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

December 2015

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Gestore dei Servizi Energetici
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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

CONTENTS

Introduction

Article 14 of Directive 2012/27/EU on energy efficiency provides that by 31 December 2015, Member States shall 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) shall 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, tertiary and industrial - was addressed separately, in the light of their 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.

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 demanding because, differently from electricity generation, which is a well-established statistical field, the data on heat generation in Italy is far more patchy: 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 oil 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, year 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	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	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: processed Eurostat data

1.2.1 Consumption for heating and cooling

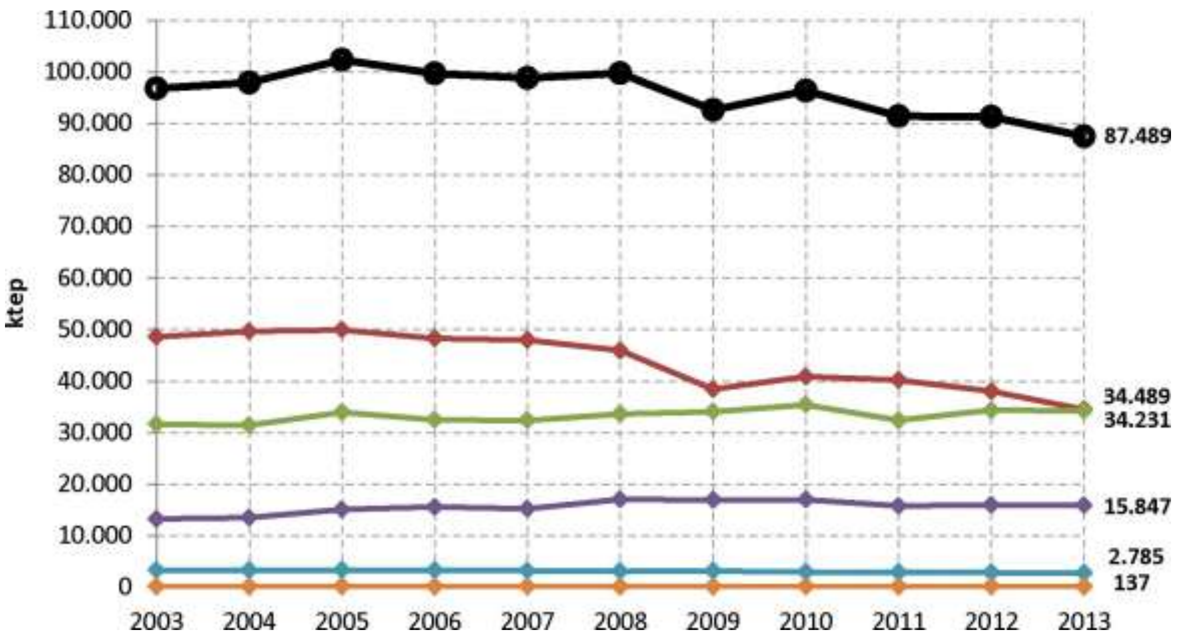
As specified in the paragraphs covering each sector, consumption for heating and cooling is defined starting from Eurostat data on consumption in the sectors of interest, shown below. Firstly, we have selected energy consumption in the sectors covered by this study, separating the share of energy consumption 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[1]	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: calculations based on Eurostat data

Figure 1 - Development of energy consumption over the period 2003-2013 in the sectors covered by this study



• totale	• total
♦ industria	♦ industry
♦ residenziale	♦ residential
♦ servizi	♦ services
♦ agricoltura	♦ agriculture
♦ altro	♦ other

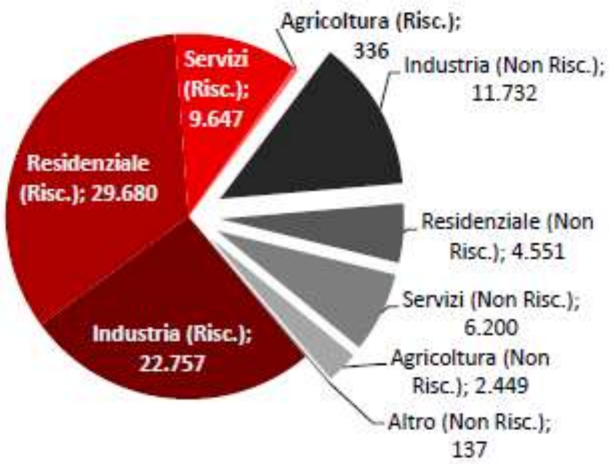
The development of energy consumption shows a declining trend. In 2013, the value came to about 87.5 Mtoe, the lowest in the past ten years. The trend is mostly driven by the industrial sector, which has been declining since 2005. On the other hand, consumption by the residential sector has gone up, 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 use for the operation of works vehicles, lighting and other electric uses, etc.),

[1] 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 the energy generated by the pumping), consumption for energy purposes (net of the consumption of raw materials) of refineries, coke ovens and hydrocarbon plants.

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



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

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)

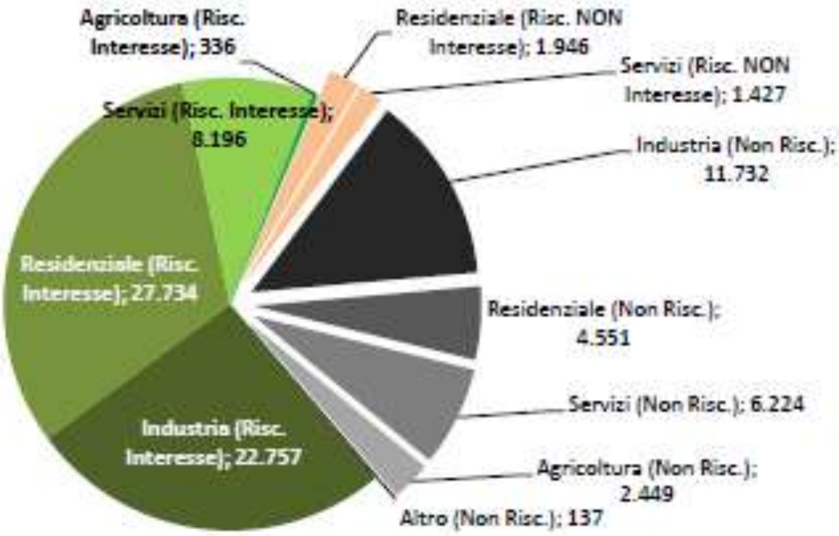
	oil products	natural gas	coal	electricity	derived heat	renewable sources and waste	total
residential	2 709	18 073	0	1 209	931	6 759	29 680
services	612	7 259	0	1 451	154	171	9 647
industry	5 768	10 030	2 396		4 008	556	22 757
agriculture	146	128			20	42	336
total	9 235	35 490	2 396	2 660	5 113	7 527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

As for the sources used for heating and cooling, the main one is natural gas (57%), followed by oil 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 paragraphs. The following chart sets out the next steps to be implemented for identifying the demand relevant to this study; specifically, the grey colour indicates the "non-heating" components of consumption, the orange colour the non-relevant heating components, and the grey colour the demand for heating which is the subject of all the following analyses.

Figure 3 - 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 that put to other uses (grey) (data in ktoe)



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

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%**

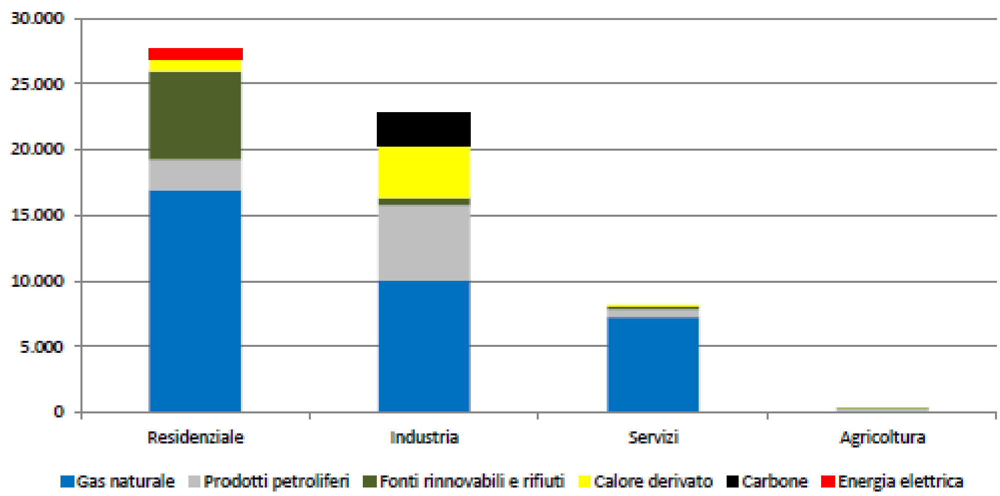
Table 6 - Consumption for heating and cooling in Italy (ktoe) relevant to the assessments made in this study

	oil 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: processed 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 oil 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 4 - Consumption in 2013 for heating, relevant to the study, broken down by sector and energy source (data in ktoe)



- Natural gas
- Oil products
- Renewable energy sources and waste
- Derived heat
- Coal
- **Electricity**

1.2.2 Derived heat

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

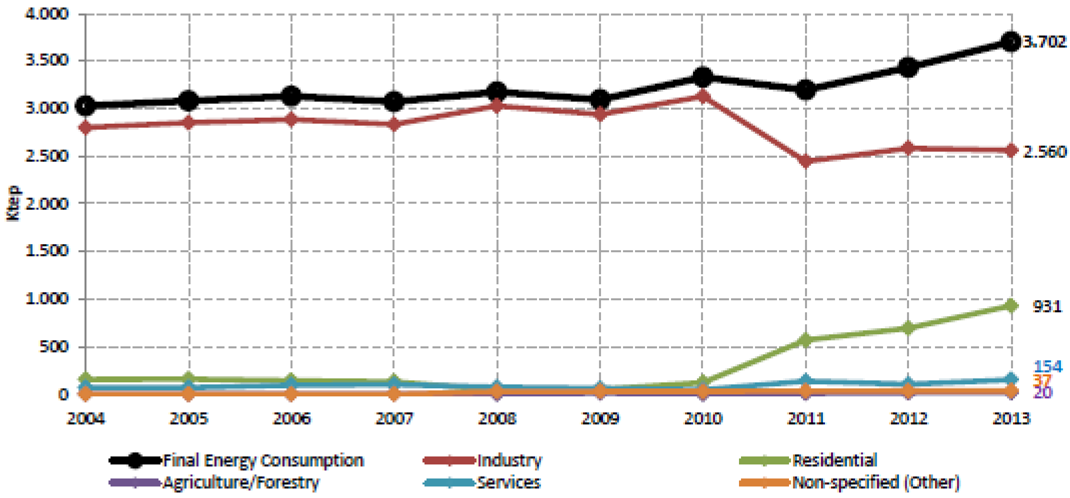
Table 7 - Consumption of derived heat in Italy between 2004 and 2013 (data in ktoe)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Consumption in Energy Sector	**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: processed Eurostat data

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



The following table shows the evolution in the mix of the energy sources which over time have led to the production of derived heat[2].

Cogeneration systems always supply more than 98% of the derived heat. As to sources, natural gas covers constantly 60% of production, followed by oil 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).

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

Table - 8 Production of derived heat (data in ktoe)

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Heat only plants	**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 Oil 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-	*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 Oil 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-	*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: processed Eurostat data

1.2.3 Variability of consumption

This paragraph 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

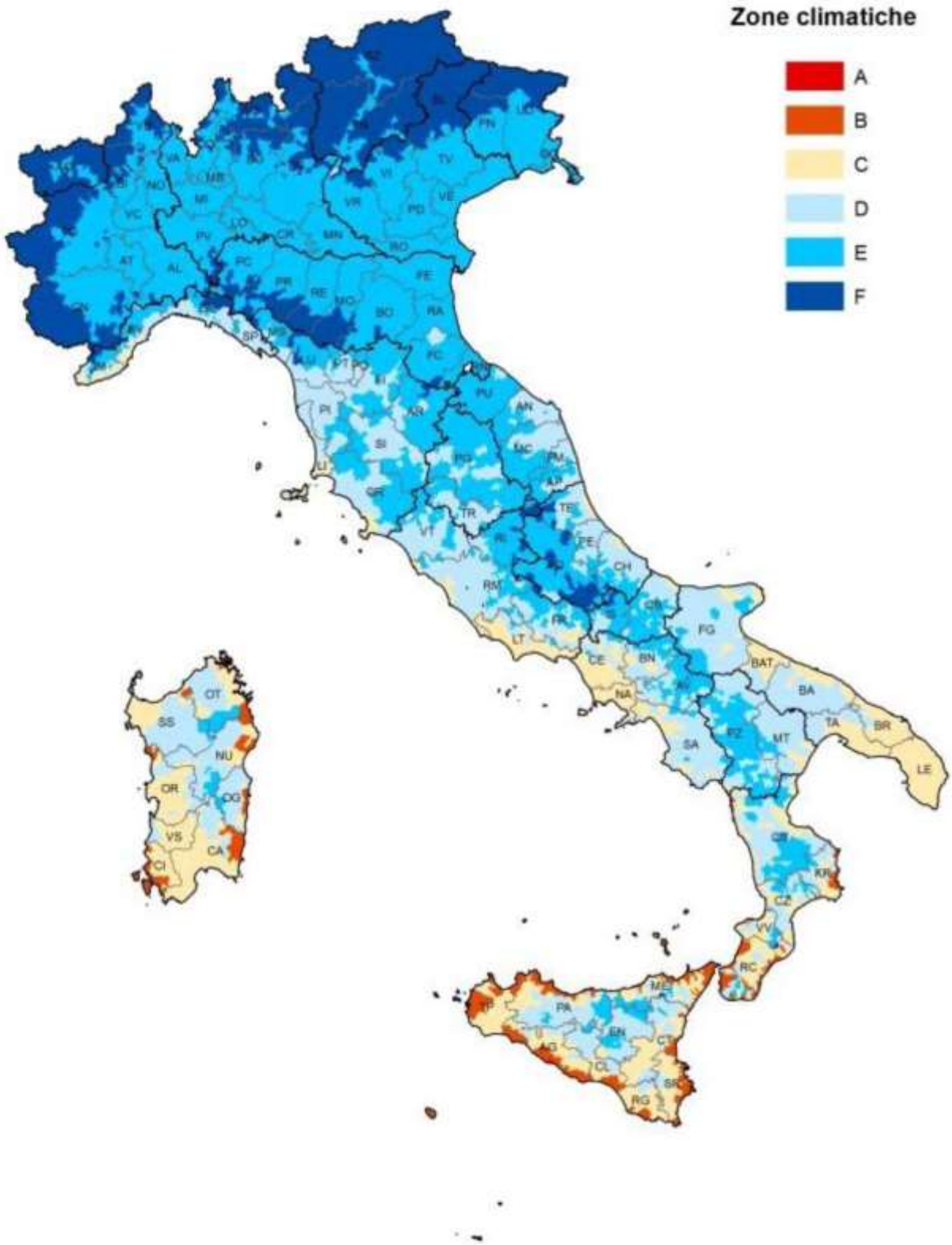
Climate conditions are well represented by the Degree Days (DD) indicator, which is defined by Presidential Decree No 412/1993 as *"the sum, extended to all the days of an annual conventional heating period, of the positive daily differences only between indoor temperature, conventionally set at 20 °C, 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 No 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 6 - National map of climate condition areas



Climate condition areas

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

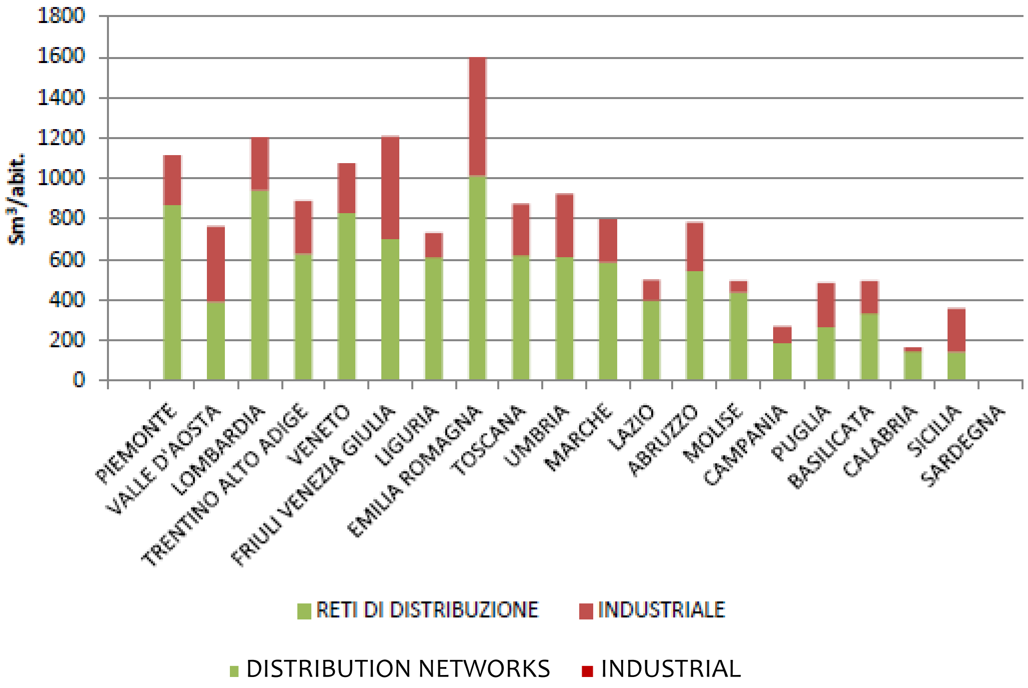
Region	Population	Number of households	Number of cohabitations	Average DD[3]
Piedmont	4 436 798	2 015 733	2 691	2 706
Valle D'Aosta	128 591	61 390	103	3 170
Lombardy	9 973 397	4 396 094	3 352	2 508
Trentino Alto Adige	1 051 951	443 007	718	3 230
Veneto	4 926 818	2 048 851	2 309	2 487
Friuli Venezia Giulia	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
Puglia	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: 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.

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

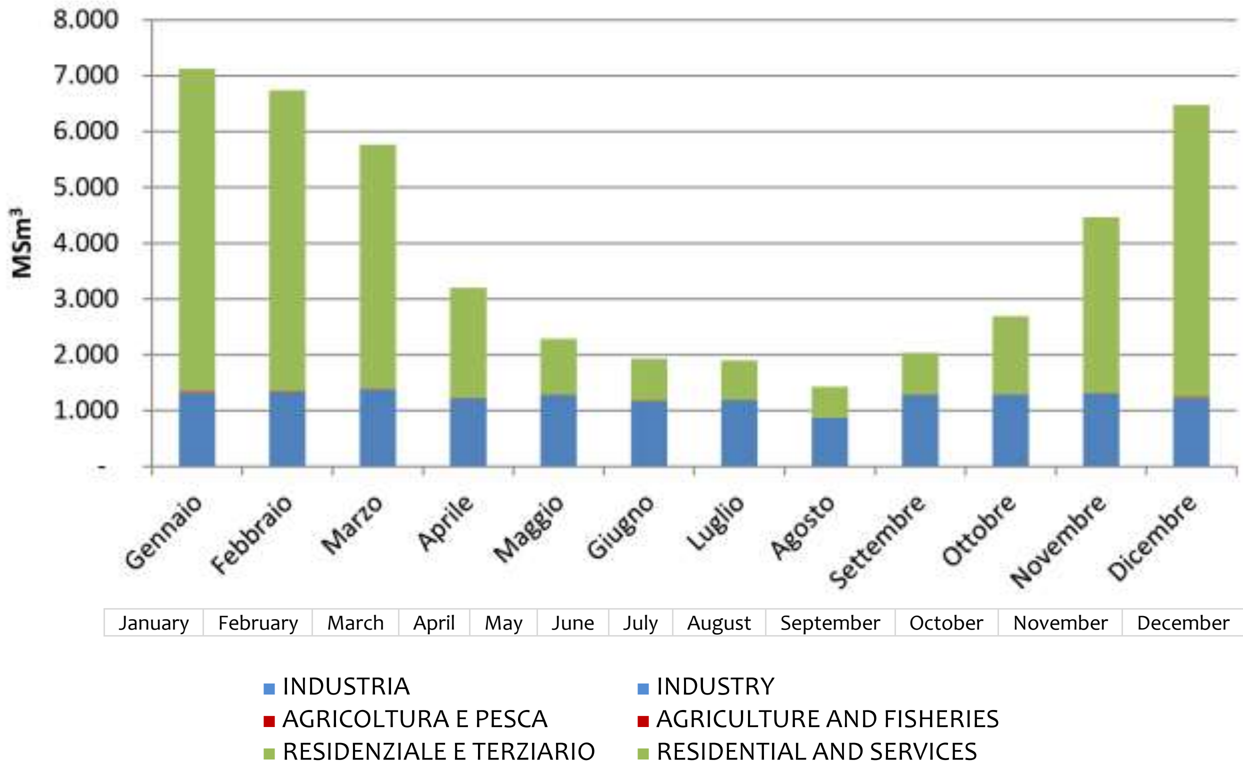
Figure 7 - Natural gas conveyed per inhabitant in 2013 (chart plotted by the Ministry of Economic Development using data from SNAM Rete Gas, S.G.I. s.p.a. and other companies) (Normal cubic metres at 38.1 MJ/m^3)



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 8 - Monthly consumption of natural gas in 2013 (Ministry of Economic Development) (Millions of standard cubic metres at 38.1 MJ/m^3)



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 [4] 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: Processed Eurostat data

4 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[5], 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)[6] 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

	oil 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.

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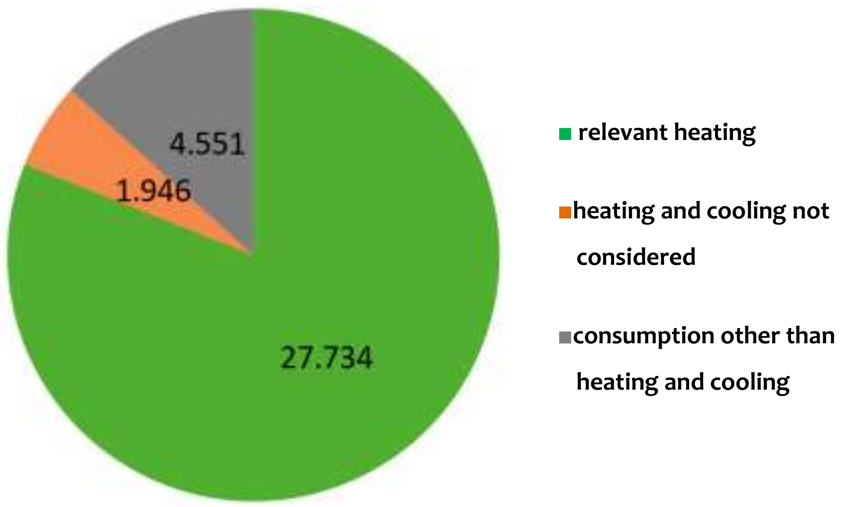
[5] *Rapporto annuale Efficienza Energetica* 2014 (Annual report on energy efficiency 2014). ENEA. *Rapporto Energia e Ambiente 2009-2010* (Energy and the Environment Report 2009-2010), ENEA.-

[6] 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, reproportioned taking into account the different use rates of the equipment (obtained from the same survey).

