuels in transport and power generation.

The **Region of Piedmont**, in its proposal for a new PEAR approved in 2015, includes in its plans for the development of urban district heating systems the maximum use of heat produced by existing CHP plants (particularly for DH in the metropolitan area of Turin).

In the **Region of Liguria**, the PEAR opened for public consultation at the end of 2014 points out that despite the high regional potential in terms of potential customers (large multi-apartment buildings, office and commercial buildings, hotels and hospitals), at the present time just a fraction of the potential for HE CHP and DH is being exploited. To develop dedicated districts, the Region plans to apply for funding under the "Horizon 2020" programme focused on "Smart Cities and Communities".

The **Region of Emilia Romagna** is focused on continuity with the schemes put in place under ROP ERDF 2007/2013, designed to foster deployment of APEA [production sites equipped for energy saving and use of RES], already financed under the Structural Funds 2007-2013. This policy includes schemes promoting the deployment of cogeneration and trigeneration systems, possibly integrated with industrial production cycles, and of district heating networks where they secure greater energy efficiency than a variety of single-site efficiency projects, by serving all the users located in a given industrial area. In particular, as concerns the improvement of buildings, urban infrastructure and the territory, energy saving, estimated on average at 20 - 25 %, would concern the whole CHP plant/district heating network system.

The **Marche Region** focused on the industrial customers mentioned in the PEAR of 2005, and identified many areas with characteristics making them suitable for energy supply by CHP systems. However, CHP applications remained limited for large shopping centres or other service sector customers. As concerns in particular "district-wide systems", the untapped potential was largely found in sites where the technical potential was high but was not matched by the same level of cost-effectiveness. Hence, widespread uptake of HE CHP (coupled with DH where this was the only way of using the heat generated) could be feasible only with new well-planned incentive schemes.

The **Region of Umbria**, in its policy document (SEAR) approved at the end of 2013, identified for the service sector measures to support CHP plants (using RES or methane) and, for district heating and cooling, funding using ERDF and EAFRD, with the aim of reducing consumption. Thus, the development of small combustion plants for the production of electricity from RES provides a major opportunity for developing small local networks able to exploit the surplus heat which is often lost.

The **Region of Molise** listed in the preliminary document to the new PEAR of 2015 the possibility of deploying HE CHP for the region's hospitals, estimating primary energy savings of about 13 600 MWh/year, or around 10 % of current consumption. The aim is also to focus on micro-CHP for smaller customers with lower demand.

The **Region of Sardinia**, in its PEAR for 2014, focuses on energy districts characterised by the presence of CHP installations fuelled by biomass having an electrical power rating of less than 1 MW, used to supply heating and cooling to households and to the service sector, located in energy districts equipped with DH networks.

Overall installed capacity is estimated to reach 3 MW by 2020; under a development scenario, the figure may rise to 6 MW; under an industrial development scenario, overall capacity could rise to 10 MW. As concerns biomass, the PEAR intends to promote, in the energy districts and municipalities of Sardinia, the use of biomass for CHP and sets for 2020 the target of developing a number of HE CHP systems using biomass having a nominal cumulative electric output of 10 MWe.

In the framework of actions for the development of cogeneration and the efficient use of biomass, the Sardinia Region promotes and supports the creation of District Heating networks to maximise the use of heat from cogeneration. To this end, the use of waste biomass is proposed, as indicated in the "Study on the energy potential of biomass in Sardinia", to supply small-size CHP/CCHP systems (with output of less than 1 MW electric), feeding neighbourhood or district micro-networks in areas having suitable geographical and climate characteristics and availability of locally produced biomass. The aim of the Sardinia Region is to develop 10 plants by 2020, possibly located in the energy districts. The Region promotes the development and installation of hybrid systems, which combine different energy sources and optimise their conversion. The plan also pinpoints the facilities with the highest heat consumption, such as public offices, hospitals, schools, universities, student accommodation blocks and care homes as those best suited for installation of these systems.

On the other hand, the **Region of Campania**, in its PEAR approved in 2009, set as a minimum target, for gas plants with an output of less than MWe, an increase in installed electrical capacity of 50 MWe by 2013 and 100 MWe by 2020, thereby achieving additional savings of non-renewable primary energy estimated at 25 ktoe/year by 2013 and 50 ktoe/year by 2020.

The **Action Plan of the Sicily Region** contains various information sheets on actions and measures involving cogeneration (including self-production), focusing on the creation of small fixed production plants using biomass or natural gas.

The following table lists those regions which provide in their Energy and Environmental plans (PEAR) – and in other documents – assessments on the potential for the development of **district heating**, followed by brief descriptions, region by region, of the main data found in regulatory measures on assessment of the potential for DH.

Table 114 – DH: Regions which provide assessment of potential in their energy plans (PEAR) or in other documents

REGION	Potential for DH	Source consulted	Year of source
Piedmont		Draft document for the new PEAR Contribution of DH to BS targets	2015 2013
Valle d'Aosta		PEAR	2014
Lombardy		PEAR integrated with SEA	2015
Bolzano		Climate and energy plan of Alto Adige 2050	2011
Trento		DGP 836/2015 – Plan of energy investments (DH) DGP 1826/2014 – Availability of wood chips in the province PEAP	2015 2014 2013
Veneto		PEAR – Proposal for the Regional Assembly	2014
Friuli Venezia Giulia		PER	2015
Emilia Romagna		PER – II Implementing plan 2011-2013 Preliminary analysis for assessing geothermal potential	2011 2010
Liguria		PEAR proposal	2014
Tuscany		PAER	2015
Umbria		SEAR	2016
Marche		PEAR	2005
Lazio		Policy Document – New Energy Plan of Lazio	2015
Abruzzo		PER	2009
Molise		Draft document for the new PEAR 2015	2015
Campania		Draft PEAR and launch of SEA	2009
Apulia		Adoption of the updated PEAR and launch of consultation for SEA	2015
Basilicata		PIEAR	2010
Calabria		PEAR	2005
Sicily		PEARS	2009
Sardinia		Draft PEAR and launch of consultation	2014

The **Valle d'Aosta Region** included in its PEAR for 2014 – among the energy efficiency and energy conversion efficiency actions by 2020 – the DH project for the city of Aosta (thermal production of 95 GWht/year at the plant with useful energy delivered to customers, minus network losses, of about 85 GWht/year and an electricity generation of about 30.5 GWhe by 2020) and the DH project at Breuil Cervinia (heat generation of about 82.7 GWht by 2020 and electricity generation of about 8.3 GWhe). By 2020, an increase in heat plants of 19 MW has been estimated, plus an additional 8.5 MW from CHP units in medium-sized systems or mini DH networks, for an aggregate heat generation from biomass by 2020 of approximately 354 GWh/year.

The **Region of Lombardy** participated in the European project 'BioEnerGIS' (completed at the end of 2011), which supported public and private stakeholders in picking the best sites for new district heating networks using biomass, by overlaying the data on heat demand with the availability of local biomass. For the residential sector, the input data are annual energy consumption, available at municipal level and by type of fuel, distinguished further by census zone, number of flats and buildings, average size of apartments and heating rate for energy vectors at municipal level as proxies. The census zones are georeferenced: this makes it possible to convert the quantity of energy demand in a census zones into quantity per cell. The census zone level offers good spatial resolution: in Lombardy, there are about 49 000 census zones in 1 546 municipalities, with an average population of 200 inhabitants per census zone and an average surface area of 0.488 km^2. The data analysis in the residential sector includes the breakdown into kWh/year by municipality and census zone (estimate), distinguished by fuel (estimate), over the period 2000-2008. The optimal size for local production in the Lombardy region is generally between 1 and 10 MW: considering heat production only, this equates to a potential of nearly 130 new biomass plants with a capacity of 10 MW.

According to the estimates provided, using all the "sustainable" wood biomass of Lombardy it would be possible to install 1 283 MW (about 10 times the heat capacity of the district heating systems existing in Lombardy in 2012) and to produce about 320 ktoe, thereby increasing sixfold the aggregate quantity of energy produced in 2012 by biomass district heating, which is of about 50 ktoe. Under the high and medium scenarios of the PEAR 2020, efficiency increases in the DH networks are estimated at 120 ktoe in the residential sector and 80 ktoe in the service sector. As concerns the scenarios for 2020 for RES penetration and development, biomass for domestic use, district heating and industrial and agricultural use totals 1 140 ktoe in the high scenario and 806 in the medium scenario; geothermal energy (direct use or district heating) equates to 30 ktoe in the high scenario and 13 ktoe in the medium scenario; waste RES in district heating amounts to 130 ktoe in the high RES scenario and 110 ktoe in the medium scenario.

The **Autonomous Province of Trento**, in its PEAP 2013-2020 approved in 2013, estimated DH energy from biomass by 2020 to be 17 or 22 ktoe under the low and high scenario respectively. The assessment of the quantity of wood chips available has attracted considerable interest, owing to the results of the European project BIO-EN-AREA, which calculated the quantity currently used and estimated the still untapped potential in the province. The Regional Executive, by Decree No 1826 of 27 October 2014, carefully surveyed the demand from wood chips from new business initiatives in the sector and, in light of the saturation of the resources, it decided not to finance plants fuelled by wood chips, including DH systems, in municipalities already served or easily reachable by methane pipelines. It also decided not to finance cogeneration systems fuelled by wood chips, not connected to a DH network or lacking customers able to use the heat generated.