Figure 9 - Heating consumption selected out of the total for the residential sector. Year 2013 (data in ktoe)



1.3.2 Demand for heating: geographical distribution

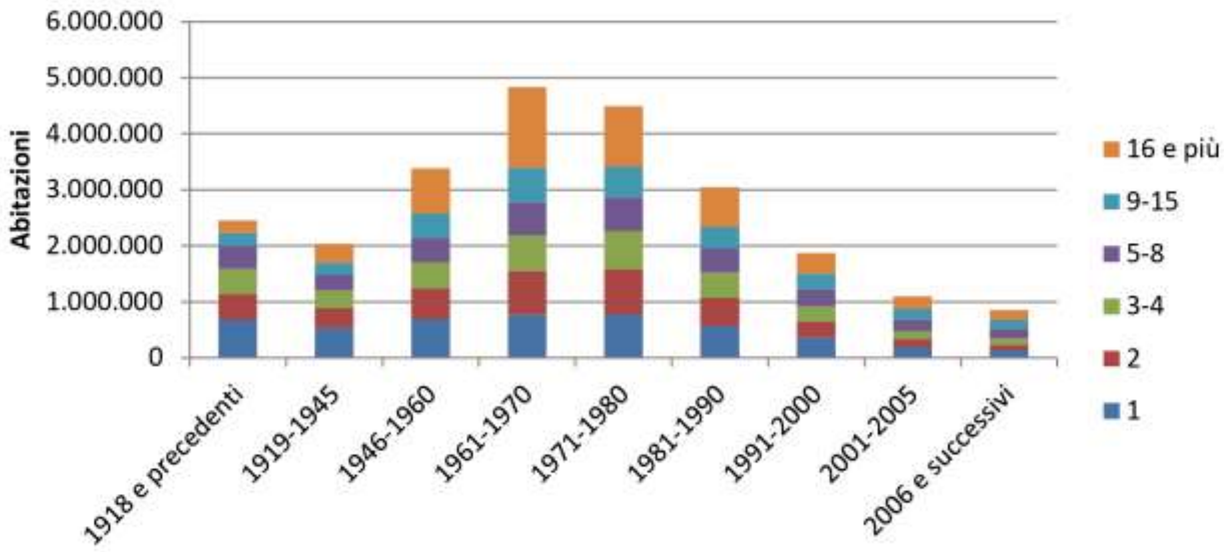
At the end of 2013 Italy had a population of 60 782 668; the number of households, which are taken in this study as the units making up the demand for heat, was 25 791 690.
As stated earlier, energy consumption for heating and cooling in households is made up mainly of consumption for winter heating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

	Building size class							
Building period	detached house	2 semidetached houses	3-4 flats	5-8 flats	9-15 flats	16 flats or more	**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: Processed data from Istat census 2011

Figure 10 - Number of dwellings by period of construction and building size class(Istat census 2011)



Abitazioni	Dwellings
1918 e precedenti	1918 and earlier
2006 e successivi	2006 and later
16 e più	16 or more

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[7] (climate condition area - building period - 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 make the calculation, it was necessary to reconstruct the composition the occupied built stock in each municipality[8];
- **Top-down correction**: correction of the results obtained using the previous method to take into account the fact that the consumption calculated refers to standard climate conditions, is referred 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.

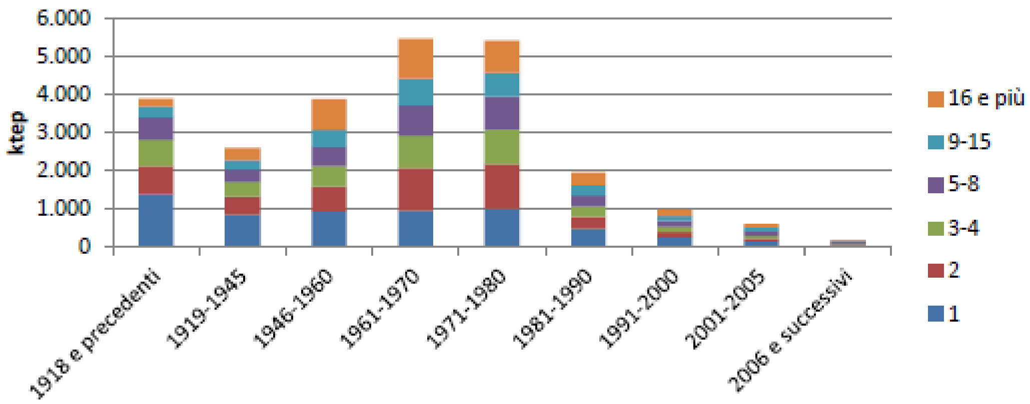
[7] *Analisi tecnico-economica di interventi di riqualificazione energetica del parco edilizio residenziale italiano* (Technical-economic analysis of energy efficiency projects in the housing sector in Italy), Ricerca Sistema Energetico, February 2014.

[8] 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 house	2 semidetached houses	3-4 flats	5-8 flats	9-15 flats	16 flats and more		
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 11 - Consumption for winter heating of the residential sector broken down by period of construction and number of dwellings in the building



ktep	ktoe
1918 e precedenti	1918 and earlier
2006 e successivi	2006 and later
16 e più	16 or more

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 / Vallèe d'Aoste	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
Puglia	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:

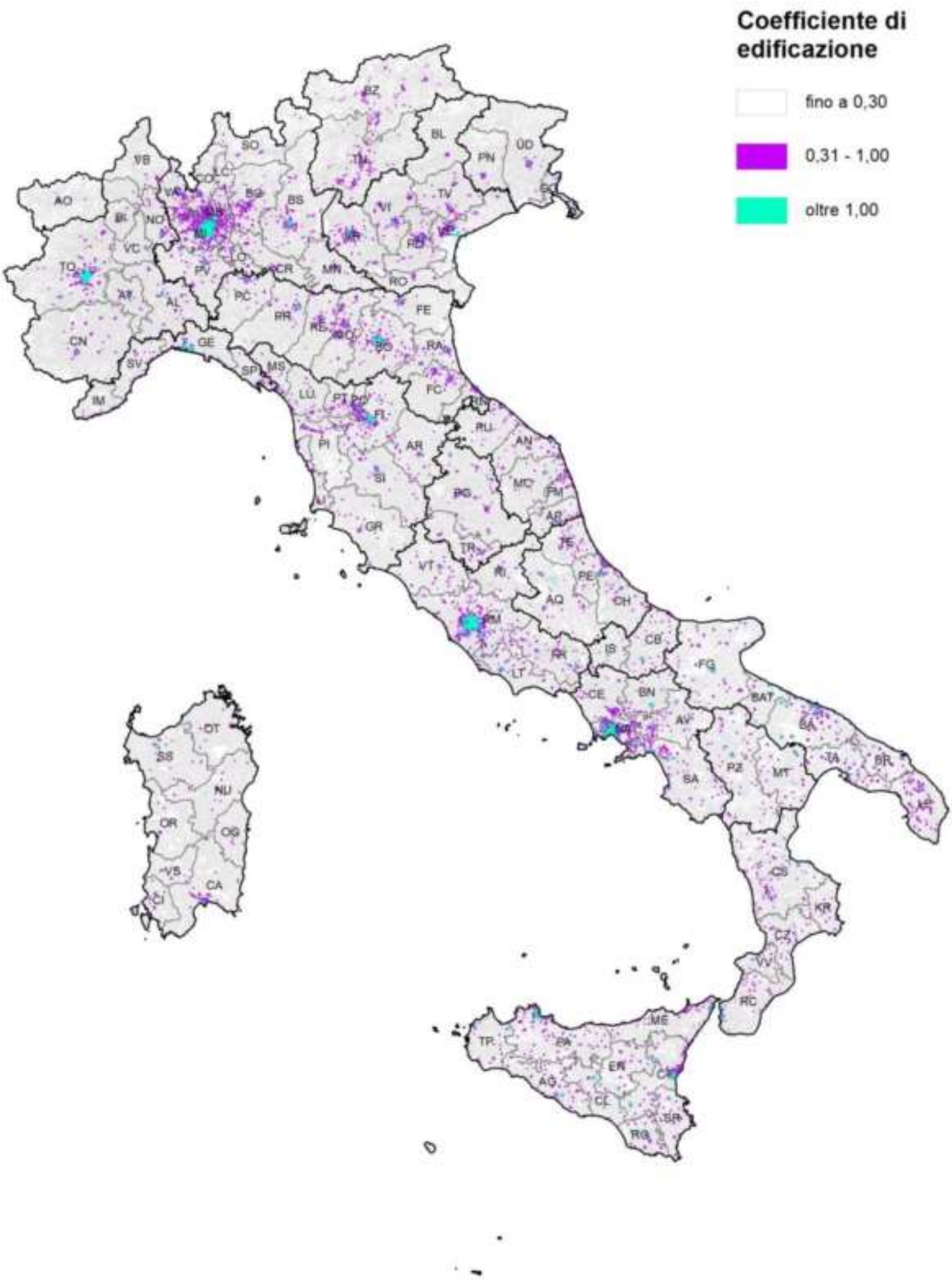
PR_i: Plot ratio of the i area surveyed [%]

Su_i: inhabited usable floor areas surveyed by the Istat Census 2011[m^2]

A_i: i area of the ISTAT 2011 census area [m^2]

The geographical resolution at which the plot ratio was calculated is very detailed, since the census zones (on which the aggregate value Su_i is calculated) 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 12 - Map of the plot ratio



Coefficente di edificazione	Plot ratio
Fino a 0,30	up to 0.30
Oltre 1	over 1.00

Geographically, the areas with high plot ratio are those of the country's large urban centres, where they cover several square km of land area (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%.

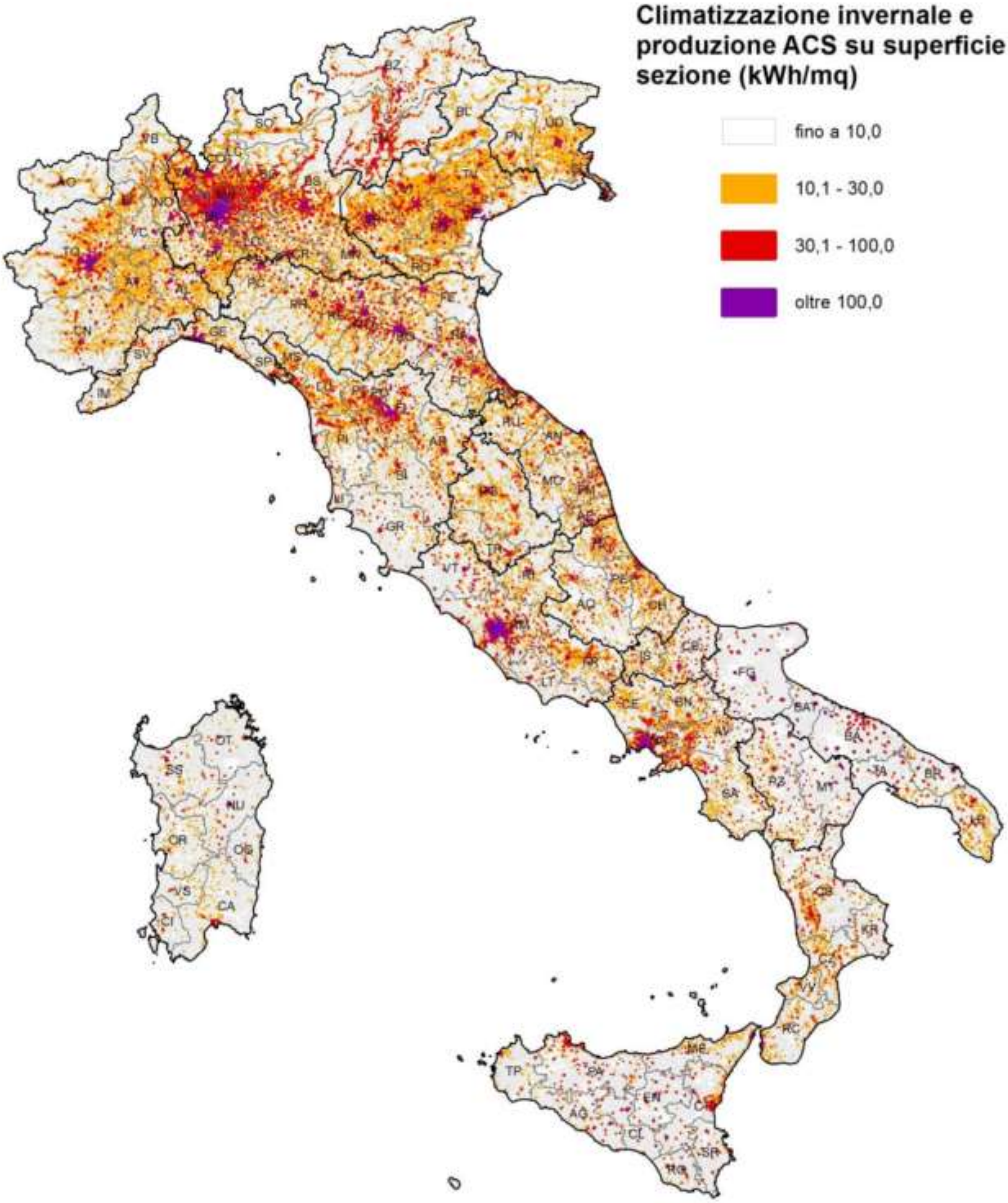
Table 16 - Characteristics of the areas with plot ratio >0,3

Climate condition area	No of 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/m^2) 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 13 - Density of residential consumption for winter heating and domestic hot water production. Year 2013



Climatizzazione invernale e produzione ACS su superficie sezione (kWh/mq)	Winter heating and DHW production in the census zone area (kWh/m^2)
Fino a 10,0	Up to 10.0
Oltre 100,0	More than 100.0

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 the areas with densities in excess of 30 kWh/m^2.

Table 17 - Breakdown of relevant residential consumption and of 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/m^2	consumption in areas with densities* between 30 and 100 kWh/m^2 (GWh)	consumption in areas with densities* of more than 100 kWh/m^2 (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 [9] supplied by heat pumps.

Table 18 - Consumption by 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: Processed Eurostat data

[9] 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[10].

Table 19 - Consumption by the service sector in Italy (data in ktoe) broken down by use (year 2013)

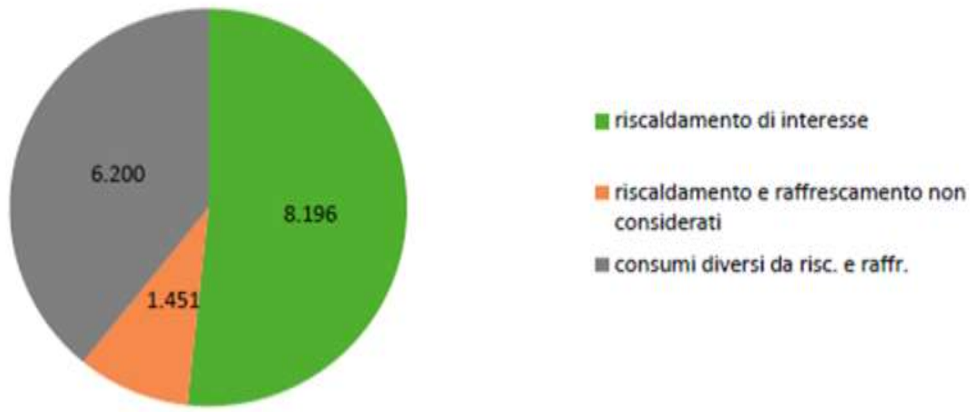
	Solid fuels	Oil products	Gas	Derived heat	Renewable energies	Electricity	Total
Heating and cooling	**0.0**	611.5	7 259.0	153.9	171.1	1 450.8	9 646.3
Winter heating, DHW and other uses	*0.0*	*611.5*	*7 259*	*153.9*	*171.1*	*1 025.6*	*9 221.1*
Summer cooling						*425.2*	*425.2*
other electrical uses						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 of 8.2 Mtoe.

[10] 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, instead, the parameters set out in Commission Decision No 2013/114/EU are used.

Figure 14 - Consumption for heating and cooling selected out of the total in the service sector. Year 2013 (data in ktoe)



- **relevant heating**
- **heating and cooling excluded**
- **consumption other than heating and cooling**

1.4.2 Demand for heating: sectoral and geographical distribution

The service sector is highly diverse in terms of structure and consumption profile. The following table shows a reconstruction of consumption made by GSE on the basis of detailed assessments made by RSE[11] on each sub-sector, relying on extensive literature[12].

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

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

U. Curdo *Indagine sui consumi e sulla diffusione delle apparecchiature nel settore terziario in Italia*, CESI Rapporto 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.

Ufficio Studi Confcommercio *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 sub-sector (data in ktoe)

	national area (m^2)	consumption for heating (ktoe)
Public administration	72 308 533	964.0
Health service	56 908 138	1 289.4
Leisure time 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 sub-sector, based on:

- Specific consumption parameters, typical of each sub-sector, 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 sub-sectors 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 sub-sector, which are useful to reproportion the provincial data supplied by OlM 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 sub-sector (data in ktoe)

	Public administration	Health	Leisure activities	Education	Hotels	Sports centres	Offices	Retail - Supermarkets	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
Puglia	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 Oil 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: processed Eurostat data

Differently from 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 too include a share for heating (e.g. electrical ovens or heat pumps) but it was decided not to calculate it, as 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 2w.7 Mtoe.

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

	electricity	gas	oil 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

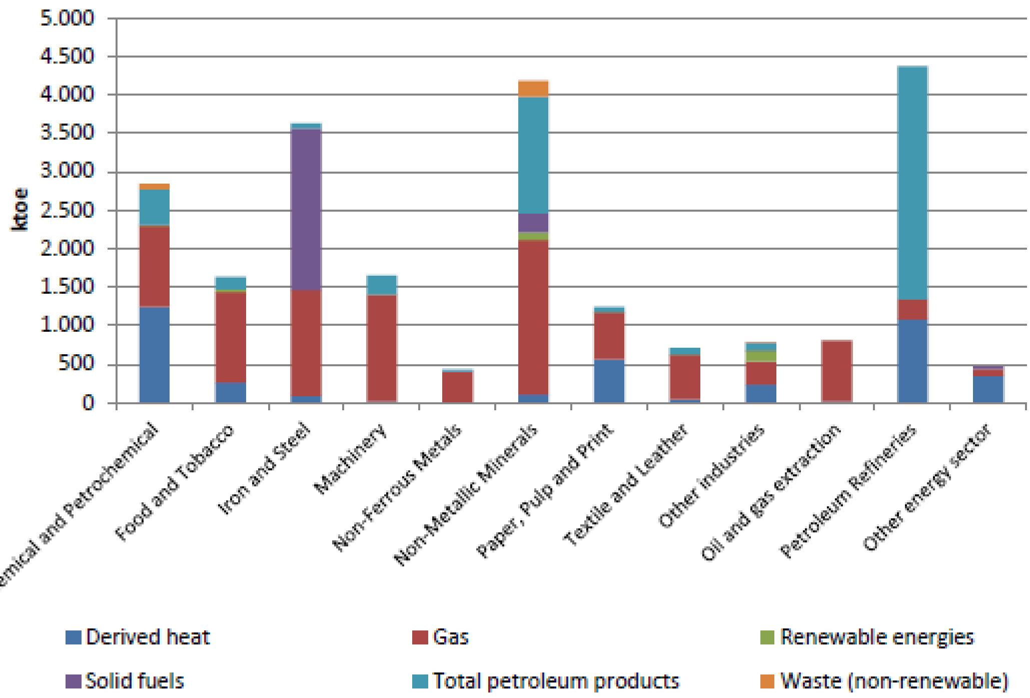
Heating consumption is broken down by sector, as shown in the table and chart below. The highest energy consumption in industry is by refineries, and ceramics and glass works, followed by iron & steel plants and by the chemical and petrochemical industries.

Table 24 - Heating consumption in industry (including the energy industry) in Italy by sub-sector, year 2013 (data in ktoe)

	Derived heat	Gas	Renewable energies	Solid fuels	Total petroleum products	Waste (non-renewable)	TOTAL
Chemical and Petrochemical	1 243.2	1 053.2	6.8	1.4	469.5	71.1	2845.2
Food and Tobacco	265.8	1 173.9	29.7	0	160	0	1629.4
Iron and Steel	87.1	1 375.2	0	2 104.3	66.7	0	3633.3
Machinery	15.4	1 386.6	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	2 004.3	95.7	251.2	1 519.6	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	1 077.8	264	0	0	3 032.9	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: processed Eurostat data

Figure 15 - Heating consumption in industry (including the energy industry) in Italy by sub-sector, 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[13].

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.

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[14]. 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:

[13] http://ec.europa.eu/clima/policies/ets/registry/documentation_en.htm
[14] *Ad hoc* maps on these data are provided in the following paragraphs.

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

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

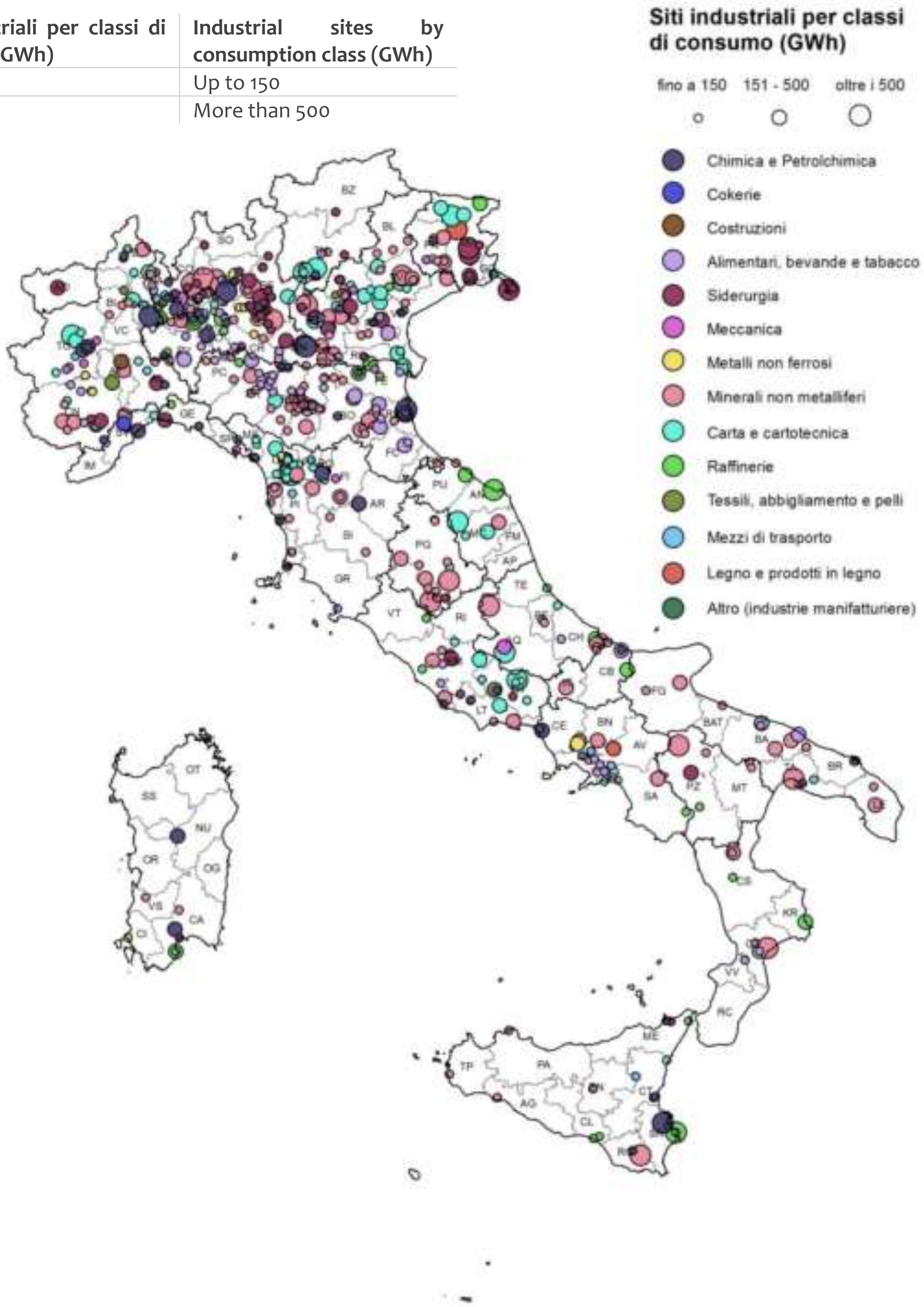
To calculate the average emission factors of the different 'i' average emission factors of the different industrial sectors the following data were used: the fossil fuel mixes by sector taken from the Eurostat energy balances and the specific emission factors of national fuels taken from ISPRA and IPCC.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

Table 25 - Average emission factors by industry sector

Sector	Sub-sector	$FE_k (tCO_2/TJin)$
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

Figure 16 -Industrial sites with total annual consumption of primary energy in excess of 20 GWh

Siti industriali per classi di consumo (GWh)	Industrial sites by consumption class (GWh)
Fino a 150	Up to 150
Oltre I 500	More than 500



	Chimica e Petrolchimica	Chemical and Petrochemical
	Cokerie	Coke Ovens
	Costruzioni	Construction
	Alimentari, bevande e tabacco	Food, Drink and Tobacco
	Siderurgia	Iron and Steel
	Meccanica	Mechanical Engineering
	Metalli non ferrosi	Non-Ferrous Metals
	Minerali non metalliferi	Non-metallic Minerals
	Carta e cartotecnica	Paper, Pulp and Print
	Raffinerie	Refineries
	Tessili, abbigliamento e pelli	Textile, Clothing and Leather

	Mezzi di trasporto	Transport Equipment
	Legno e prodotti in legno	Wood and wood products
	Altro (industrie manifatturiere)	Other (manufacturing industries)

C

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: calculations based on 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

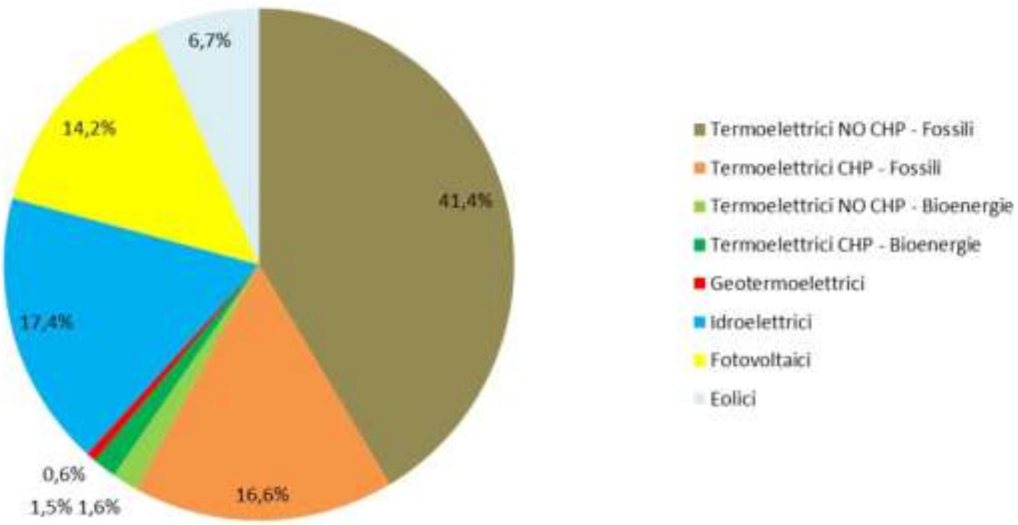
2 Cogeneration in the national stock of power plants

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[15]. 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[16].

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 17 - Breakdown of gross electric output by electrical power stations in 2013 - Total 128,4 GW



- Thermoelectric NO CHP – Fossil Fuels
- Thermoelectric CHP – Fossil Fuels
- Thermoelectric NO CHP – Bioenergy
- Thermoelectric CHP - Bioenergy
- Geothermal electricity
- Hydropower
- Photovoltaic
- Wind turbines

Analysis of the time series of installed capacity shows significant, steady growth over the past 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.

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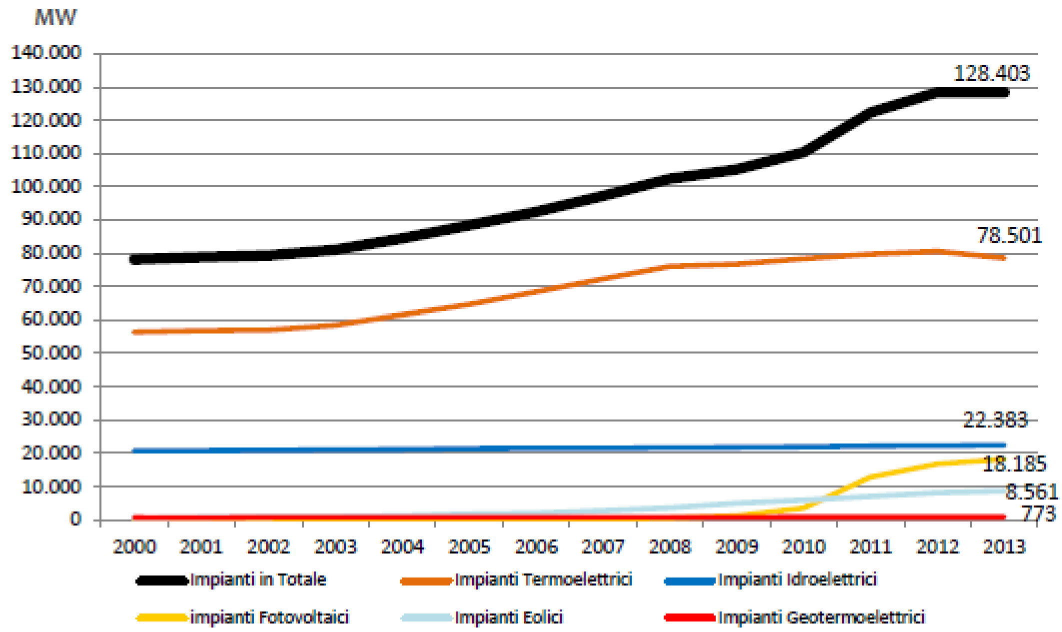
[15] This group includes plants using the following sources: fossil fuels, geothermal energy, bioenergy and waste.

[16] The capacity refers to all the overall capacity of plants that include units which in 2013 produced energy in CHP mode.

Figure 18 - Time series of gross output of electric power plants



Key

- Total power plants
- Thermal power plants
- Hydropower plants
- Photovoltaic plants
- Wind power plants
- Geothermal power plants

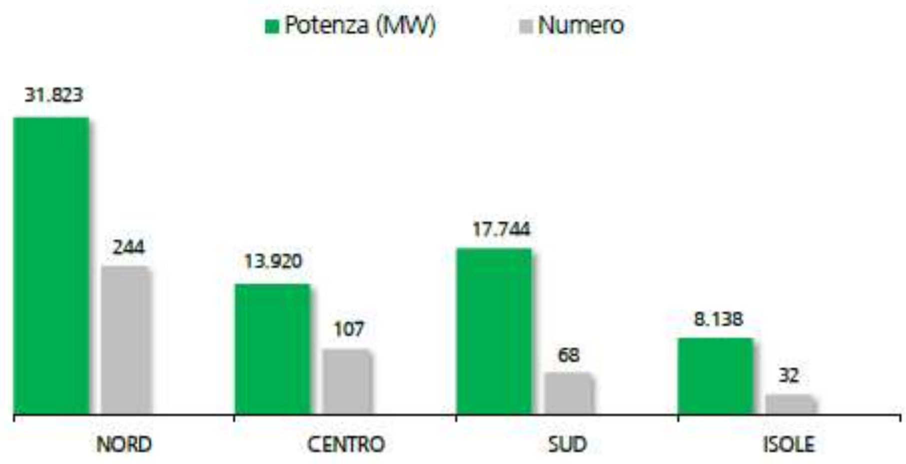
The national peak loads in the order of 55 GW, usually reached in summer, and the thermoelectric power output which last year (2014) dropped below 200 TWh[17], indicate a significant thermoelectric over-capacity, with several stations used mainly for reserve purposes, while others are largely inactive and close to decommissioning.

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 of 71.6 GW (90% of thermoelectric and 56% of the total).

Thermal power stations having a capacity of more than 5MW 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).

[17] 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.

Figure 19 - Geographical distribution of thermal power stations having a power output of more than 5MW. Output and number



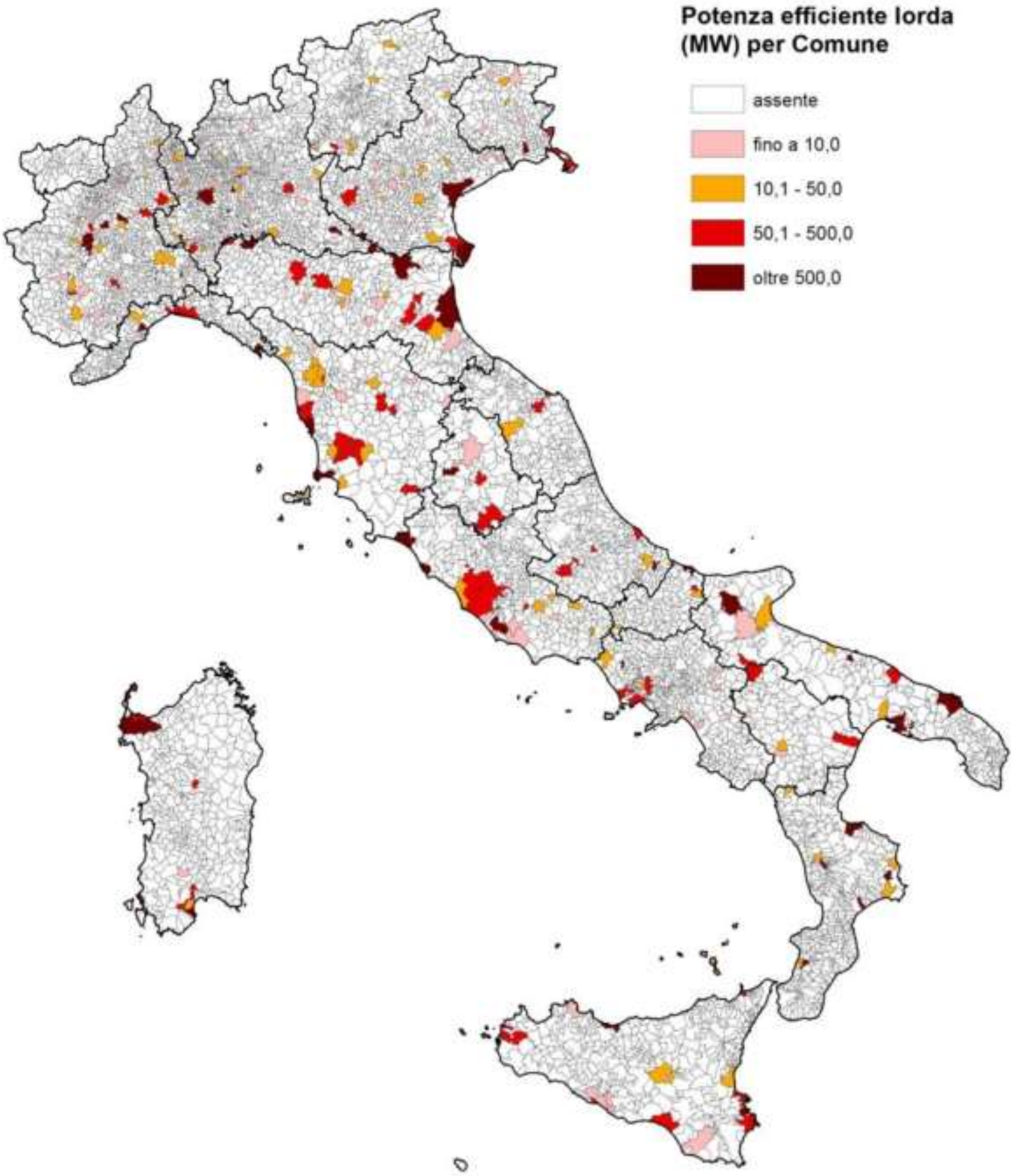
Potenza	Capacity (output)
Numero	Number
NORD	North
CENTRO	Centre
SUD	South
ISOLE	Islands

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 20 - geographical distribution of thermoelectric capacity by plants exceeding 5 MW



	Potenza efficente lorda (MW) per comune	Gross electric output (MW) by municipality
	Assente	None
	Fino a 10,0	up to 10.0
	Oltre 500,0	over 500.0

A look at the map shows that the highest thermoelectric capacity is located in the north of the country, in absolute terms and in terms of geographical concentration. The main reasons include both the greater demand for electricity in northern Italy[18] 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 a fair degree of match between the country's large industrial poles and some of the areas with the greatest thermoelectricity 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).

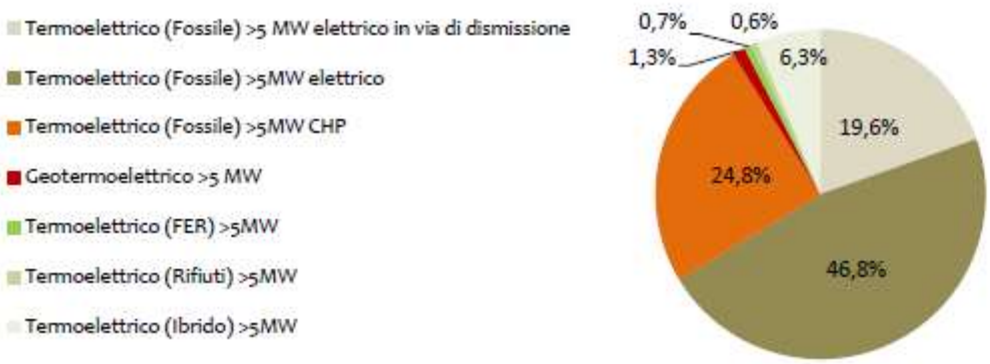
The plants included in the map have a capacity of >5 MWe and use a thermal fuel.

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

- thermoelectric (fossil): plants using fossil fuels such as coal, oil 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 coming from the underground.

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 in 71.6 GW, minus about 20% of plants currently being decommissioned.

Figure 21 - mix of thermoelectric generation> 5MW - Total 71.6 GW



Thermoelectric power (fossil fuels) >5 MW electric being shut down
Thermoelectric power (fossil fuels) >5 MW electric
Thermoelectric power (fossil fuels) >5MW CHP
Geothermal electricity >5MW
Thermoelectric power (RES) >5MW
Thermoelectric power (waste) >5MW
Thermoelectric power (hybrid) >5MW

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

Looking at the energy sources of thermal power stations having a capacity exceeding 5MW we can note that the vast majority (about 90%) uses fossil fuels; a share (25% of total installed capacity) of those plants is used for cogeneration. 1.3% of the thermoelectric capacity mix is made up of geothermal electrical plants, only 0.7% is made up of plants using bioenergies[19] and about 7% waste-to-energy plants and hybrid plants.

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 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 5MW, enabling them to achieve the above-mentioned minimum annual electricity production of 20GWh.

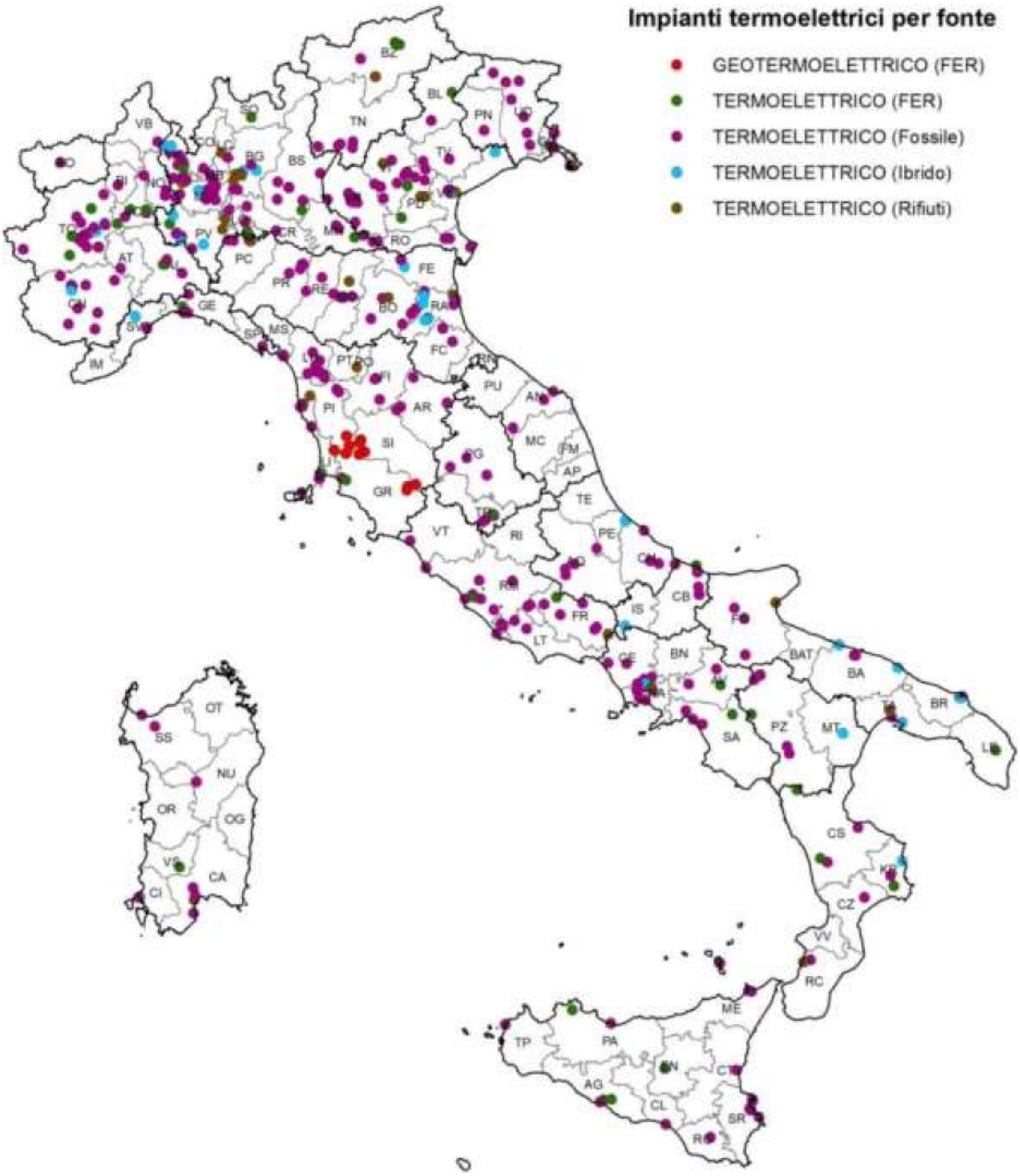
The plants have been characterised by collating and harmonising the data from several database managed by a range of different energy sector players (Terna, GSE, AIRU, Utilities).

The thermal power stations have been characterised in terms of:

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

[19] 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.

Figure 22 - Geographical distribution of thermal power stations having a capacity of more than 5 MW



Thermal power stations by energy source

	GEOTHERMAL ELECTRICITY (RES)
	THERMOELECTRIC POWER (RES)
	THERMOELECTRIC POWER (Fossil)
	THERMOELECTRIC POWER (hybrid)
	THERMOELECTRIC POWER (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.

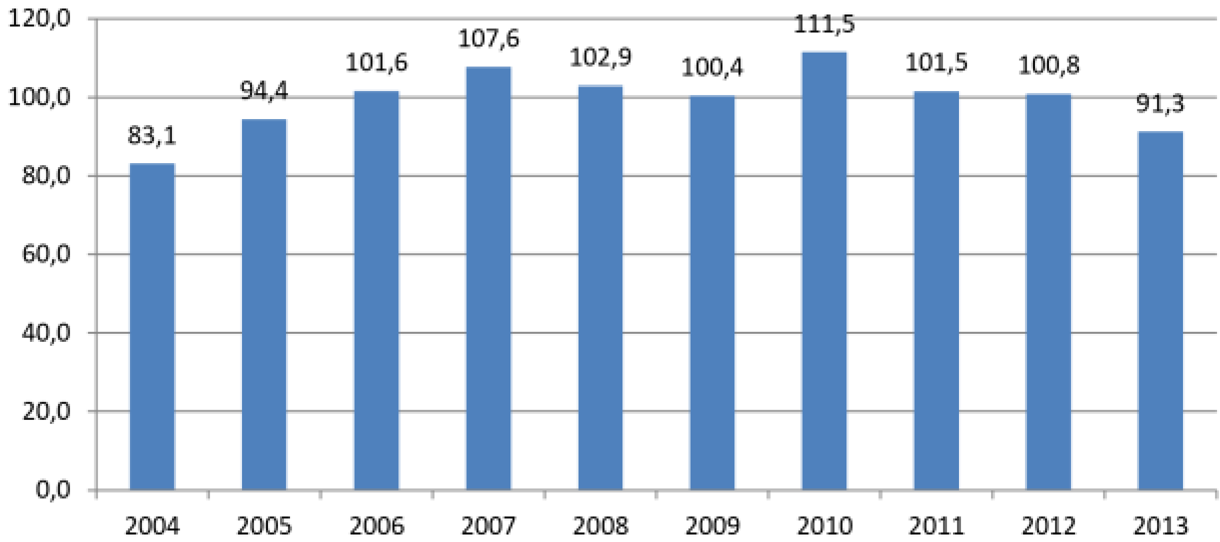
2.2 Cogeneration (CHP) plants

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.

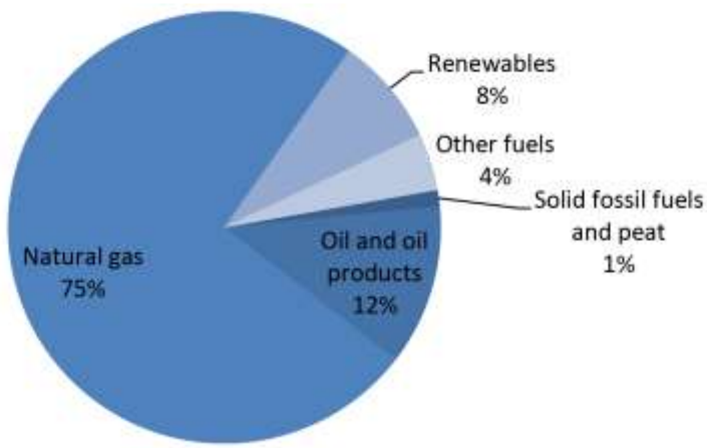
In 2013, electricity generation in CHP plants amounted to 91.3 TWh, based on installed capacity of 23GW.