The **Autonomous Province of Bolzano**, under the Climate and Energy Plan for Alto Adige 2050 approved in 2011, has planned further expansion of the existing DH for the city of Bolzano, with use of the surplus heat from the new waste incineration plant. On completion of this project, the DH network will cover over 20 % of the city's heat demand and will replace approximately 22 500 000 litres of diesel fuel. Furthermore, the heat from waste incineration will be used in absorption cooling systems for large customers, e.g. the hospital of Bolzano.

Moreover, several areas suitable for the use of deep geothermal energy have already been identified: geothermal energy can be used both to generate electricity and to supply heat to the DH network. According to project data, heat output would amount to 17 054 kW, while the electric output would be 2 000 kW. Self-consumption of energy amounts to 10-12 % of electric output.

The **Region of Veneto**, which has already financed with ROP funds 2007/2013 a series of measures to increase the use of DH networks, in the section 'potential for energy generation from geothermal sources' of the 2014 draft PEAR for approval by the Regional Assembly, called for pilot demonstration projects exploiting the geothermal sources available to supply direct heat to DH networks. The scenario to 2020 is that several DH networks for civil customers could be installed in the region, having an aggregate output of 20 MW, and including 1.1 ktoe of renewable sources. Another fuel besides geothermal is wood, in particular wood chips. The PEAR includes a detailed survey of the potential supply of this fuel (calculating more than 1 200 000 t/year).

The **Region of Tuscany**, through the PAER approved by the Regional Assembly in early 2015, has calculated among renewable heat sources by 2020, 29 ktoe of biomass from district heating, 2.2 ktoe of heat pumps connected to district heating and 48.9 ktoe of direct geothermal and/or district heating.

The **Region of Piedmont**, based on the trends in past years, estimated in 2013 a contribution from DH to the regional targets under the burden-sharing rules of about 100 Mm^3 in heated volume by 2020. This scenario is based on the assumption of specific support measures for the development of DH, linked to HE CHP and/or the generation of heat from RES.

The **Region of Umbria**, in its policy document (SEAR) approved at the end of 2013, identified measures for the service sector to support CHP plants (using RES or methane) and, for district heating and cooling, funding using ERDF and EAFRD, with the aim of reducing consumption.

The **Region of Emilia Romagna**, in the three-year period 2011-2013, set the target for network extension at around 35 km and the increase in volume served at about 5 200 000 m^3, corresponding to an estimated heat supply of 166 000 MWht/year. The Energy Implementation Plan 2011-2013 included among its policy targets both the increase in energy efficiency and the production of energy from RES, including through increases in HE CHP and district heating and cooling. The Second Energy Implementation Plan of 2011 pointed out this region was ranked third in Italy, after Lombardy and Piedmont, in terms of the size of DH networks, with more than 26 installations, about 1 200 000 MWht of heat distributed (equal to about 103 ktoe) and more than 35 Mm^3 of buildings served by DH. As shown by the investments proposed by the Plan, a major role for district heating could be played by the measures planned by multiutilities and local authorities, together with the development of plants in environmentally suitable areas.

In the **Region of Liguria**, DH plants contribute to the achievement of the energy efficiency targets set out in the PEAR 2014-2020, with a share of 332 ktoe. The same PEAR (which for each RES, including DH, provides a useful SWOT analysis), includes among key development actions the installation of advanced technology systems such as CHP and CCHP and district heating and cooling systems, for the purpose of reducing consumption, including through use of resources from the ERDF 2014-2020.

The **Region of Friuli Venezia Giulia**, in its REP for 2015, sets out regional measures to support DH networks (creation of revolving and/or guarantee funds), in line with the ROP ERDF 2007-2013 resources used in previous years. In the industrial sector, for example in the iron and steel industry in Friuli, the feasibility is being assessed of constructing an urban district heating network using recovered heat from offgas; currently, the company recovers this heat for its internal district heating system and plans to cool electricity and control stations using absorption equipment. The main sources of energy that can fuel district heating networks in connection with possible applications in the region are also being analysed: solar heating, heat pumps, biomass, incinerators, industrial heat recovery, etc. The measures envisaged also include converting conventional power plants into more sustainable plants (upgrading of the distribution network, smart grids, district heating and storage systems). In the civil sector, the focus is mostly on conurbations, the aim being to convert traditional energy generation plants into more sustainable systems (upgrading the distribution network, smart grids, district heating and storage systems).

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