Figure 23 - Time series of electricity generation by CHP plants (TWhe)



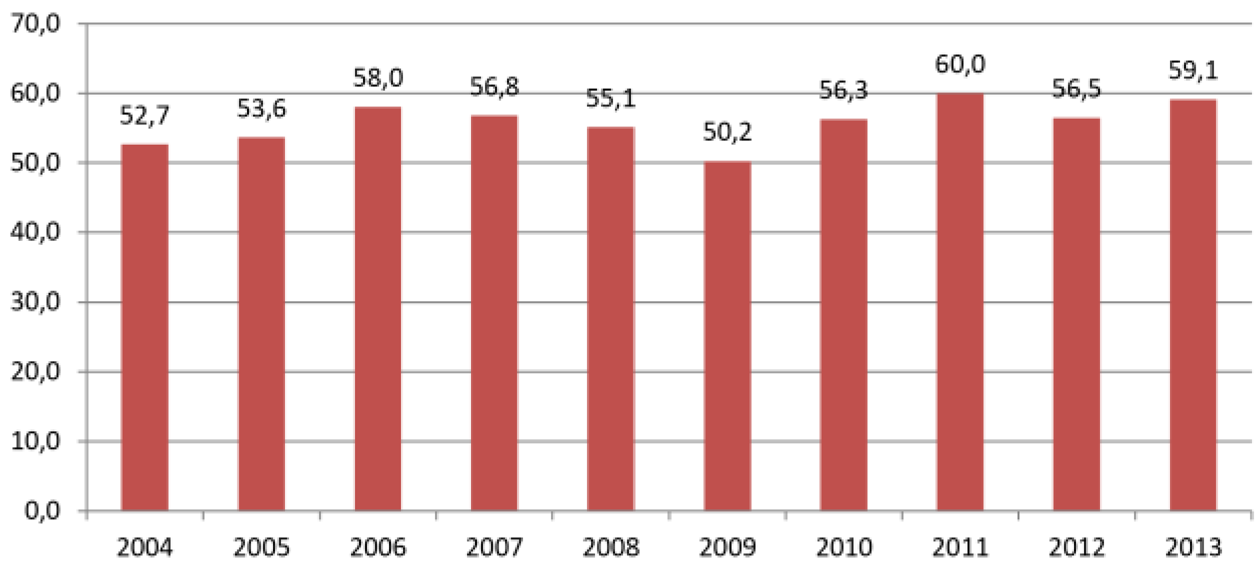
Focusing attention on 2013 we can note that the fuel most used in these plants is natural gas which alone accounts for 75% of gross power generation from CHP.

Figure 24 - Electricity output from CHP plants in 2013 by source - Total 91.3 TWhe



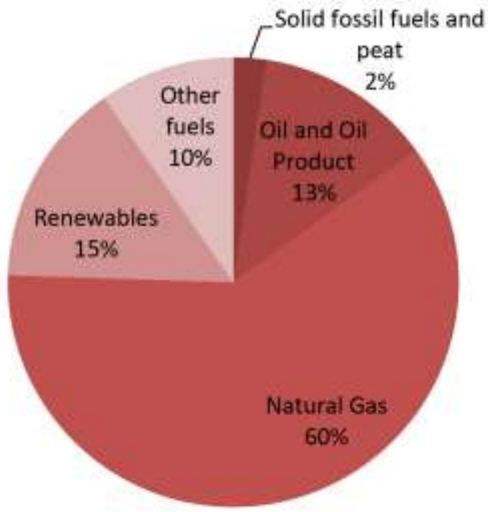
The useful heat from CHP plants in 2013 stood at 59.1 TWht, up from the previous years. The trend observed in individual years is slightly different from that of electricity, but it mirrors the same fluctuations.

Figure 25 – Time series of the useful heat produced by CHP plants (TWht)



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

Figure 26 - 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. Values used for 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 of 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 27 - Time series of “electricity from cogeneration” as defined in Annex 1 to Directive 2012/27/EU (TWh)

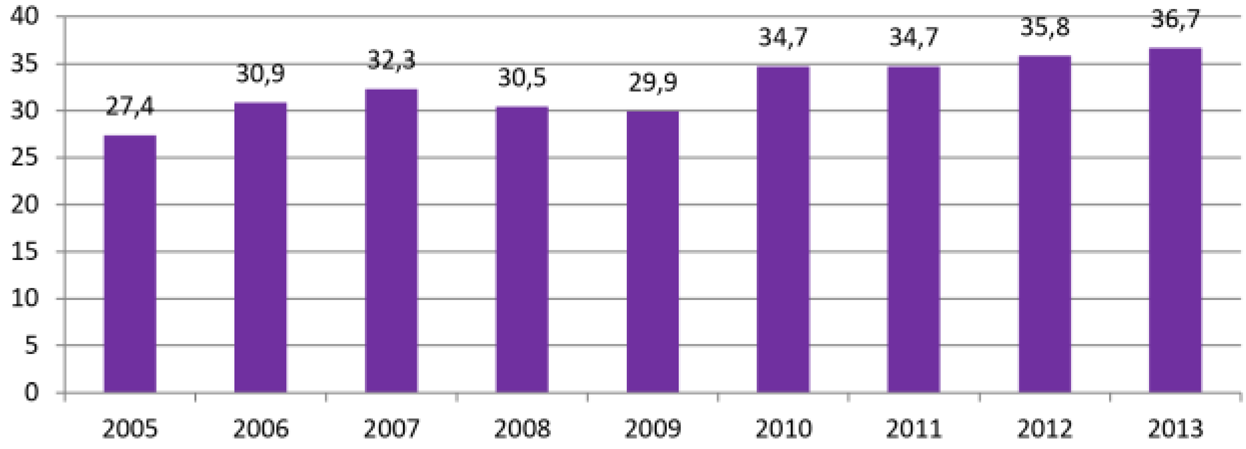
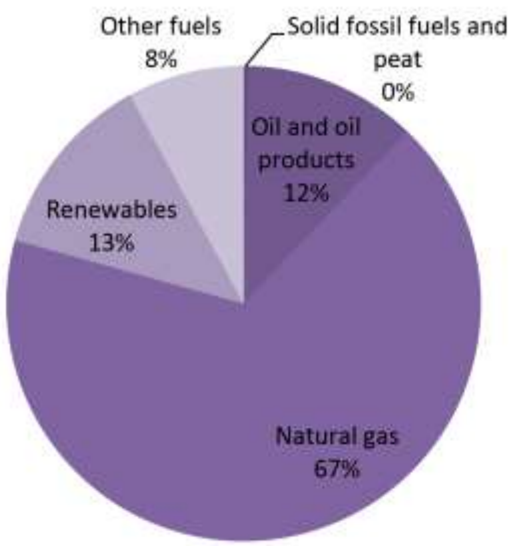


Figure 28 – Production of electricity from cogeneration in 2013 by source – Total 36.7 TWhe



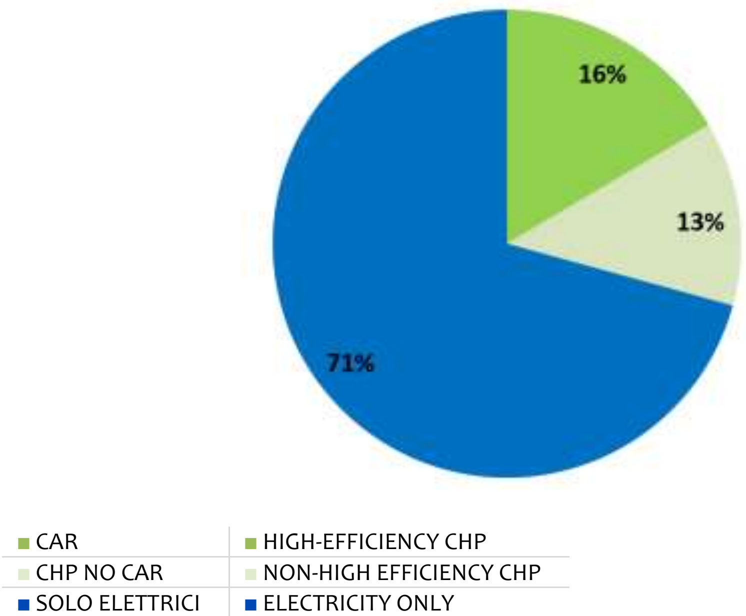
2.3 High-efficiency cogeneration (CHP) plants

The analyses in this paragraph derive partly from calculations made based on the data from applications submitted to GSE, for the energy produced in 2013, for recognition of high-efficiency cogeneration, pursuant to the Ministerial Decree of 4 August 2011, and for recognition of cogeneration, pursuant to Decision AEEG 42/02 for cogeneration units associated with a district heating network, qualified 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 cogeneration production from cogeneration units provides primary energy savings (PES) of at least 10 % compared with the references 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 of cogeneration type, and more than half of this share met the definition of high-efficiency cogeneration.

Figure 29 - Breakdown of thermoelectric output by level of cogeneration



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 a close to 40% of the national thermoelectric capacity.

The thermal power stations producing electricity only are spread quite evenly across the country. On the other hand, high-efficiency CHP plants are more numerous[20] in the north, indicating the link between the development of high-efficiency CHP, the presence of industrial sites and high demand for residential heating.

The following map provides a snapshot of the current spread of cogeneration in Italy. The plants

[20] The capacity refers to all the overall capacity of plants that include units which in 2013 produced energy in CHP mode.

considered have electrical capacity over 5MWe[21] and the operating data for assessing their compliance with high-efficiency cogeneration requirements refer to the year 2013.

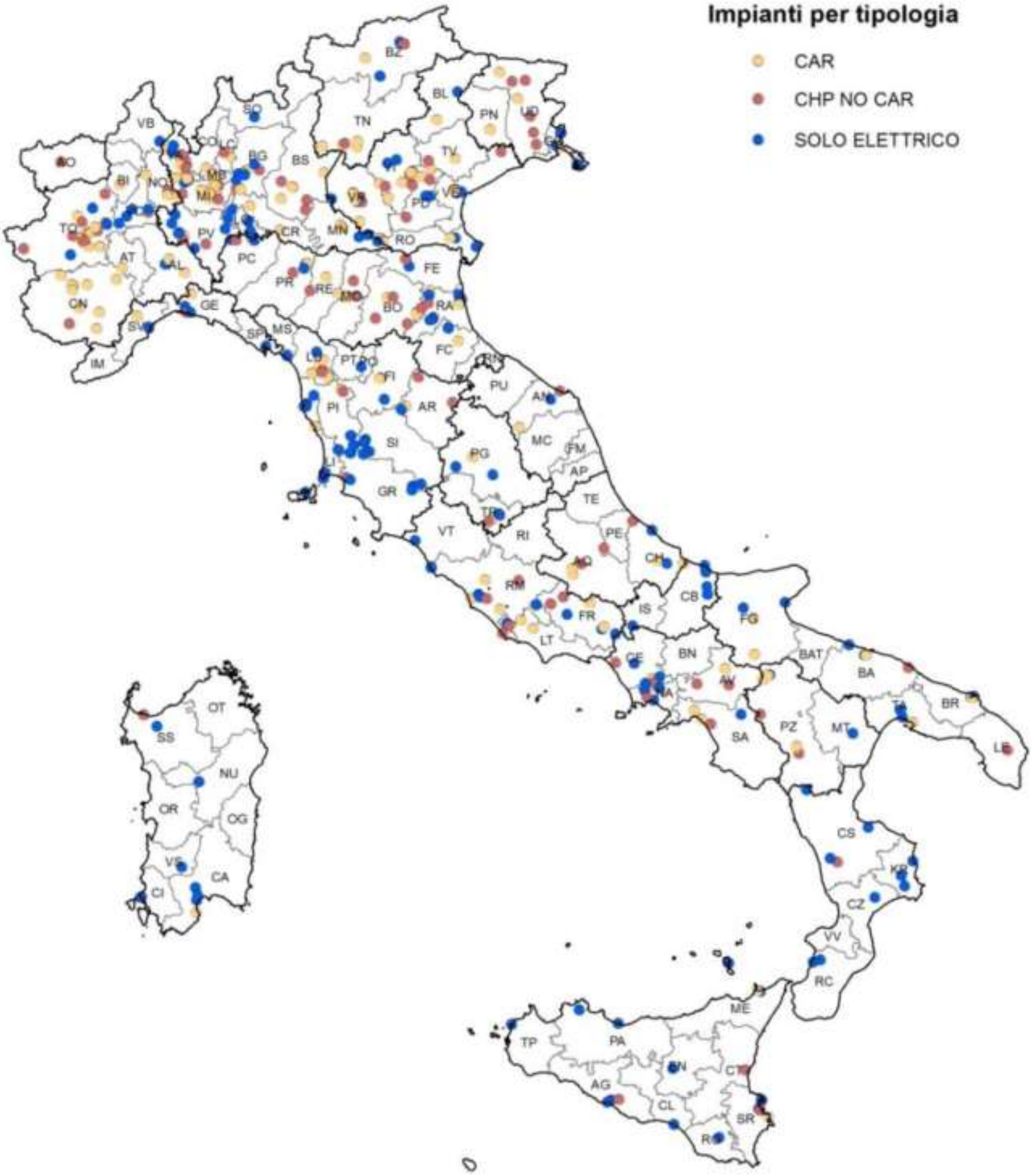
Plants have been classed with regard to cogeneration as follows:

- Electricity only: producing only electricity
- Non-high-efficiency CHP: plants producing both electricity and heat but which in 2013 did not meet the requirements for classification as high-efficiency CHP22
- High-efficiency CHP: plants which in 2013 produced electricity and heat in accordance with high-efficiency requirements.

[21] 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.

[22] 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 30 – Map of the thermal power having a size greater than 5 MWe, classed as to cogeneration



Plants by type

- HIGH-EFFICIENCY CHP
- NON HIGH-EFFICIENCY CHP
- ELECTRICITY ONLY

2.3.1 High-efficiency 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 which applied to GSE for recognition as high-efficiency units. The electricity produced in high-efficiency cogeneration more 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 31 – Number of units (100%=1.025 units)

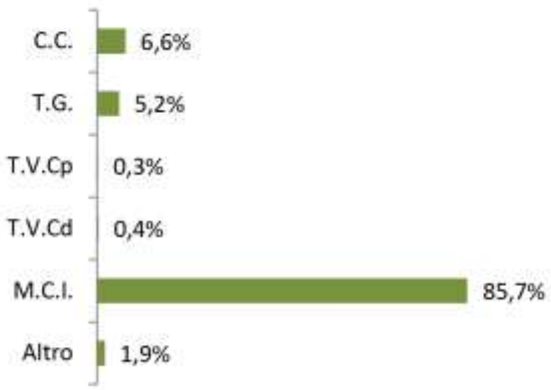
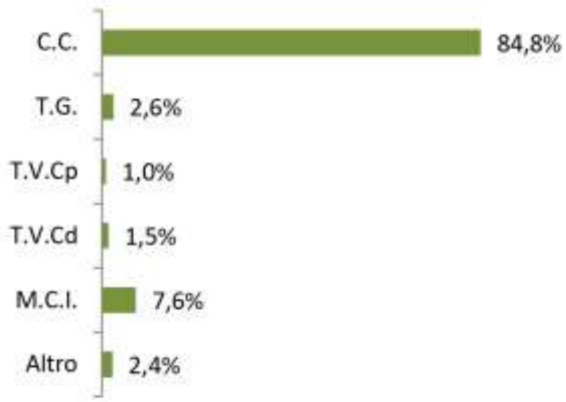


Figure 32 – Generation capacity (100%=13.087 MW)



C.C.	CC
T.G.	GT
T.V.Cp	SBPT
T.V.Cd	SCET
M.C.I.	ICE
Altro	Other

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 greatest contributors to the production of electricity and heat are certainly 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 33 - "Gross" Electricity (100% = 55.019 GWhe)

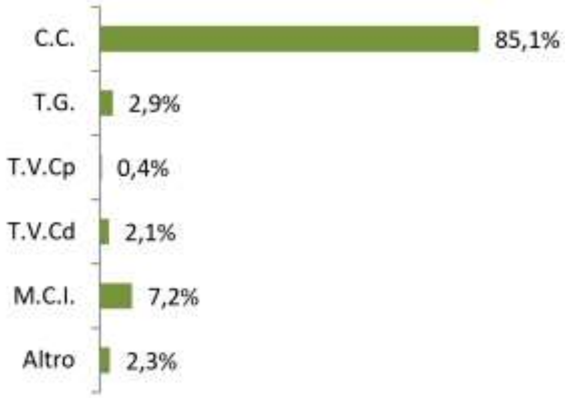
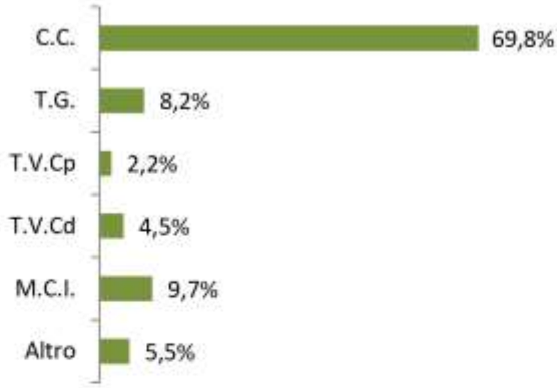


Figure 34 - Useful heat (100% = 31.331 GWht)

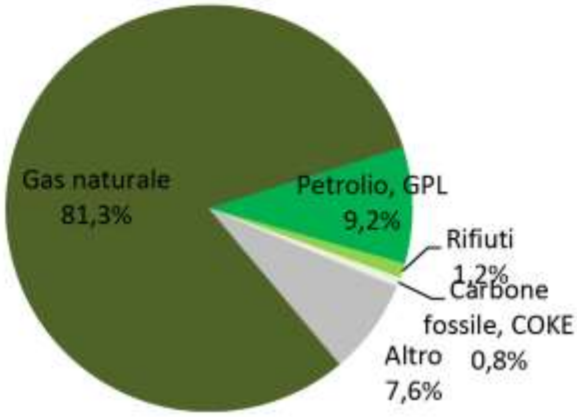


C.C.	CC
T.G.	GT
T.V.Cp	SBPT
T.V.Cd	SCET
M.C.I.	ICE
Altro	Other

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



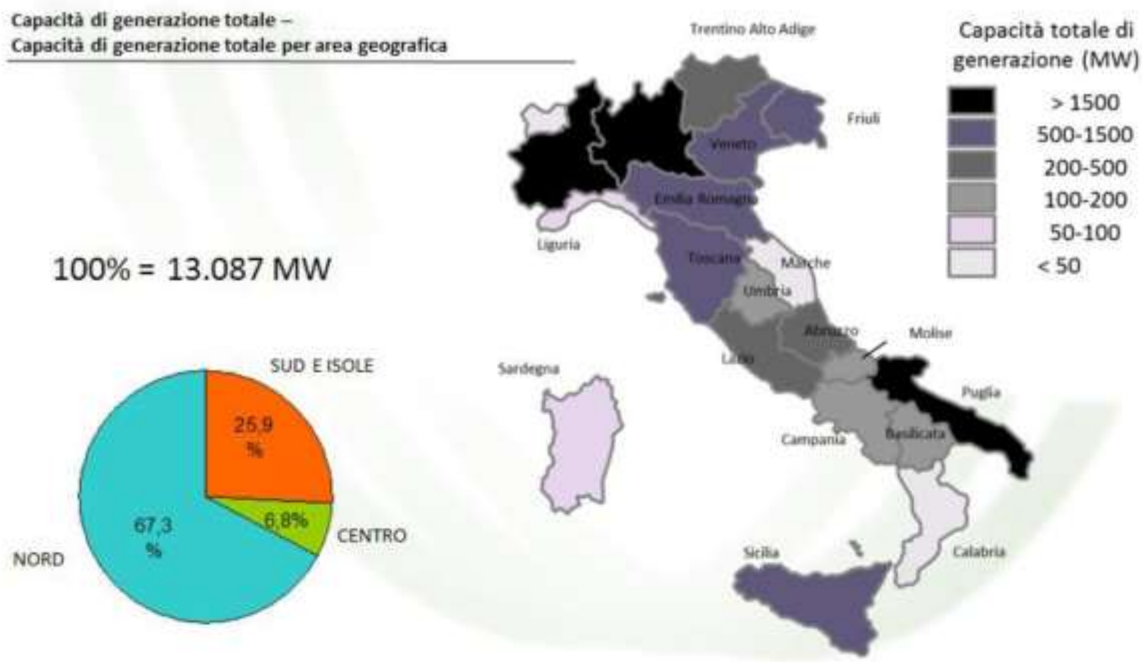
Gas naturale	Natural gas
Petrolio, GPL	Oil, LPG
Carbone fossile, coke	Coal
Altro	Other

2.3.2 High-efficiency CHP: geographical 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 36 - 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)

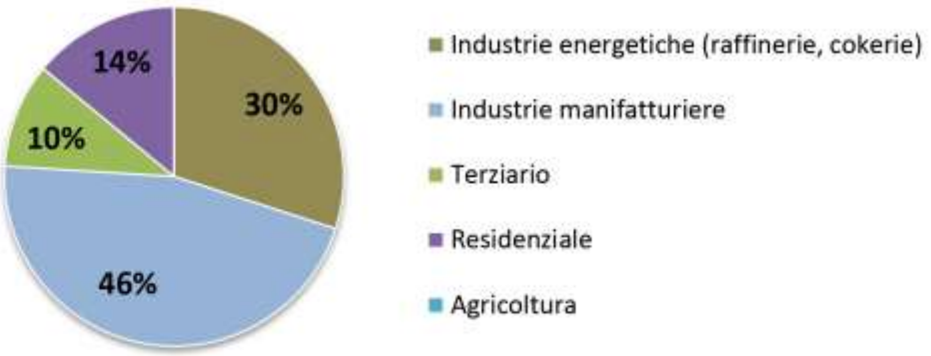
NORD	**NORTH**
CENTRO	**CENTRE**
SUD E ISOLE	**SOUTH AND ISLANDS**

2.3.3 High-efficiency 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); 24% by the residential and service sectors, mostly via district heating infrastructure[23].

Figure 37 - Breakdown of the final uses of the heat produced by high-efficiency CHP per sectors

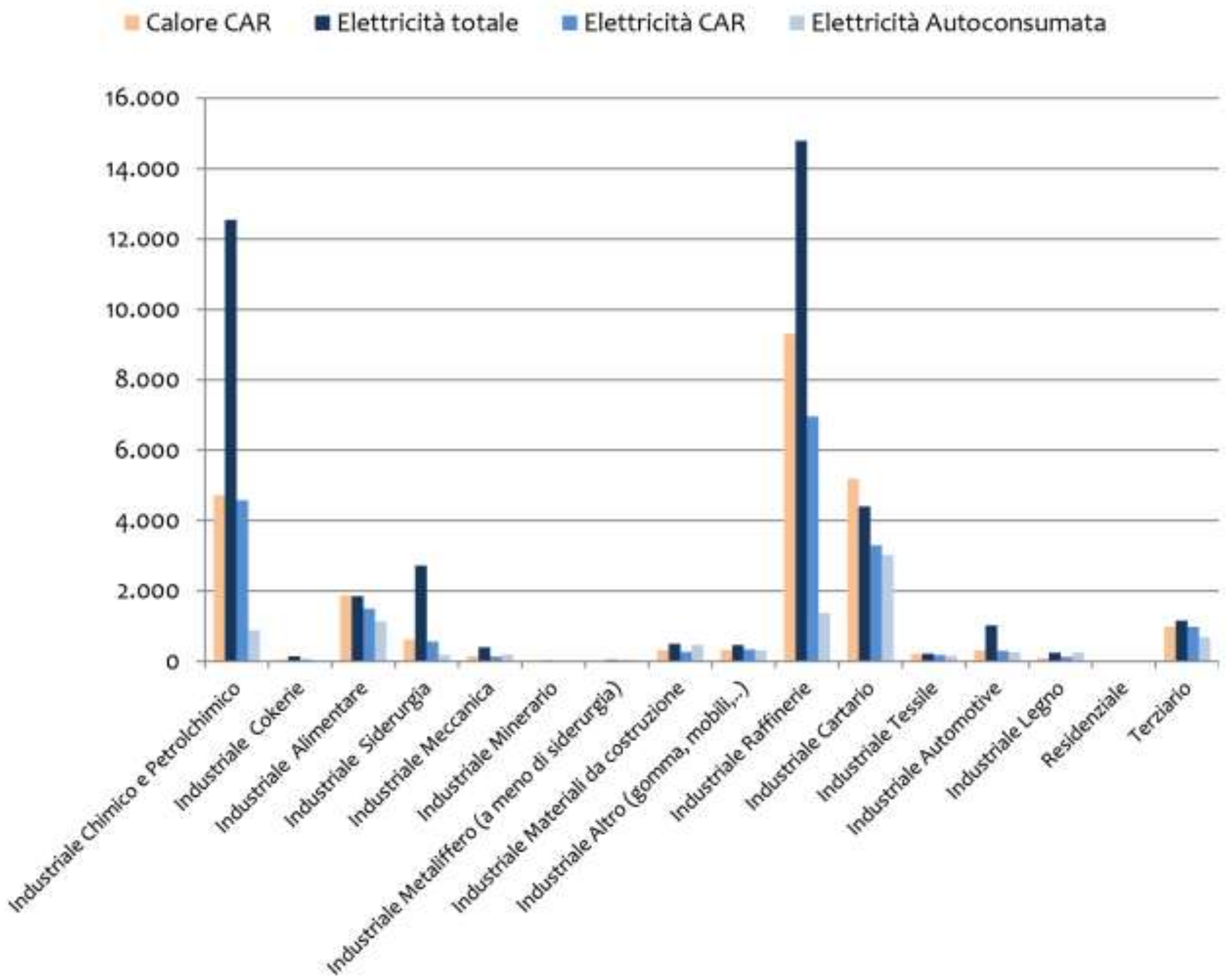


- Energy industries (refineries, coke ovens)
- Manufacturing industries
- Services
- Residential
- Agriculture

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.

[23] 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 38 - Electricity (total produced, produced by high-efficiency CHP, self-consumed) and useful heat from individual high-efficiency CHP units[24] by sector



Calore CAR	Heat from high-efficiency CHP
Elettricità totale	Total electricity
Elettricità CAR	Electricity from high-efficiency CHP
Elettricità Autoconsumata	Self-consumed electricity
Industriale Chimico e Pretrolchimico	Industrial Chemical and Petrochemical
Industrial Cokerie	Industrial Coke Ovens
Industriale Alimentare	Industrial Food
Industriale Siderurgia	Industrial Iron and Steel
Industriale Meccanico	Industrial Mechanical Engineering
Industriale Minerario	Industrial Mining
Industriale Metallifero (a meno di siderurgia)	Industrial Metal processing (except for iron and steel)
Industriale Materiali da costruzione	Industrial Building materials
Industriale Altro (gomma, mobili,..)	Industrial Other (rubber, furniture,…)
Industriale Raffinerie	Industrial Refineries
Industriale Cartario	Industrial Paper
Industriale Tessile	Industrial textiles
Industriale Automotive	Industrial Automotive
Industriale Legno	Industrial Wood
Residenziale	Residential
Terziario	Services

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

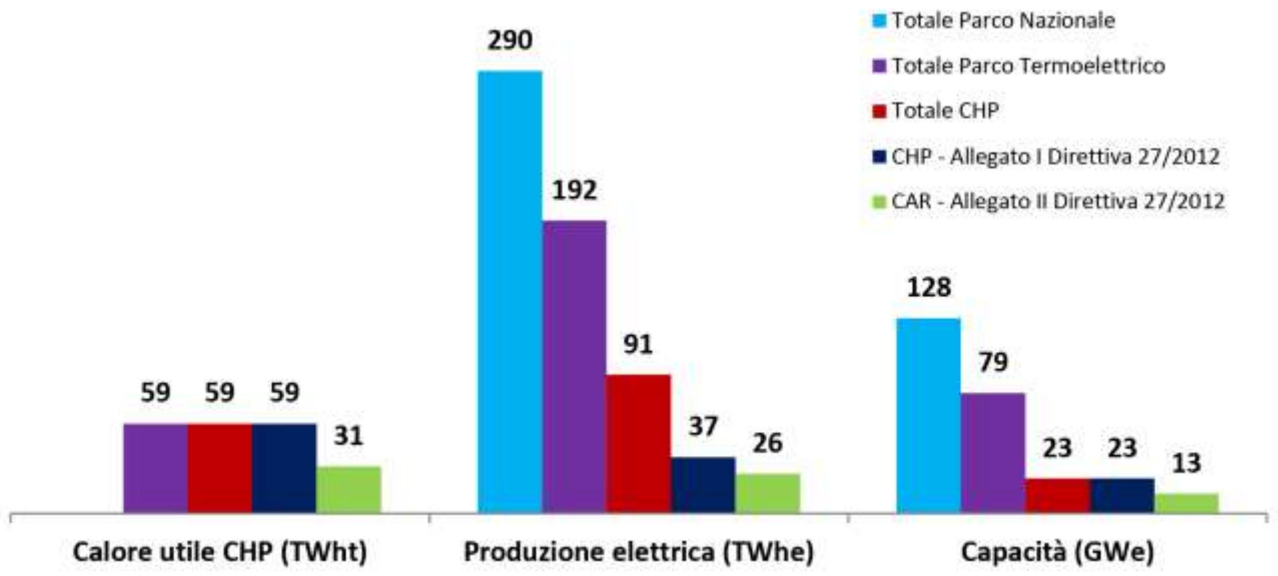
2.4 Overview of the national stock of power plants

This paragraph 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 more is 26 TWhe.

Figure 39 - Summary diagram of the national stock of thermal power stations, specifying capacity[25] (GWe), electricity production (TWhe) and useful heat (TWht)



Calore utile CHP (TWht)	**Useful heat CHP (TWht)**
Produzione elettrica (TWhe)	**Electricity production (TWhe)**
Capacità (GWe)	**Capacity (GWe)**

- Total National Stock
- Total Stock of Thermal Power Stations
- Total CHP
- CHP – Annex I Directive 2012/27/EU
- High-efficiency CHP – Annex II Directive 2012/27/EU

[25] The capacity refers to all the overall capacity of plants that include 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 or process heating and for domestic hot water supply.[26]

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 which 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-sized.

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

In 2013, the thermal energy produced from plants serving district heating networks amounted to 11 270 GWh, while the thermal energy supplied to customers amounted to 9 331 GWh and losses during heat distribution were of 1 938 GWh (17% of the energy produced).

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

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

Table 28 - Overview of the district heating networks present in Italy in 2013

Municipalities with district heating	**Number**	**199**		
Total heated space*	**Mm3**	**302**		
Length of distribution networks*	**km**	**3 807**		
Thermal energy supplied	**MWht**	**9 331 310**		
Residential	"	5 988 980	% of total	64%
Services	"	2 677 505	"	29%
Industrial	"	209 512	"	2%
Process uses	"	455 313	"	5%
Cooling supplied*	**MWht**	**101 608**		
Services	"	99 832	% of total	98%
Residential	"	1 337	"	1%
Industrial	"	439	"	0%
Losses	**MWht**	**1 938 267**	% of produced energy	17%
Thermal energy produced	**MWht**	**11 269 578**		
FOSSIL FUEL no CHP	"	2 533 322	% of total	22%
FOSSIL FUEL CHP	"	5 558 365	"	49
RES non CHP	"	1 209 271	"	11%
RES CHP	"	441 811	"	4%
*WASTE non CHP***	"	5 006	"	0%
*WASTE CHP***	"	1 521 802	"	14%
Efficient plants	**Number**	**153**	**MWht**	**8 141 830**
RES>50%	"	113	"	1 482 006
CHP > 75%	"	18	"	5 104 773
BOTH CHP > 75 % AND RES > 50%	"	13	"	236 764
COMBINATION > 50%	"	9	"	1 318 288
Non-efficient plants	**Number**	**46**	**MWht**	**3 127 747**

* Source: only AIRU

** Where necessary for calculations, the biodegradable share of waste was considered equal to 50%

The existing district heating networks are almost solely located in the north of the country. Of these, 63% is located in three regions (Piedmont, Lombardy, Trentino Alto Adige) where 78% of the thermal energy from district heating is located. As to Central Italy, a significant exception is Tuscany, where district heating networks distribute geothermal heat, which abounds in part of the Region. Again in Central Italy, other district heating networks are to be found in the town of Osimo (province of Ancona) and in a district of Rome.

3.1 Sectors of use

Ninety-five percent 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.

Below is the breakdown by sector of the energy delivered for space heating and DHW production. A few district heating networks differ from the rest in that they supply thermal energy to more than one sector at once. As shown in the figure below, the thermal energy for space heating and DHW production is mainly delivered to the residential sector, while just a small fraction goes to the industrial sector.

Figure 40 – Thermal energy delivered by sector in 2013 (HEATING + DHW)

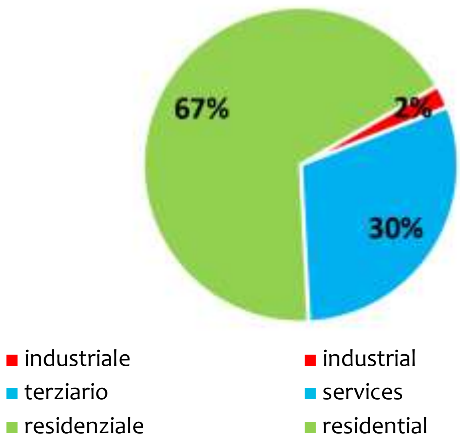
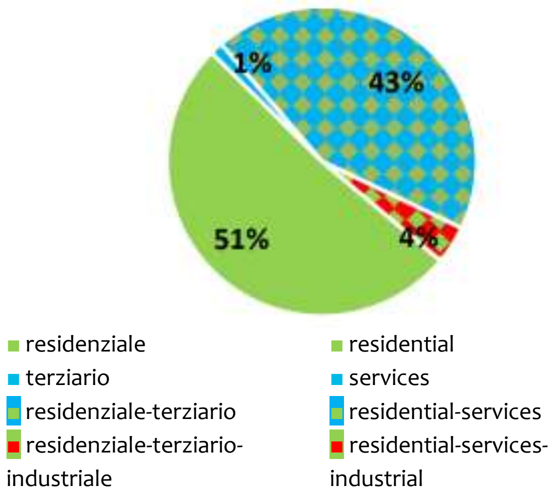


Figure 41- Thermal energy delivered by main sector or groups of sectors in 2013

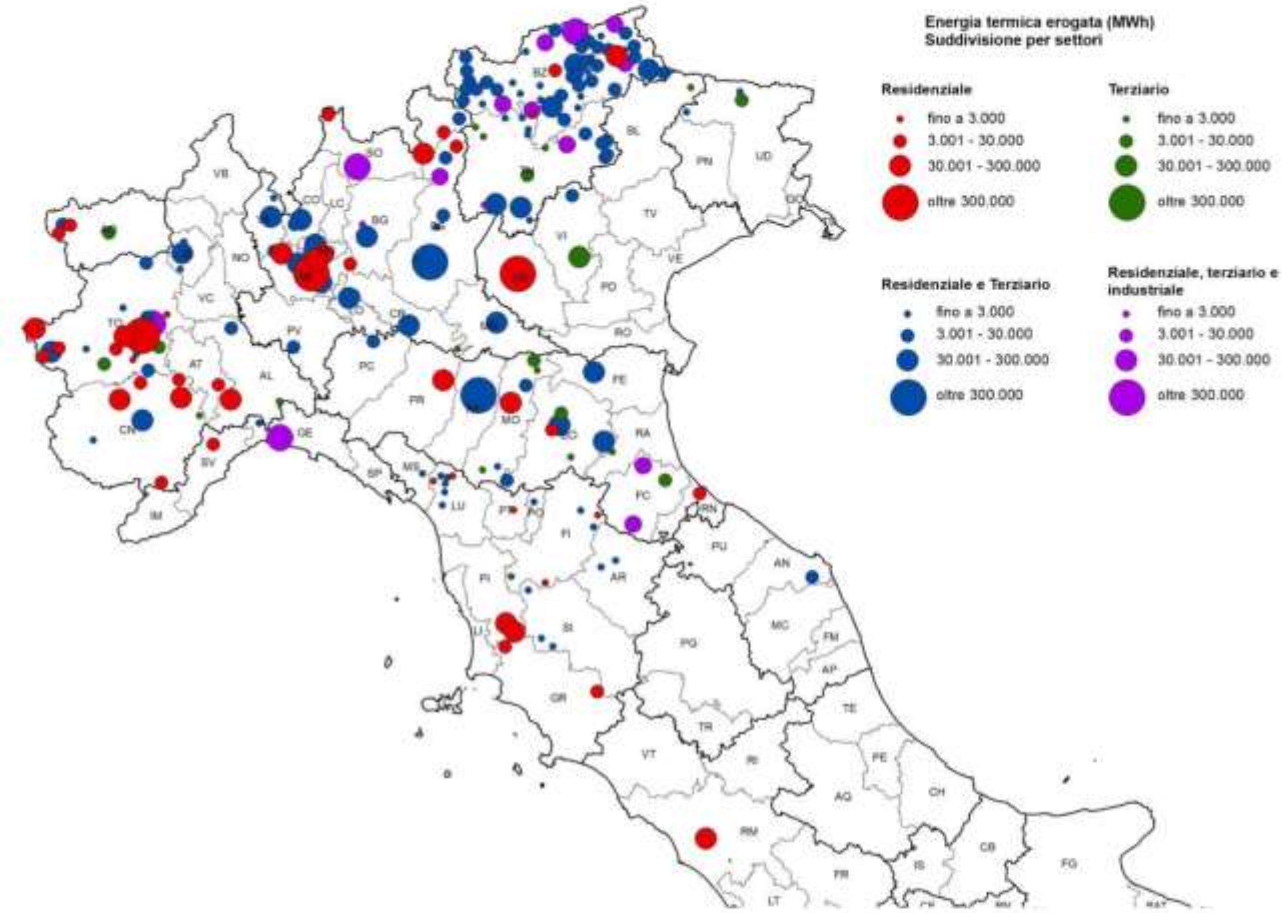


In the national district heating user market, the share of the service sector is sizeable: more than 30% of the energy delivered both by the most developed networks (Turin, Brescia, Milan, Reggio Emilia, Verona) and by some of the many small networks in the province of Bolzano goes to this sector. In any case, the presence of significant demand for thermal energy by the residential sector remains a precondition for the development of district heating, since only a tiny fraction of networks supplies primarily service sector customers (about 1% of all networks).

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

- Residential 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 42 - Geographical distribution of the thermal energy delivered by district heat networks - Breakdown by main sector (year 2013)

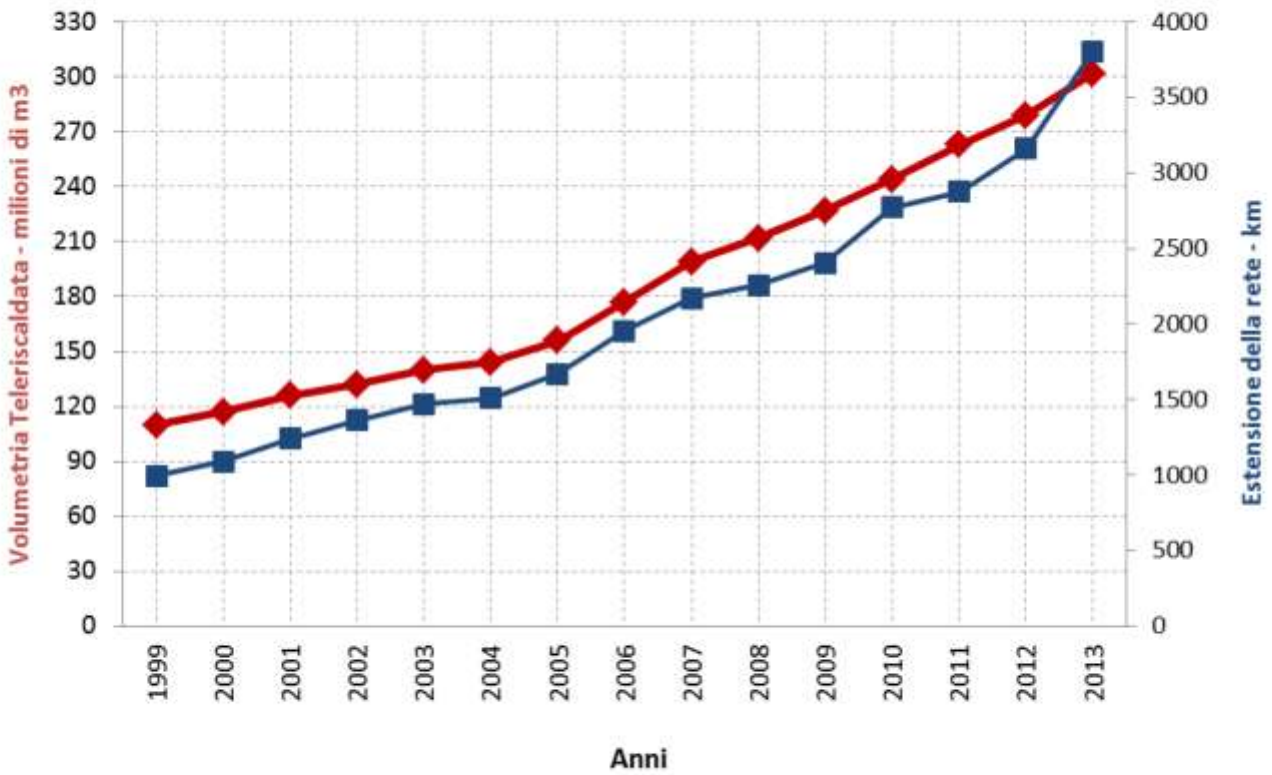


Energia termica erogata (MWh) Suddivisione per settori	Thermal energy delivered (MWh) Breakdown by sector
■ **Residenziale** Fino a 3 000 Oltre 300 000	■ **Residential** Up to 3 000 More than 300 00
■ **Terziario** Fino a 3 000 Oltre 300 000	■ **Services** Up to 3 000 More than 300 00
■ **Residenziale e Terziario** Fino a 3 000 Oltre 300 000	■ **Residential and services** Up to 3 000 More than 300 00
■ **Residenziale, terziario e industriale** Fino a 3 000 Oltre 300 000	■ **Residential, services and industrial** Up to 3 000 More than 300 00

3.2 Evolution of district heating in Italy

Over the past 15 years, district heating has advanced steadily in Italy. As shown by the chart below, between 1999 and 2013 the space heated has increased by 175% overall, while the length of the networks has increased by 282%. According to the data published in the AIRU yearbook, accompanied by information held by GSE, at the end of 2013, 302 million m^3 of demand points were served by district heating networks having a total length of more than 3 800 km.

Figure 43 - Progression in the volume heated and length of district heating networks



Volumetria Teleriscaldata – milioni di m^3	**Building volume heated by DH – million m^3**
Estensione della rete – km	**Length of network – km**
Anni	**Years**

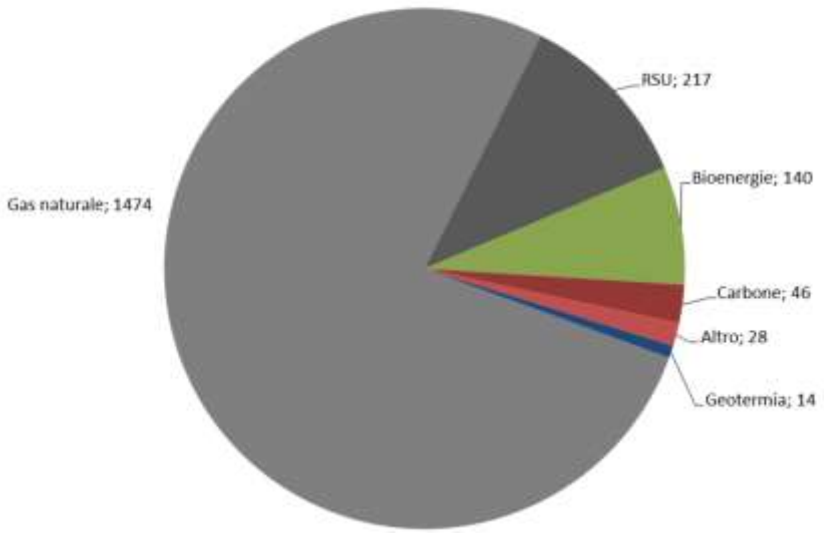
The development of district heating in Italy started later than in other European countries. The causes of this initial delay are mainly the national climate, on average less cold than that of countries where DH developed earlier, and the methane supply programme, launched in the 1950s in Northern Italy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

The earliest DH projects were implemented in the 1970s, with the networks in Modena (Quartiere Giardino, 1971), Brescia (1972), Mantua (1972), Verona (Forte Procolo, 1973), Reggio Emilia (Rete 1 and Pappagnocca, 1979). Among these, the Brescia network developed fastest, reaching in 1990 20 million m^3 served by DH, making up half of the total volume heated by DH in Italy at the time. In the 1980s and 1990s new networks were commissioned in a number of Italian cities, some small and linked to specific residential developments (Rome), while others consisted of large-scale projects to supply DH to entire city districts (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 Energy sources and technologies

The energy inputted into the district heating networks in the national territory in 2013, amounted to 1 919 ktoe in total. Together, renewable sources make up 19% of the total, fossil fuels 81%, or 1 547 ktoe. The main source used is natural gas, with 1 474 ktoe or 77% of total input. Municipal solid waste comes second (11.3%) with 217 ktoe, including both the biodegradable and the non-biodegradable portion. Biomass, solid, liquid and gaseous, makes up 7.3% of total input, while coal and geothermal sources are far less important, contributing respectively 2.4% and 0.8%.

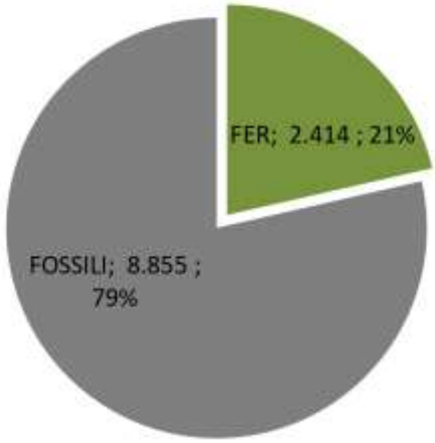
Figure 44 - Energy sources used for district heating networks in 2013 (ktoe)



Gas naturale	Natural gas
RSU	Municipal solid waste
Bioenergie	Bioenergy
Carbone	Coal
Altro	Other
Geotermia	Geothermal sources

The thermal energy produced by the plants serving the district heating networks in Italy in 2013 amounted to about 11 270 GWht, of this, 79% comes from fossil fuels and the remaining 21% from RES (including in both cases the respective share of waste).

Figure 45 - Thermal energy produced by plants serving district heating networks (GWht and %)



FOSSILI	FOSSIL FUELS
FER	RES

The networks using RES, while of small size, are quite numerous; they account for 59% of the number of existing networks[27].

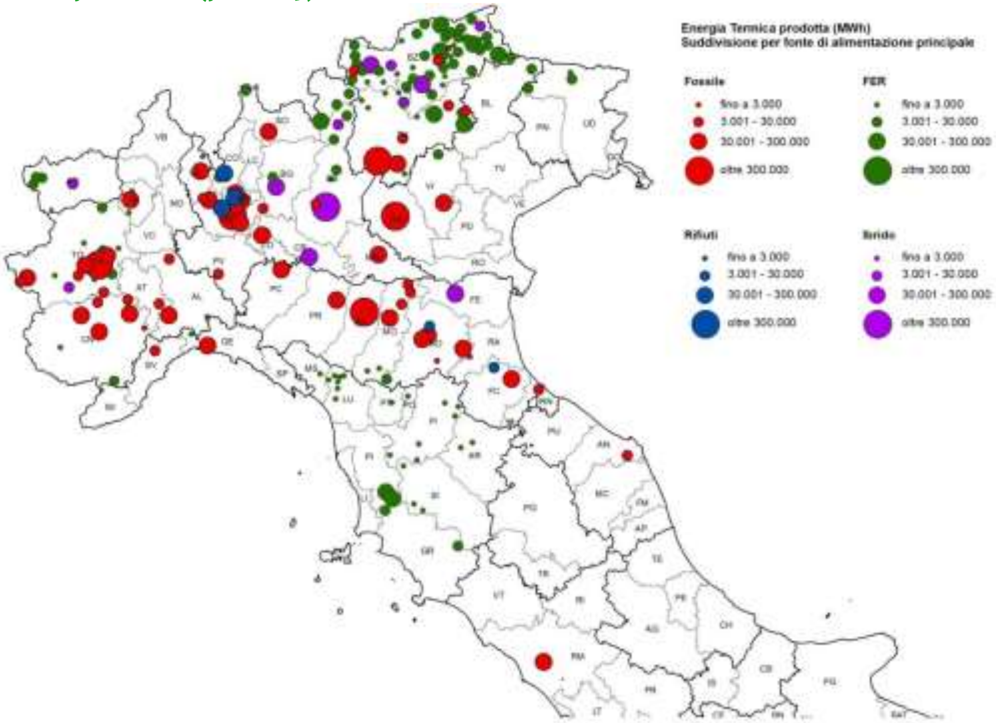
As shown by the following map, most of the networks using RES are located in mountain areas (especially Trentino Alto Adige), where methane-based networks are less developed and the availability of biomass is greater. District heating networks using RES are also found in Tuscany, where the main source 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 delivered by the 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%.

[27] Within this share, 32% use RES only, while the remaining 27% use mostly RES (>70%).

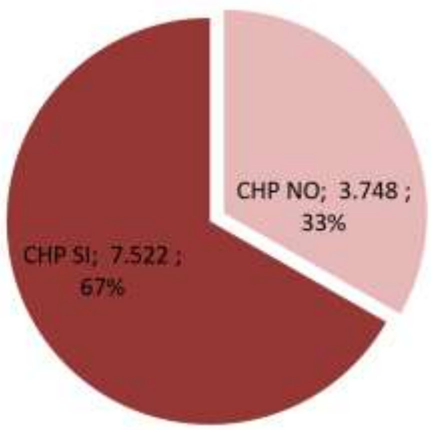
Figure 46 - Geographical distribution of the thermal energy produced by plants serving district heating networks - Breakdown by main fuel (year 2013)



Energia Termica prodotta (MWh)	Thermal energy produced (MWh)
Suddivisione per fonte di alimentazione principale	**Breakdown by main fuel**
Fossile Fino a 3 000 oltre 300 000	**Fossil** Up to 3 000 over 300 000
Fer Fino a 3 000 oltre 300 000	**RES** Up to 3 000 over 300 000
Rifiuti Fino a 3 000 oltre 300 000	**Waste** Up to 3 000 over 300 000
Ibrido Fino a 3 000 oltre 300 000	**Hybrid** Up to 3 000 over 300 000

As to technologies used, 67% of the energy (7 522 GWht) was produced in cogeneration plants.

Figure 47 - Thermal energy (GWht) produced by plants serving district heating networks - Breakdown CHP/NON-CHP (year 2013)

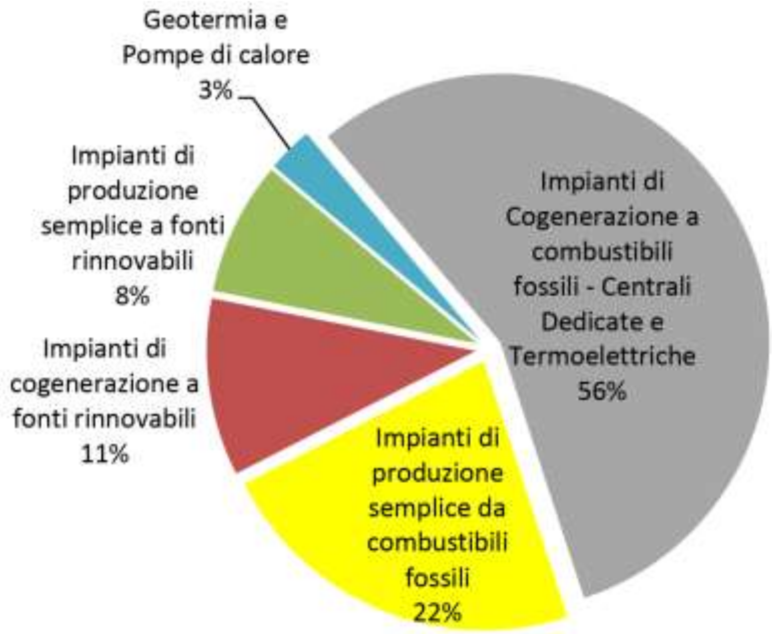


CHP NO	NON-CHP
CHP SI	CHP

Fifty-six percent of the thermal energy distributed through district heating networks is produced in cogeneration installations using fossil fuels in dedicated units or in thermal power stations. The backup energy produced by means of simple fossil-fuel boilers makes up 22%. Clearly, most of the energy from fossil fuels comes from cogeneration installations (71% of total fossil fuels).

Considering the plants using renewable sources, including the biodegradable portion of waste, 11% of the energy is produced by cogeneration installations using biomass, 8% by non-CHP plants using biomass and 3% by geothermal systems and heat pumps.

Figure 48 - Thermal energy produced by production technology (year 2013)

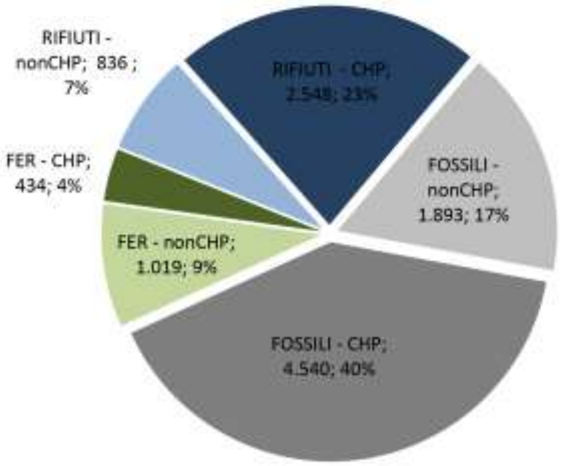


Key

Geotermia e Pompe di calore	Geothermal units and heat pumps
Impianti di produzione semplice a fonti rinnovabili	Simple production units using renewable sources
Impianti di cogenerazione a fonti rinnovabili	Cogeneration plants using renewable sources
Impianti di produzione semplice da combustibili fossili	Simple production units using fossil fuels
Impianti di Cogenerazione a combustibili fossili – Centrali Dedicate e Termoelettriche	Cogeneration plants using fossil fuels – Dedicated plants and thermal power stations

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 49 - Thermal energy produced (GWht) by source and type of CHP and non-CHP plant (year 2013)



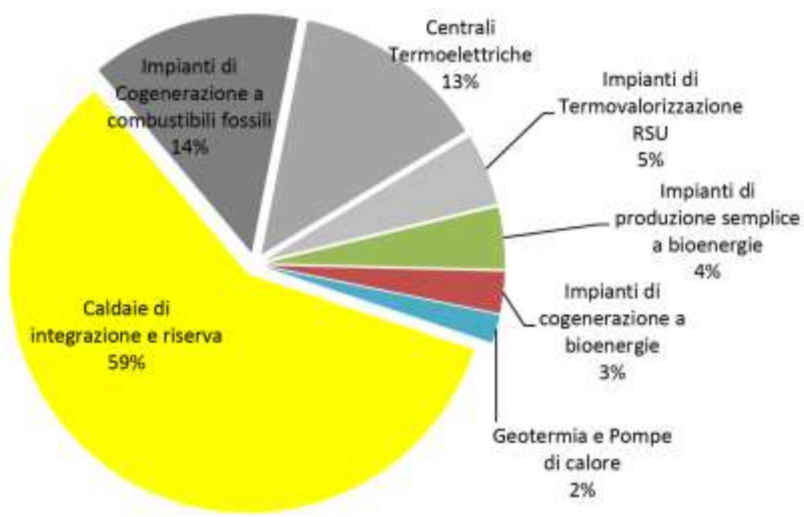
RIFIUTI – nonCHP	WASTE – non-CHP
FER – CHP	RES – CHP
FER –nonCHP	RES –non-CHP
FOSSILI – CHP	FOSSIL FUELS – CHP
FOSSILI – nonCHP	FOSSIL FUELS – non-CHP
RIFIUTI – CHP	WASTE - CHP

As to the thermal capacity of the plants installed in Italy and serving district heating networks, this amounts to 8 056 MW thermal[28].

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.

[28] Data applying to the group of plants surveyed by AIRU.

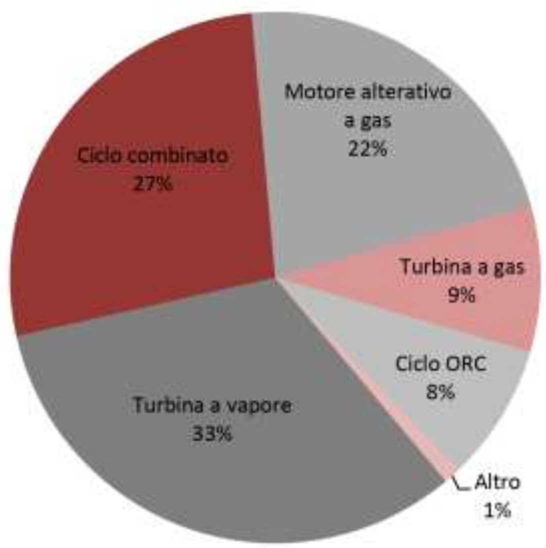
Figure 50 - Thermal capacity serving district heating - Distribution of plants by type (year 2013)



Impianti di Cogenerazione a combustibili fossili	Cogeneration plants using fossil fuels
Caldaie di intergrazione e riserva	Backup boilers
Geotermia e Pompe di calore	Geothermal units and heat pumps
Impianti di cogenerazione a bioenergie	Cogeneration plants using bioenergies
Impianti di produzione semplice a bioenergie	Simple generation units using bioenergies
Impianti di Termovalorizzazione RSU	Waste-to-energy systems using municipal solid waste
Centrali Termoelettriche	Thermal power plants

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

Figure 51 - Breakdown by type of system of the thermal capacity installed in dedicated cogeneration units (2013)



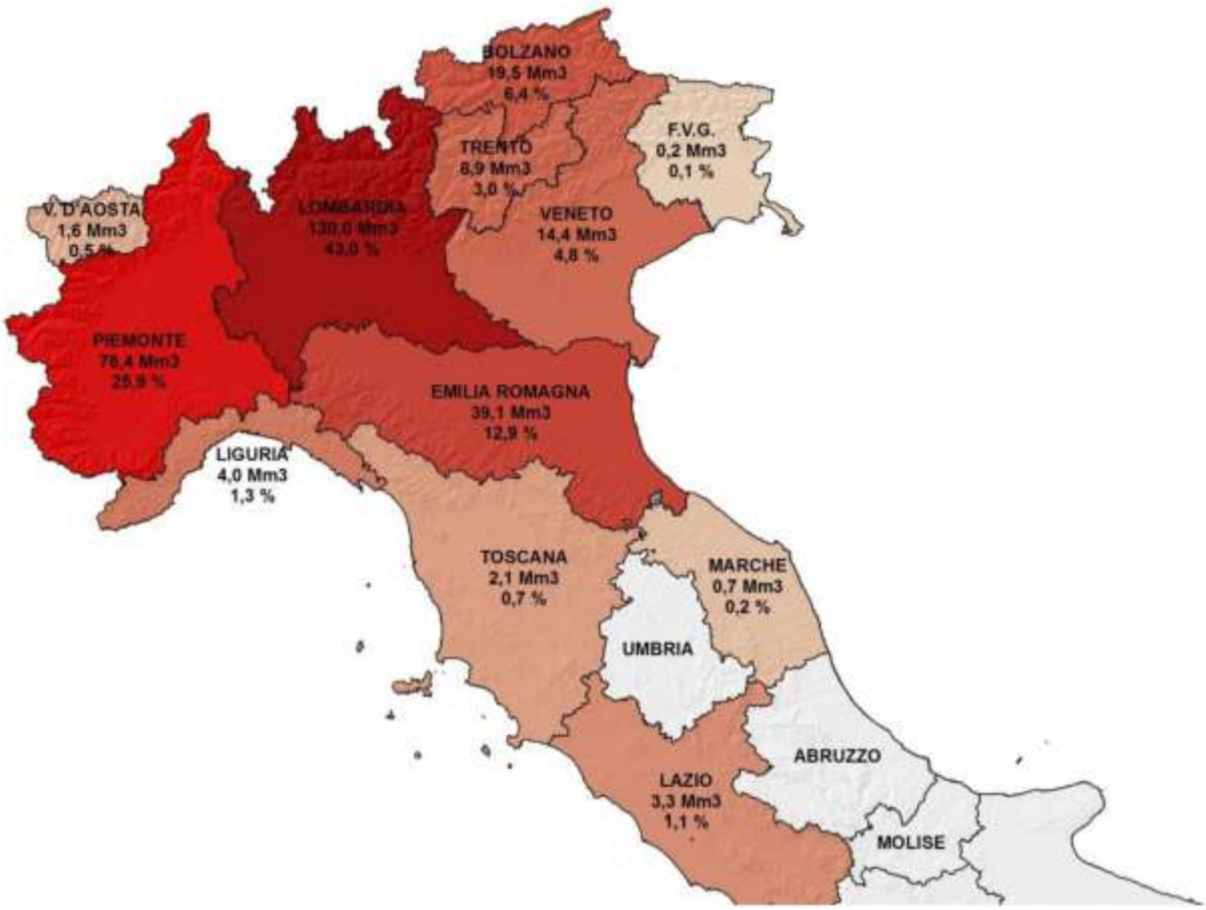
Ciclo combinato	Combined cycle
Motore alterativo a gas	Alternative gas engine
Turbina a gas	Gas turbine
Ciclo ORC	Organic Rankine Cycle (ORC)
Altro	Other
Turbina a vapore	Steam turbine

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 302 million m^3 in 199 cities. This stock is almost entirely concentrated in five regions in the north (290 million m^3 or 96%). Lombardy holds the primacy, with 130 million m^3 (43% of the total), followed by Piedmont, Emilia Romagna, Trentino Alto Adige (mostly Bolzano) and Veneto. As concerns the regions of central Italy small district heating networks are located in Lazio, Tuscany and in the Marche.

Figure 52 - Geographical distribution of built stock volumes served by district heating in Italy (year 2013)

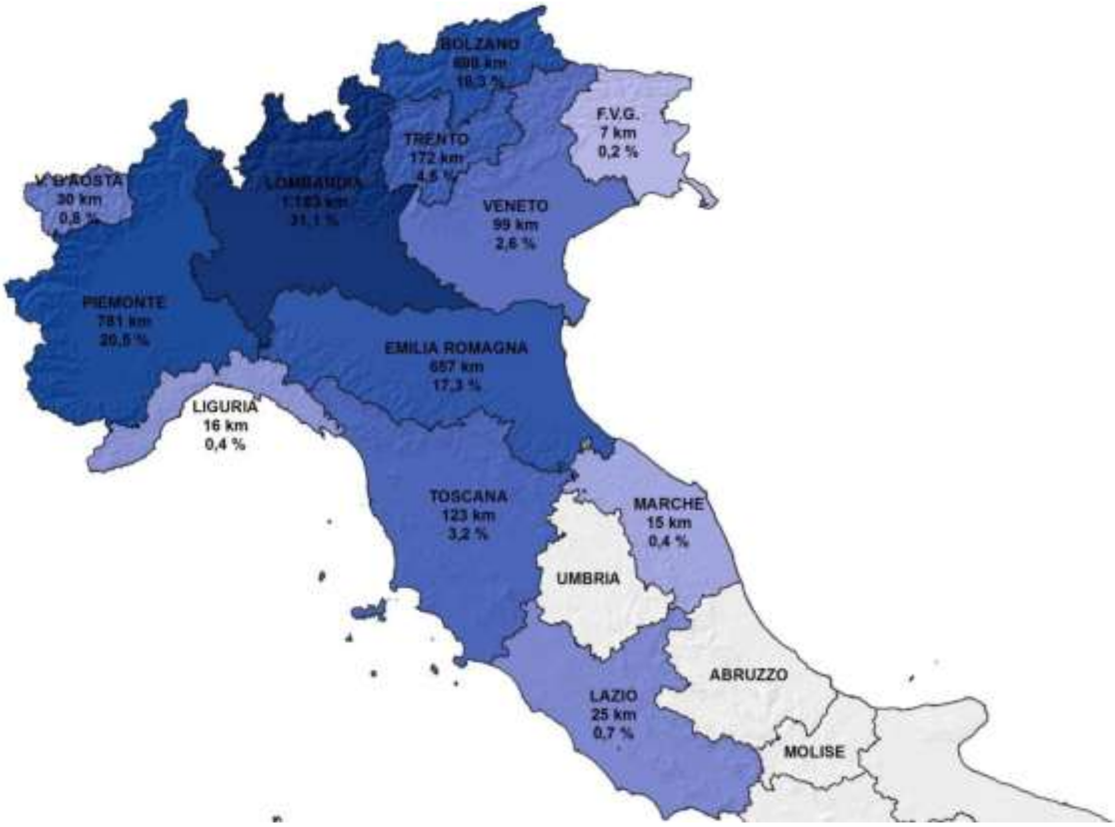


Looking at the ratio of volumes served by district heating units to the resident population we see a sharp divide between Trentino Alto Adige, with a value of about 27 m^3 per inhabitant (38 m^3 at Bolzano) and the other regions. Trentino Alto Adige is followed by Piedmont (18 m^3/inhabitant), Lombardy (13 m^3/inhabitant), Valle d'Aosta (12.4 m^3/inhabitant) and Emilia Romagna (8.8 m^3/inhabitant). Next come Veneto (2.9 m^3/inhabitant), Liguria (2.5 m^3/inhabitant) and all the others.

Urban district heating comprises 3807 km of primary network. Here too northern regions are in the lead: Lombardy has 31.1% of Italy's total district heating networks, followed by Trentino Alto Adige

(22.8%), Piedmont (20.5%) and Emilia Romagna (17.3%).

Figure 53 - Geographical distribution of district heating networks (year 2013)



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 2014defines 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;

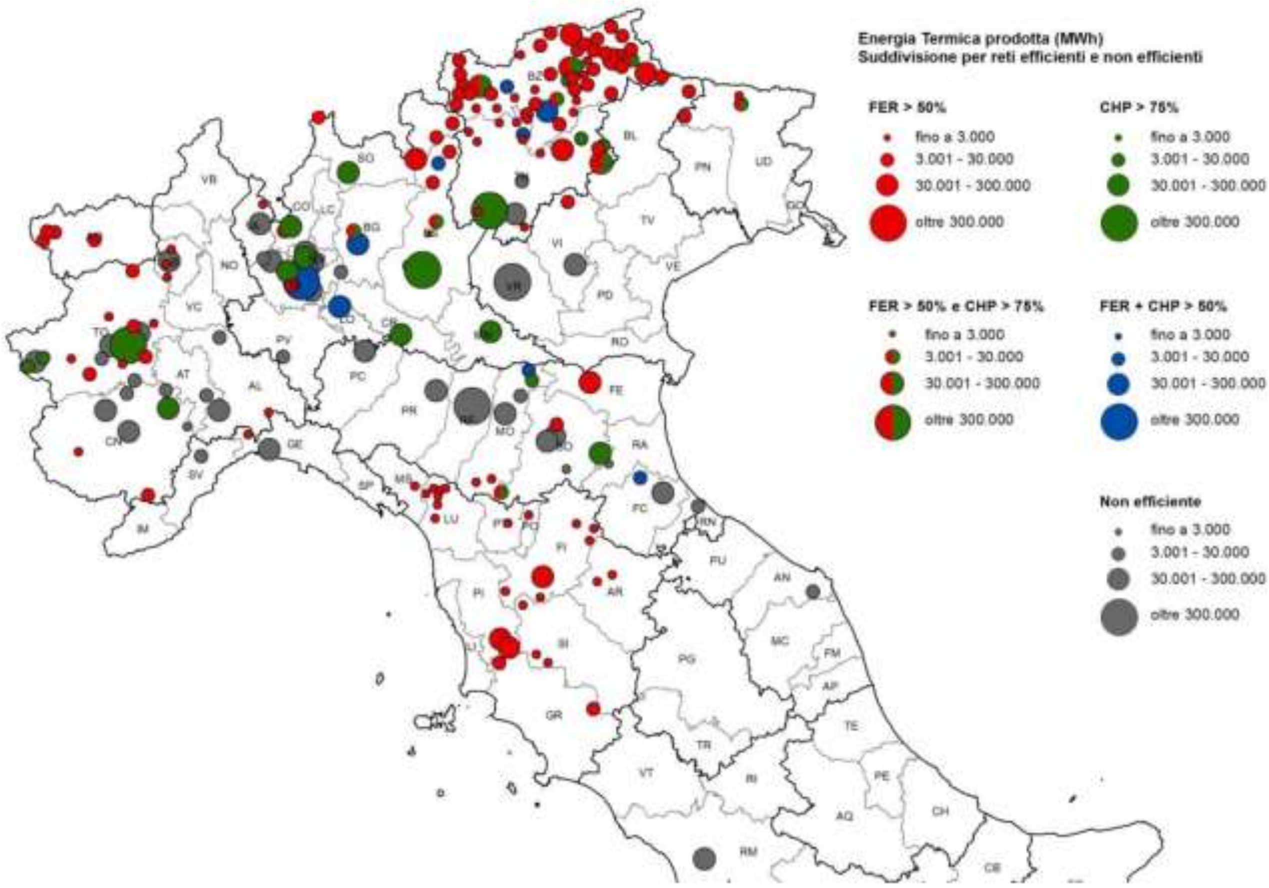
d. 50 percent of a combination of the above.

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%: the district heating systems that in 2013 used at least 50 % of renewable energy
- CHP>75%: the district heating systems that in 2013 used at least 75% of cogenerated heat
- RES >50% and CHP>75%: the district heating systems that in 2013 met both of the above requirements
- RES + CHP >50%: the 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 54 - Geographical distribution of district heating networks (efficient and non-efficient) with indication of the thermal energy they use (year 2013)



Energia Termica prodotta (MWh)	**Thermal energy produced (MWh)**
Suddivisione per reti efficienti e non efficienti	**Breakdown by efficient and non-efficient networks**
FER > 50% fino a 3 000 oltre 300 000	**RES > 50%** up to 3 000 over 300 000
CHP > 75% fino a 3 000 oltre 300 000	**CHP > 75%** up to 3 000 over 300 000
FER > 50% e CHP >75% fino a 3 000 oltre 300 000	**RES > 50% and CHP >75%** up to 3 000 over 300 000
FER + CHP > 50% fino a 3 000 oltre 300 000	**RES + CHP > 50%** up to 3 000 over 300 000
Non efficiente fino a 3 000 oltre 300 000	**Non-efficient** up to 3 000 over 300 000

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 23% of networks, producing about 28% 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; elsewhere, the source is geothermal, e.g. in Tuscany and at Ferrara.

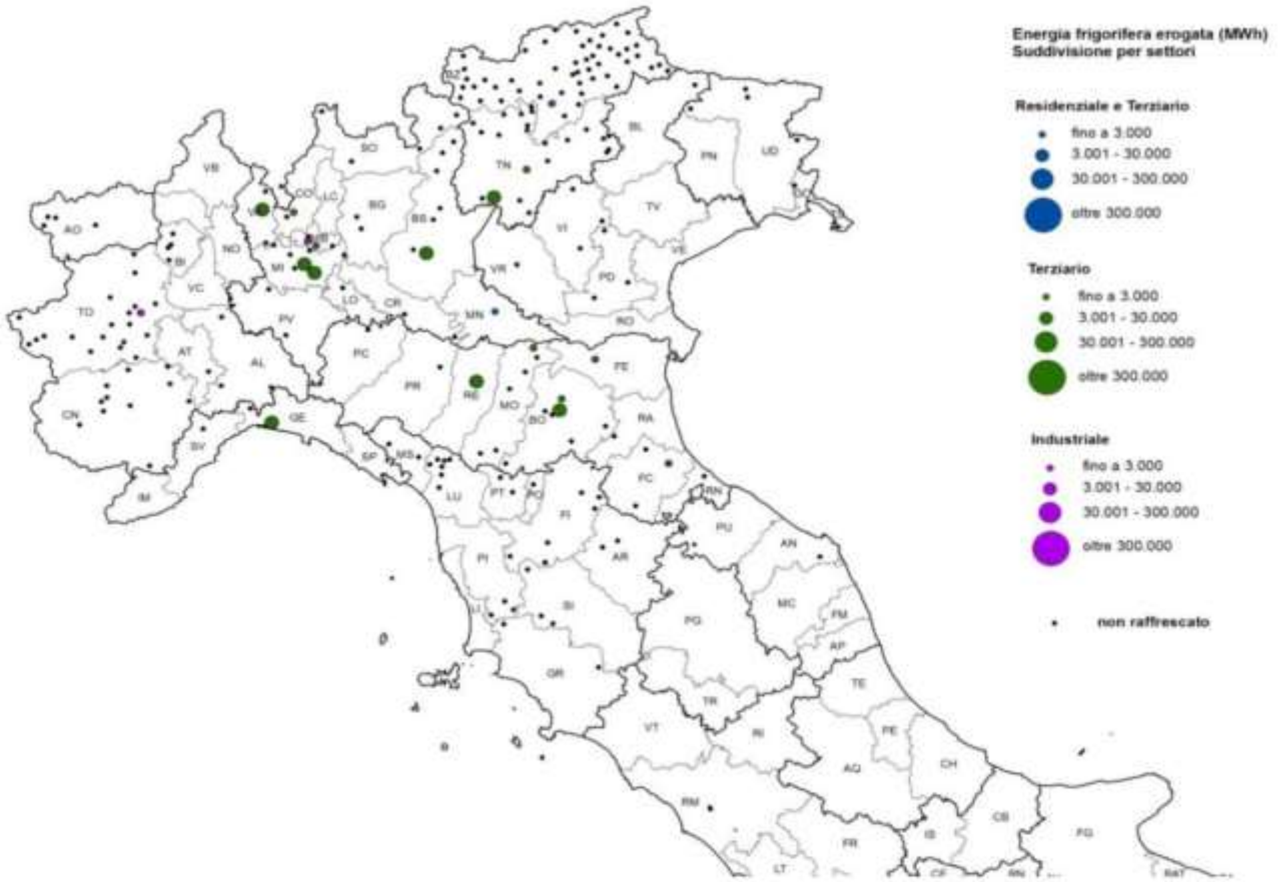
There are also major district heating systems using cogeneration installations (Turin, Brescia, Mantua) which meet the second efficiency condition listed. Other, small plants are able to meet both the requirement of over 50% RES and a cogeneration share of over 75% (these are found mostly in Trentino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

Efficiency through 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.

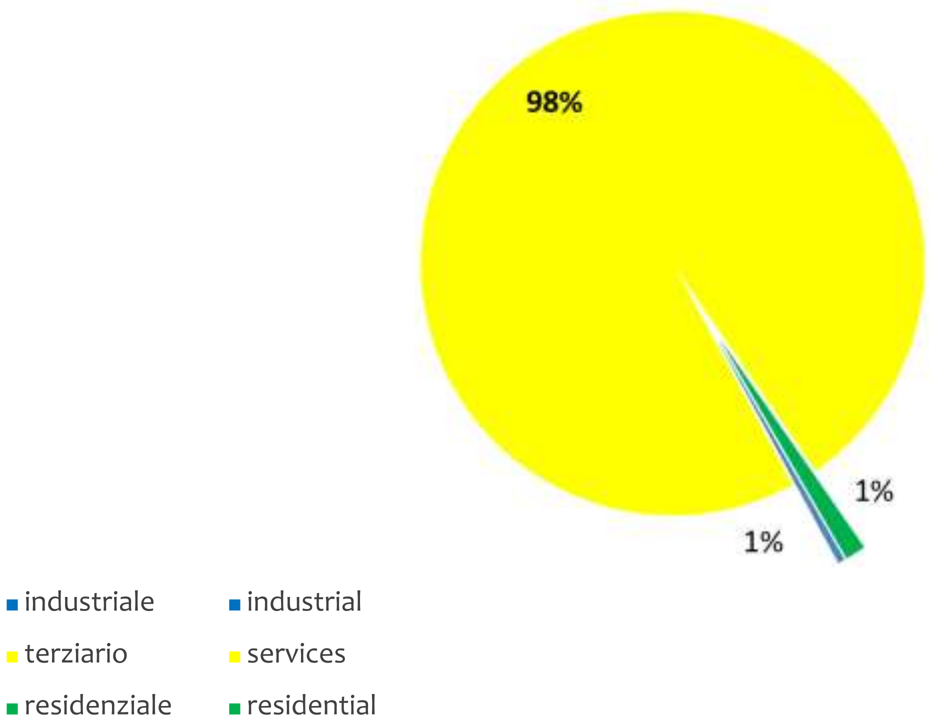
Figure 55 - Geographical distribution of the cooling energy delivered by district heating and cooling networks - Breakdown by sector (year 2013)



Energia frigorifera erogata (MWh) Suddivisione per settori	Cooling energy supplied (MWh) Breakdown by sector
Residenziale e Terziario fino a 3 000 oltre 300 000	**Residential and Services** up to 3 000 over 300 000
Terziario fino a 3 000 oltre 300 000	**Services** up to 3 000 over 300 000
Industriale fino a 3 000 oltre 300 000	**Industrial** up to 3 000 over 300 000
Non raffrescato	**Not cooled**

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 56 - Cooling energy delivered by sector by district cooling networks (year 2013)



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

After in-depth analysis of cogeneration and district heating, this chapter[29]provides 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[30]. The degree of detail and specificity of the information varies according to user sectors. However, for each 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, consumed directly 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.

[29] See in particular paragraphs 4.1 and 4.2.

[30] 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 29 - 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 underground	1	0.0%
Oil products		Boilers	Energy contained in oil products	2 709	9 4 %
Gas		Boilers	Energy contained in the 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: calculations based on 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 oil 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 household heating is held by *solid biomass*, on account of the great number of units, stoves and boilers using wood or pellets, supplying in total about 6.6 Mtoe.

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 fuel wood in open fireplaces, closed fireplaces, boilers, stoves, etc., to produce heat;
- the overall consumption of fuel wood in households exceeds 17.7 million tonnes (the average annual consumption per household is of about 3.2 tonnes). Only 45% of households purchase all the wood they use: the rest gathers at least part 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 almost entirely 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 about 2.5 million m^2 of household solar panels were in place, with a total energy output of 124 ktoe, or 0.4% of total consumption for heating.

Geothermal energy consists of the portion of ground heat, in the form of water or steam, extracted from the ground from 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 30 - 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 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%
Oil products		Boilers	Energy contained in oil 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: calculations based on 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 oil 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 too the share of renewable sources is very low (171 ktoe, or 1.8% of the total). As usual, natural gas is by far 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 oil products comes behind, at just over 600 ktoe (6.5%).

Table 31 - 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 underground	77	0.8%
	Biogas	Boilers	Thermal energy contained in biogas	25	0.3%
Oil products		Boilers	Energy contained in oil 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: calculations based on 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, oil products play the leading role, accounting for 46.2% of total consumption, followed by gas with 40.6%. Renewable sources, instead, are mainly used to heat agricultural greenhouses, aquafarming and fish farming facilities, and their overall contribution is 13.2%.

Table 32 - 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%
Oil products		Boilers, portable generators	Energy contained in oil products	146	46.2%
Gas		Boilers	Energy contained in gas	128	40.6%
TOTAL SOURCES				**316**	**100%**

Source: calculations based on 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, we have some important information on the availability of heating and cooling systems and equipment, 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 33 - Households divided by presence/lack and type of the only or main home heating system

Regions	Household heating system					
	Present				Absent *(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
Puglia	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% lack any heating unit, and these are mainly located in southern Italy (mostly in 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/geographic 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 34 - 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
Puglia	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 35 - Gas distribution in Italy

Region	Municipalities with methane	Quantity of gas supplied per region (thousands of Nm3)	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
Puglia	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 Nm^3 of gas, markedly less than the average value in the north of the country (1.95 Nm^3).

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 36 - Regional distribution of Italian municipalities without methane supply

Region	Total municipalities	Municipalities without methane	Population of municipalities without methane (%)
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
Puglia	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 the Centre-south, home heating using electricity has a higher incidence (especially with heat pumps); in Umbria, Basilicata, Calabria and especially in Sardinia, the share 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 37 - Households by type of systems using wood and pellets and breakdown by region, per 100 households using respectively wood and pellets

Regions	Wood			Pellet	
	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
Puglia	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 are 13.4% of the total for wood and 18.5% for pellets.

As to *water heating*, instead, the following table shows the stock of DHW production systems, by region.

Table 38 - Households divided by presence/lack and type of the only or main water heating system

Regions	Households with water heating system						No system (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
Puglia	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 lower values in the province of Bolzano, in Calabria, Sicily and Sardinia. Excepting 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 composition of water heating systems by source is similar to that described for space heating: at national level, natural gas has 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 has a subsidiary space heating system; vis-à-vis the main system, the subsidiary one is far more often a single unit, either fixed (61% of subsidiary units) or portable (33%).

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

Table 39 - Households divided by presence/lack and type of the only or main air conditioning system

Regions	Presence				No system *(per 100 households)*	Total
	Central or independent air conditioning system	Fixed or portable systems (cooling only)	Hot air/cold air air conditioning (heat pumps)	**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
Puglia	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 paragraph 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 40 - 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 41 - Percentage distribution of municipal waste management in Italy (2012)

Landfill	Waste-to-energy	Sorted 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. Specifically, more than 5 Mton of waste are burnt in waste-to-energy plants, making up 18% of the total produced. Approximately 7 Mton of waste is recycled, while the remaining 4.5 Mton is composted.

To estimate the energy which can be obtained from MSW in 2023[31], a total production of some 31.5 million tonnes was considered (source: ISPRA). The quantity of waste conveyed to waste-to-energy plants is estimated to increase to 9.77 Mton, or 31% of total production. Only 3 Mton of waste will still be sent to landfills; this share can be used for energy purposes through the production of landfill biogas. Considering a calorific value of 0.23 toe/t of dry matter, the energy value from the burning of municipal solid waste is expected to reach 2.25 Mtoe in 2013.

Table 42 - Scenario to 2023. Energy produced from municipal solid waste

Management of municipal solid waste	Management of municipal solid waste (%)	Energy (Mtoe)
Waste-to-energy	31	2.25

Source: ISPRA

[31] Pursuant to Legislative Decree No 102/2014 (Annex 3 in particular), in order to identify the national potential for application of high-efficiency CHP and district heating, 2013 was considered as the baseline year, and the expected development has been calculated over a 10 year period.

To break down by region the contribution of biomass from municipal solid waste, the indicator used is pro capita waste production, on the basis of the ISTAT census of the population carried out in 2011.

Table 43 - Regional distribution of waste available for waste-to-energy conversion by 2023

Region	Population 2011	Breakdown by region (Mton)	Breakdown by region (Mtoe)
Abruzzo	1 307 309	0.22	0.05
Basilicata	578 036	0.10	0.02
Calabria	1 959 050	0.32	0.07
Campania	5 747 354	0.95	0.22
Emilia Romagna	4 290 238	0.71	0.16
Friuli Venezia Giulia	1 208 615	0.20	0.05
Lazio	5 502 886	0.91	0.21
Liguria	1 570 694	0.26	0.06
Lombardy	9 653 554	1.59	0.37
Marche	1 518 928	0.25	0.06
Molise	313 660	0.05	0.01
Piedmont	4 363 916	0.72	0.17
Puglia	4 052 566	0.67	0.15
Sardinia	1 639 362	0.27	0.06
Sicily	5 002 904	0.83	0.19
Tuscany	3 601 920	0.59	0.14
Trentino Alto Adige	1 020 126	0.17	0.04
Umbria	884 268	0.15	0.03
Valle d'Aosta	126 806	0.02	0.00
Veneto	4 848 317	0.80	0.18
Total	**59 190 509**	**9.77**	**2.25**

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's agricultural land area is of almost 9 million hectares, about three quarters of which are taken up by arable crops; in particular, 40% of Italy's agricultural land is cultivated with cereals and rice, while 23% is taken up by rotated feed crops. As to permanent crops, olive groves make up about 13% of the total agricultural area.

The amount of agricultural residue by province was estimated by consulting the *database della biomassa residuale agricola italiana* (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
Puglia	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
Total	22.40

According to the assessments made, the theoretical availability of agricultural residues in a given year is of 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 estimate of the 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 paragraph estimates the quantity of biomass available from waste wood from forested areas, in particular coppice woods and timber forests.

Thus starting from 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 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
Puglia	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, we can estimate that by 2023, the availability of biomass might rise to about 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
Puglia	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 makes it possible to obtain an energy contribution of 0.53 Mtoe, considering a calorific value of 0.33 toe/t;
- as to the agrifood sector, 10% of the total is estimated to be potentially exploitable for energy purposes; exploiting 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 with the method illustrated earlier in this report[32], we used a calculation procedure based on the study by McKenna et al.[33]. By applying suitable factors to energy consumption data, this method can calculate for each industrial site the *"site heat load" Q* and can 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 paragraph 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[34];
2) application of the percentage factors of potential recovery of consumed energy, obtained from a study of the Joint Research Centre[35] based on the assessment by McKenna et al. for each industrial sector;

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[32] See paragraph 1.5.2

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

[34] See paragraph 1.5.2

[35] 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

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

Subsector	*XWH [%]*
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 sub-sector, calculated in this manner, are set out in the following table[36]. The industrial sites with the greatest potential for surplus heat recovery are the iron and steel industry and the chemical and petrochemical industries.

[36] 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 surplus heat (in GWh) from industrial sites, broken down by sub-sector (assessed on the basis of the estimate of energy consumption in 2013 by each industrial site)

Sub-sector	Potential surplus heat (GWh)
Iron and Steel	6 086
Non-Ferrous Metals	545
Chemical and Petrochemical	2 156
Non-Metallic Minerals	15 468
Food and Tobacco	390
Textile and Leather	310
Paper, Pulp and Print	1 496
Transport Equipment	178
Machinery	139
Wood and Wood Products	74
Construction	31
Non-specified (Industry)	15
Total	**26 888**

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 *"site heat load" value Q;*
- the use of a constant X_{WH} factor for each industrial sector: this fails to take into account 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 sub-sectors, 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 sub-sector 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 the performance of the technology (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 sub-sectors 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 sub-sector, 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 sub-sector 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 sub-sectors that can be served by a cogenerator. Extension of the energy results obtained in the case study to the whole reference sub-sector, 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 sub-sector, 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, hence 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 in excess of 15% the feasibility of the entire technical potential identified was assumed. For projects with an IRR below the minimum acceptability threshold (hurdle rate) the economic potential has been 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 results of assessment of the economic potential are to be interpreted as probabilistic in the sense that the estimates, albeit having rational foundations and reflecting the current regulatory and market conditions and following the principles laid down in the recent EU directives, fail to incorporate completely certain factors and barriers which are non-technical and not only economic (availability of funding, business and management policies, decision-making processes, authorisation processes, etc...) which may alter significantly implementation prospects (by restricting or extending them) .

The technical and economic potential for development of HE CHP have been expressed in terms of thermal and electrical capacity that can potentially be installed and of estimated output of thermal energy and electricity, for 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 potential for increase

Assessment of the technical and economic potential was accompanied by assessment of **environmental benefits,** such as savings on GHG emissions and the primary energy savings linked to development of the potential for HE CHP.

The **primary energy savings** have been calculated in accordance with the Ministerial Decree of 4 August 2011, which sets out the formulas and energy parameters used to calculate PES, including the reference efficiencies of the separate production of electricity and heat (which depend on the fuel, year of installation and heat recovery method) and the individual correction factors which take into account the average outdoor temperature at the site of the installation, grid voltage and the ratio of energy self-consumed to that fed into the grid[37].

The **saved GHG emissions** linked to potential developments of HE CHP have been 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 renewable energy sources 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 saved thanks to the electricity produced by HE CHP systems, considering the specific emissions of the marginal fossil technologies of the Italian electricity market, the useful heat produced by HE CHP systems and the specific emissions for the production of heat (taking as a benchmark a natural gas boiler).

The savings assessed for each typical customer of each sector have also been extended to the incremental technical and economic potential for development of HE CHP in that sector (where "incremental" indicates the difference between the potential and the gains already made in terms of capacity and energy from HE CHP 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.

[37] in accordance with Annex I to Directive 2012/27/EU and Annex I to Commission Decision 2007/74/EC.

5.2 HE CHP potential 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[38]. The cogenerated thermal energy amounts to almost 10 GWh and covers just 3.1% 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 the poorer electrical performance[39] compared with larger-sized systems. This prevents the production of electricity at competitive costs vis-à-vis the 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 thus created with the excise duty on the fuel feeding the cogenerator in civil uses 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, reducing, albeit only in minimal part, the greater benefits of the tax rebate[40]. The schemes supporting HE CHP systems, in particular white certificates, despite including elements designed to increase the premium[41] for small-size installations are unable to offset the higher investment and operation costs.

Lastly, recent rules introduced in the framework of the efficient systems for demand points *(SEU - sistemi efficienti di utenza)* (Decisions AEEGSI 578/2013/R/eel as amended, Legislative Decree 115/08, at Article 25-bis of Decree-Law No 91/14 converted by Law No 116/14) enable access to *ad hoc* incentives,

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[38] The survey of the sectors using HE CHP systems from which the statistical data was 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.

[39] 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, that of HE CHP applications in the residential sector is usually about 10 percent point lower than the efficiency of larger CHP systems; although this shortfall is balanced by better heat efficiency, in economic terms, the overall balance is negative.

[40] 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 €c/Nm3, thus with a final rebate on excise duty ranging from 3 to 12.5 €c/Nm3, hence is about 2.2-16.6 higher than the rebate granted to the industrial sector.

[41] 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.

consisting of part exemption from general system charges, provided that certain requirements are met; in particular, to be classed as SEU a system must consist of 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 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 sifts, common area lighting, electrical consumption of the heating system etc.) and cannot serve electricity use by the individual flats, 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 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 57 - Diagram summarising the process of assessing energy consumption for heating and estimating energy saving by the residential sector

CARATTERIZZAZIONE DELL'EDILIZIA RESIDENZIALE	CHARACTERISATION OF THE STOCK OF RESIDENTIAL BUILDINGS
ARCHIVIO DEGLI EDIFICI TIPO	ARCHIVE OF MODEL BUILDINGS
RICOSTRUZIONE DEI CONSUMI DI RISCALDAMENTO DEL SETTORE RESIDENZIALE	RECONSTRUCTION OF HEATING CONSUMPTION BY THE RESIDENTIAL SECTOR
ANALISI COSTI-BENEFICI DI INTERVENTI DI RIQUALIFICAZIONE ENERGETICA	COST-BENEFIT ANALYSIS OF ENERGY EFFICIENCY IMPROVEMENT PROJECTS
VALUTAZIONE DEL POTENZIALE DI RISPARMIO ENERGETICO DEL SETTORE RESIDENZIALE	ASSESSMENT OF POTENTIAL ENERGY SAVINGS 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							Total
			Before 1919	1919-1945	1946-1961	1962-1981	1982-1991	1992-2001	2002-2013	
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:

- sixty-six percent of consumption is concentrated in the country's climate condition areas E-F;
- forty-four percent 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 that carried out, focusing analysis on the main phenomena, the first constraint would be the climate condition area; it seems appropriate to consider as suitable for CHP systems the colder climate areas only, where the number of hours winter operation of heating equipment would 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 (stairwell lighting, lifts, etc.) on account of the SEU legislation (Efficient demand point systems)[42]. finally, as to heat consumption, the only demand technically attributable to the CHP system is that for space heating, excluding the demand for DHW which is almost always covered by single flat units[43]. 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.

[42] 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 makes up an individual final customer/legal entity.

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

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	central	central
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 have been identified: in the case of detached houses, the typical system envisaged is a micro-CHP system, type Stirling, with thermal capacity of about 5 kWt, suitable for detached houses with independent heating. 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.

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	ICE - gas	ICE - 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[44]	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.

[44] 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 sub-sector (as measured in the demand characterisation stage) it is possible to estimate technical potential, which in the residential sector amounts overall to 37 TWht and 9 TWhe of thermal energy and electricity obtainable from HE CHP, corresponding to an installed capacity of about 3.5 GWe.

These values represent, on the basis of the assumptions made, the maximum amount of cogenerated thermal energy and electricity technically obtainable in the sub-sectors 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 sub-sector 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)	39.207 GWh	22.230 GWh	3.038 GWh
Electricity demand by subsector (2013)	6.467 GWh	1.054 GWh	228 GWh
Technical potential for HE CHP heat	31.071 GWh	4.946 GWh	1.400 GWh
Technical potential for HE CHP electricity	6.214 GWh	2.097 GWh	610 GWh
Technical potential for HE CHP thermal capacity	10.357 MWt	2.545 MWt	945 MWt
Technical potential for HE CHP electrical capacity	2.071 MWe	1.079 MWe	412 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, the typical cost of full service contracts was applied: their value is based on the system's hours of operation. The maintenance cost per hour of operation offered by suppliers grows in almost linear terms with the size of the system; for small installations for which no market information was available, the data supplied by RSE were used[45].

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.

As concerns commodities, the final consumer prices of the gas and electricity absorbed by users have been drawn from Eurostat, reference year 2014[46]. 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).

All the installations considered in the residential sector, being HE CHP and having a capacity below 200 kWe, meet the requirements for accessing the net metering scheme[47]. 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

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[45] 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

[46] "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

[47] 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.

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)[48].

The self-consumed electricity is charged an excise duty on electricity in the same way as purchased 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 taken from the statistical data of GME based on the average prices of the centralised market for EEC in 2014[49].

The weighted average price 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[50].

[48] 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.
[49] http://www.mercatoelettrico.org/It/Statistiche/TEE/StatisticheTEE.aspx
[50] This approach reflects the JRC guidelines "Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level" 2015.

Table 56 - Economic-financial parameters used to make the financial simulation in the residential sector

	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 €/kW/year	313 €/kW/year	0 €/kW/year
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 CHP gas	81.84 €/MWh	63.71 €/MWh	47.53 €/MWh
Price of electricity offtaken	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 Nm3/kWh	0.22 Nm3/kWh	0.22 Nm3/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 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 offtaken	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 high heat and power demand high enough to justify investment[51].

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 layouts (districts, very large condominiums etc.).

[51] Some examples would be luxury villas, districts, very large condominiums with many common services such as swimming pools etc. and enjoying greater economies of scale. These cases are not covered in this study as they are felt to be marginal at national level.

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)	39 207 GWh	22 230 GWh	3 038 GWh	64 475 GWh
Electricity demand by subsector (2013)	6 467 GWh	1 054 GWh	228 GWh	7 749 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 electric 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%	0.264%	0.015%
Share of electrical demand covered by HE CHP (2013)	0.005%	0.045%	2.140%	0.074%
Technical potential for HE CHP heat	31 071 GWh	4 946 GWh	1 400 GWh	37 416 GWh
Technical potential for HE CHP electricity	6 214 GWh	2 097 GWh	610 GWh	8 921 GWh
Technical potential for HE CHP thermal capacity	10 357 MWt	2 545 MWt	945 MWt	13 847 MWt
Technical potential for HE CHP electrical capacity	2 071 MWe	1 079 MWe	412 MWe	3 562 MWe
Economic potential for HE CHP heat	0 GWh	0 GWh	0 GWh	0 GWh
Economic potential for HE CHP electricity	0 GWh	0 GWh	0 GWh	0 GWh
Economic potential for HE CHP thermal capacity	0 MWt	0 MWt	0 MWt	0 MWt
Economic potential for HE CHP electrical capacity	0 MWe	0 MWe	0 MWe	0 MWe

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 have been calculated in accordance with the Ministerial Decree of 4 August 2011. GHG emission savings have been calculated with the GSE method used to monitor the GHG emissions saved through RES energy efficiency, as explained in detail in the section on method at the beginning of this chapter.

The reference efficiencies for the production of electricity only, used to calculate PES and savings, have been reduced vis-à-vis the default values set out in the MD quoted for natural gas (52.5%), by virtue of the correction factors introduced by the same Decree, which grant a greater premium to the lower power losses from installations connected with low voltage which consume the electricity they have produced.

The overall savings which can be estimated on the incremental technical potential in the residential sector amount to about 770 ktoe, which would reduce by about 2% energy consumption in the sector. 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 almost 30%. Overall, the incremental technical potential would make it possible to reduce emissions from the residential sector by about 2.5 Mton CO_2 or about 5% 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 technical and economic potential for efficiency gains in the residential sector

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building	Total residential under HE CHP conditions
Reference electrical efficiency	47.2%	48.1%	48.6%	-
Reference thermal efficiency	90.0%	90.0%	90.0%	-
User primary energy savings	0.3 toe	0.9 toe	7.6 toe	-
PES	13.1%	21.3%	21.6%	-
Threshold PES	0.0%	0.0%	0.0%	-
PES incremental technical potential	537.8 ktoe	180.2 ktoe	51.9 ktoe	769.9 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	65.9 tCO_2	-
Emissions produced by substitute technologies	4.9 tCO_2	11.4 tCO_2	91.7 tCO_2	-
CO_2 savings by users	0.8 tCO_2	3.1 tCO_2	25.9 tCO_2	-
Percent emission reduction	-17.0%	-27.5%	-28.2%	-27.5%
CO_2 savings incremental technical potential	1 745.9 $ktCO_2$	603.6 $ktCO_2$	176.3 $ktCO_2$	2 525.8 $ktCO_2$
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 evolution scenarios in the residential sector and impact on analysis of potential

According to the ENEA scenarios simulated using the Times model, final consumption by 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 58 - Final consumption evolution scenario 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 respectively by 2.3 GWht and 0.5 GWhe; 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 2013

	Detached house	Medium-sized multi-apartment building	Large multi-apartment building	Total residential under HE CHP conditions
Technical potential for HE CHP heat	29 159 GWh	4 642 GWh	1 314 GWh	35 114 GWh
Technical potential for HE CHP electricity	5 832 GWh	1 968 GWh	572 GWh	8 372 GWh
Technical potential for HE CHP thermal capacity	9 720 MWt	2 389 MWt	887 MWt	12 995 MWt
Technical potential for HE CHP electrical capacity	1 944 MWe	1 013 MWe	386 MWe	3 343 MWe
Economic potential for HE CHP heat	0 GWh	0 GWh	0 GWh	0 GWh
Economic potential for HE CHP electricity	0 GWh	0 GWh	0 GWh	0 GWh
Economic potential for HE CHP thermal capacity	0 MWt	0 MWt	0 MWt	0 MWt
Economic potential for HE CHP electrical capacity	0 MWe	0 MWe	0 MWe	0 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.

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 sub-sector 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 sub-sectors for HE CHP installations are healthcare, hotels and a subset of sports facilities, precisely swimming pools. Aggregate consumption by these subsectors comes to about 30% of overall heating consumption by services.

As to the fuels used in 2013, natural gas covered almost 89% of the consumption selected for this report. The share of oil 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 services sector in 2013[52], by the main public and private subsectors, focusing on those best suited for CHP conversion.

[52] 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 services sector in Italy in 2013, by sub-sector and use.

Service subsector	Electricity consumption (GWh)	Thermal energy consumption (GWh)	Consumption Total (GWh)	Consumption Total (ktoe)
Public administration	4 662	11 212	15 873	1 365
Health service	6 494	14 996	21 490	1 848
Leisure time 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
Street 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, among sports facilities only those with swimming pools were selected, as they have high power consumption coupled with very high heat demand throughout the year[53].

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 felt scarcely useful to design a business case for replacement of a heat pump with a CHP system sized to deliver the heat required.

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.

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[53] 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.).

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 would therefore be rather low, except in the case of a school with associated 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 structures, the case studies show the average thermal demand assessed by GSE through analysis of the data on the energy certificates stored in the databases held by the Region of Lombardy[54]. The hospitals have been characterised, from the viewpoint of demand, based on the average values of healthcare buildings with volume above 45 000 m^3, 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 structures is negligible[55]. 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 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[56]. The large hotel used as 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.

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[57]; 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.

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

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

[56] 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

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

Table 64 - Energy demand from standard customers in the services sector

	Health service		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.

Table 65 - Technical parameters and energy outputs of HE CHP systems under the operating conditions assume for the services sector

	Health service		Hotels		Sports facilities
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool
Type of technology	ICE - gas	ICE - gas	ICE - gas	ICE - gas	ICE - 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	1 540.7 MWh	130.1 MWh	445.6 MWh	1 484.3 MWh
Share of demand for CHP heat	52%	52%	27%	23%	81%
Heat generated by backup boiler	101.3 MWh	1 422.2 MWh	354.9 MWh	1 491.9 MWh	473.7 MWh
HE CHP electricity produced by the CHP system	45.8 MWh	1 194.9 MWh	56.5 MWh	310.1 MWh	981.0 MWh
Total electricity produced by the CHP system	45.8 MWh	1 300.8 MWh	56.7 MWh	321.3 MWh	1 012.8 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	1 271.3 MWh	15.3 MWh	262.3 MWh	431.9 MWh
Electricity off-taken from the grid	289.2 MWh	3 431.9 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	3 454.4 MWh	210.5 MWh	908.5 MWh	2 979.6 MWh
Total CHP system consumption	168.4 MWh	3 760.5 MWh	211.1 MWh	941.3 MWh	3 074.1 MWh
Consumption of backup boiler	112.6 MWh	1 580.2 MWh	394.3 MWh	1 657.6 MWh	526.3 MWh
Electricity off-taken ex-ante	335.0 MWh	4 703.2 MWh	227.0 MWh	750.0 MWh	981.0 MWh
Boiler consumption ex-ante	234.5 MWh	3 292.1 MWh	538.9 MWh	2 152.8 MWh	2 175.6 MWh

By extending the energy outputs obtained in the case study to the entire reference sub-sector 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 sub-sector relevant for the purposes of HE CHP, and associated technical potential for development of high-efficiency cogeneration

	Health service		Hotels		Sports facilities	Total Service sector potentially served by HE CHP
	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	23 762 GWh
Electricity demand by subsector (2013)	3 530 GWh	2 964 GWh	5 057 GWh	6 216 GWh	842 GWh	18 609 GWh
Technical potential for HE CHP heat	3 815 GWh	3 203 GWh	799 GWh	842 GWh	2 748 GWh	11 407 GWh
Technical potential for HE CHP electricity	1 591 GWh	2 484 GWh	347 GWh	586 GWh	1 816 GWh	6 825 GWh
Technical potential for HE CHP thermal capacity	1 319 MWt	753 MWt	285 MWt	302 MWt	898 MWt	3 557 MWt
Technical potential for HE CHP electrical capacity	550 MWe	584 MWe	124 MWe	210 MWe	594 MWe	2 061 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.

As concerns commodities, the final consumer prices of the gas and electricity absorbed by users have been drawn from Eurostat, reference year 2014[58]. 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.

The EH CHP installations considered for hotels and small healthcare facilities, have a capacity below 200 kWe, and would hence 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 the power off-taken is priced at the net metering tariff. The excess quantity

[58] "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

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)[59].

The self-consumed electricity is charged an excise duty on electricity just as 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 while non-energy intensive customers connected in medium voltage (e.g. large hotels, hospitals and swimming pools) are charged a lump sum annual duty established according to the system's capacity, pursuant to Decision AEEGSI 609/2014/R/eel as amended.[60]

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 taken from the statistical data of GME on the average prices of the centralised market for EEC in 2014[61].

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[62].

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[59] 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.

[60] 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 a x rate. The rate is 0.273 EURc/kWh while the factor a and the hours are, in the case of HE CHP systems, respectively 0.6 and 5000.

[61] http://www.mercatoelettrico.org/It/Statistiche/EEC/StatisticheTEE.aspx

[62] 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-financial parameters used to make the financial simulation in the services sector

	Health service		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 CHP gas	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 Nm3/kWh	0.22 Nm3/kWh	0.22 Nm3/kWh	0.22 Nm3/kWh	0.22 Nm3/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 services sector

	Health service		Hotels		Sports facilities
	Minor healthcare facility	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	572m €/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 services sector

	Health service		**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, treatment centres, 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 in individual hotels' conditions (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 of 35% .

Table 70 - Technical and economic potential of the services sector on the basis of demand in 2013

	Health service		**Hotels**		**Sports facilities**	**Total Service sector potentially served by HE CHP**
	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	23 762 GWh
Electricity demand by subsector (2013)	3 530 GWh	2 964 GWh	5 057 GWh	6 216 GWh	842 GWh	18 609 GWh
Heat from HE CHP in the subsector (2013)	1.1 GWh	409.6 GWh	1.6 GWh	6.5 GWh	64.3 GWh	483.1 GWh
Electricity from HE CHP in the subsector (2013)	0.4 GWh	391.0 GWh	0.8 GWh	7.4 GWh	45.6 GWh	445.2 GWh

HE CHP thermal capacity in the subsector(2013)	0.4 MWt	96.1 MWt	0.8 MWt	3.0 MWt	22.4 MWt	122.7 MWt
HE CHP electrical capacity in the subsector(2013)	0 2 MWe	91 7 MWe	0 4 MWe	3.4 MWe	15.9 MWe	111.6 MWe
Share of thermal demand covered by HE CHP (2013)	0.014%	6.650%	0.055%	0.179%	1.774%	8.672%
Share of electrical demand covered by HE CHP (2013)	0.012%	13.191%	0.017%	0.119%	5.418%	18.756%
Technical potential for HE CHP heat	3 815 GWh	3 203 GWh	799 GWh	842 GWh	2 748 GWh	11 407 GWh
Technical potential for HE CHP electricity	1 591 GWh	2 484 GWh	347 GWh	586 GWh	1 816 GWh	6 825 GWh
Technical potential for HE CHP thermal capacity	1 319 MWt	753 MWt	285 MWt	302 MWt	898 MWt	3 557 MWt
Technical potential for HE CHP electrical capacity	550 MWe	584 MWe	124 MWe	210 MWe	594 MWe	2 061 MWe
Economic potential for HE CHP heat	0 GWh	3 203 GWh	0 GWh	296 GWh	2 748 GWh	6 247 GWh
Economic potential for HE CHP electricity	0 GWh	2 484 GWh	0 GWh	206 GWh	1 816 GWh	4 506 GWh
Economic potential for HE CHP thermal capacity	0 MWt	753 MWt	0 MWt	106 MWt	898 MWt	1 757 MWt
Economic potential for HE CHP electrical capacity	0 MWe	584 MWe	0 MWe	74 MWe	594 MWe	1 251 MWe
Incremental economic potential for HE CHP heat	0 GWh	2 794 GWh	0 GWh	289 GWh	2 683 GWh	5 766 GWh
Incremental economic potential for HE CHP electricity	0 GWh	2 093 GWh	0 GWh	199 GWh	1 770 GWh	4 062 GWh
Incremental economic potential for HE CHP thermal capacity	0 MWt	656 MWt	0 MWt	103 MWt	876 MWt	1 635 MWt
Incremental economic potential for HE CHP electrical capacity	0 MWe	492 MWe	0 MWe	70 MWe	578 MWe	1 140 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 respectively 5.8 TWht and 4.1 TWhe and, in terms of electrical capacity, about 1.1 GWe.

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 have been calculated in accordance with the Ministerial Decree of 4 August 2011. GHG emission savings have been calculated with the GSE method used to monitor the GHG emissions saved through RES energy efficiency, as explained in detail in the section on method at the beginning of this chapter.

The overall savings which can be estimated on the incremental technical and economic potential in the services sector amount respectively to 431 ktoe and 219 ktoe, which would reduce energy consumption in the sector by about 2% and 1% respectively.

The CO2 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 1.5 and 0.9 Mton CO2 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 technical and economic potential for efficiency gains in the services sector

	Health service		Hotels		Sports facilities	Total Service sector potentially served by
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool	
Reference electrical efficiency	45.5%	48.9%	48.0%	49.1%	49.5%	
Reference thermal efficiency	90.0%	90.0%	90.0%	90.0%	90.0%	
User primary energy savings	4.7 toe	60.2 toe	4.5 toe	18.8 toe	56.0 toe	
PES	24.3%	16.2%	19.6%	12.4%	17.4%	
Threshold PES	0.0%	0.0%	0.0%	0.0%	0.0%	
PES incremental technical potential	161.8 ktoe	105.5 ktoe	27.3 ktoe	35.3 ktoe	101.0 ktoe	430.9 ktoe
PES incremental economic potential	0.0 ktoe	105.5 ktoe	0.0 ktoe	12.3 ktoe	101.0 ktoe	218.8 ktoe

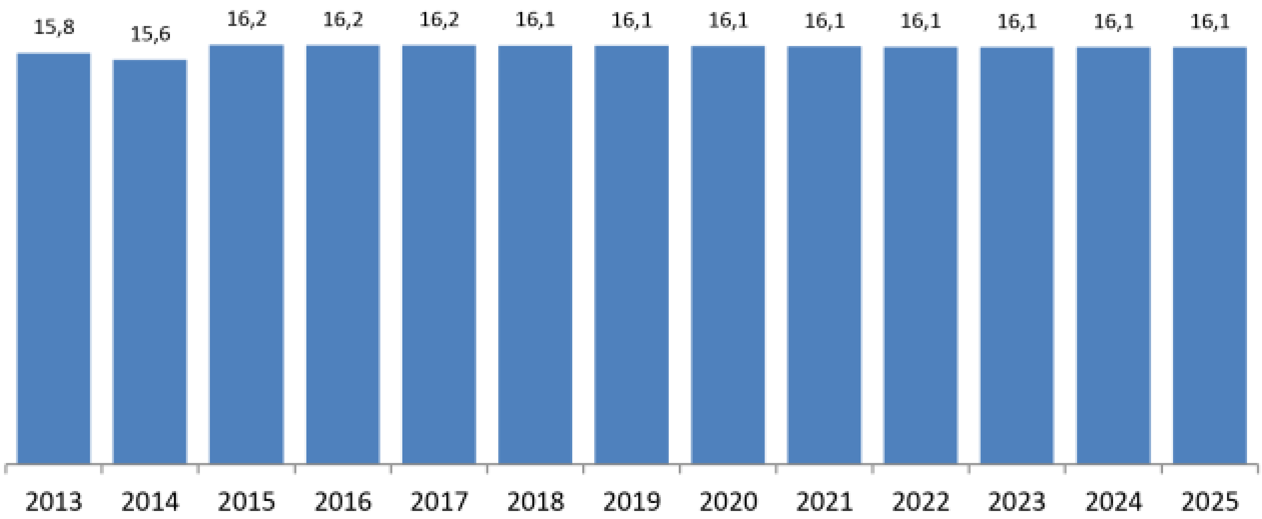
Table 72 - CO2 savings linked to individual HE CHP initiatives and to the incremental technical and economic potential in the services sector

	Health service		Hotels		Sports facilities	Total Service sector potentially served by
	Minor healthcare facility	Hospital	Small hotel	Large hotel	Swimming pool	
Emissions produced by HE CHP	34.6 tCO2	708.7 tCO2	43.2 tCO2	186.4 tCO2	611.3 tCO2	
Emissions produced by substitute technologies	48.3 tCO2	959.3 tCO2	58.4 tCO2	259.4 tCO2	837.6 tCO2	
CO2 savings by users	13.8 tCO2	250.6 tCO2	15.2 tCO2	73.0 tCO2	226.3 tCO2	
Percent emission reduction	-28.5%	-26.1%	-26.1%	-28.1%	-27.0%	
CO2 savings incremental technical potential	477.9 ktCO2	439.4 ktCO2	93.4 ktCO2	137.0 ktCO2	408.4 ktCO2	1 551.6 ktCO2
CO2 savings incremental economic potential	0.0 ktCO2	439.4 ktCO2	0.0 ktCO2	47.5 ktCO2	408.4 ktCO2	892.2 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 59 - Final consumption evolution scenario in the services 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 services sector on the basis of demand in 2023

	Health service		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	11 576 GWh
Technical potential for HE CHP electricity	1 614 GWh	2 521 GWh	352 GWh	595 GWh	1 843 GWh	6 925 GWh
Technical potential for HE CHP thermal capacity	1 338 MWt	764 MWt	290 MWt	306 MWt	912 MWt	3 609 MWt
Technical potential for HE CHP electrical capacity	558 MWe	592 MWe	126 MWe	213 MWe	602 MWe	2 092 MWe
Economic potential for HE CHP heat	0 GWh	3 251 GWh	0 GWh	300 GWh	2 788 GWh	6 339 GWh
Economic potential for HE CHP electricity	0 GWh	2 521 GWh	0 GWh	209 GWh	1 843 GWh	4 573 GWh
Economic potential for HE CHP thermal capacity	0 MWt	764 MWt	0 MWt	108 MWt	912 MWt	1 783 MWt
Economic potential for HE CHP electrical capacity	0 MWe	592 MWe	0 MWe	75 MWe	602 MWe	1 270 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 sub-sectors 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 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 sub-sector considered, hence in the overall industrial sector.

5.4.1 Characterisation of heat demand in the industrial sector

Heat demand from the industrial sector and the energy industries [63] in Italy in 2013 equals 31.6 Mtoe, 20.9 Mtoe which consists of heat for industrial processes[64], while 10.7 Mtoe meet necessary electricity uses, including a marginal share of heat which, owing to process requirements is fed via 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 and about 15% of 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 sub-sector and by company size (as measured by number of workers).

Thus, the overall demand for heat and power of each ATECO sub-sector 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-

[63] 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 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%.

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

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.

For each industrial sector furthermore, bottom-up studies of production processes were conducted, identifying the specific demand (per unit of product/turnover) and defining the share of heat demand which can be covered by CHP, based on technical constraints such as temperature[65].

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 commercial installations, with some technologies strongly in the lead based on system size (gas-powered ICE for sizes below 10 MW and GT or CCGT for larger sizes).[66]

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 $H/E_{customer\_chp}$ which could be met by cogeneration and comparing it a with the ratio $(H/E)_{cog}$ of the specific cogeneration technology. If the following result is obtained:

$$\left(\frac{H}{E}\right)_{customer\text{-}chp} > \left(\frac{H}{E}\right)_{cog}$$

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:

$$\left(\frac{H}{E}\right)_{customer\text{-}chp} < \left(\frac{H}{E}\right)_{cog}$$

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 have not been considered to equal 100% of the energy produced by the cogenerator, but have been obtained from the average recorded from installations in operation in each sector. This was felt to incorporate practical complexities in joining user and plant thermal and electrical loads specific to the production process[67]. The typical installations

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

[66] These technology choices are the most cost-effective ones, as also shown by the study cited in the previous footnote([65]) which compared the different HE CHP technologies.

[67] Peaks of heat and power demand, time mismatch between process electrical and thermal loads, heat to power ratios

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, found in 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 and in some cases even exceeded 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;
- the CHP system's H/E ratio tends to favour the electricity part for technical and economic reasons, on account of the higher price of electricity and the easier management of excess electricity vis-à-vis excess heat, thanks to the possibility of feeding excess electricity into the grid, which in the past also ensured a good return;
- some energy-intensive industries have developed over the years diversified lines of business which include the wholesale of electricity among their core operations;
- some energy-intensive industries, partly downsized by the economic crises, 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 power-intensive industries still have a margin for increased exploitation of technical potential. They include:

- Chemical and Petrochemical: in particular, some sub-sectors 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: production of building materials (ceramics);
- Non-specified (Industry): mainly rubber and furniture production;
- 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 incremental technical potential has been calculated to be 41.6 TWht and 31.9 TWhe of thermal energy and electricity obtainable from HE CHP, corresponding to a capacity to be installed of about 16.1 GWt and 12.3 GWe respectively. These values constitute the theoretical maximum amount of cogenerated thermal energy and electricity technically obtainable in the sub-sectors that can be served by a cogenerator, without considering economic and financial factors, which are discussed later.

different from those of the industrial plant, etc.

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	4 725 GWh	4 573 GWh	2 145 MWt	3 185 MWe	11 809 GWh	9 988 GWh	3 856 MWt	3 272 Mwe
Coke Ovens	49 GWh	50 GWh	27 MWt	28 MWe	36 GWh	37 GWh	14 MWt	14 Mwe
Refineries	9 311 GWh	6 959 GWh	3 733 MWt	2 807 MWe	10 164 GWh	5 312 GWh	3 953 MWt	2 072 Mwe
Food and Tobacco	1 882 GWh	1 496 GWh	471 MWt	407 MWe	3 967 GWh	3 634 GWh	1 383 MWt	1 290 Mwe
Iron and Steel	620 GWh	565 GWh	825 MWt	778 MWe	2 277 GWh	1 886 GWh	767 MWt	639 Mwe
Machinery	152 GWh	131 GWh	136 MWt	98 MWe	4 482 GWh	3 041 GWh	2 307 MWt	1 566 Mwe
Mining and Quarrying	12 GWh	16 GWh	3 MWt	4 MWe	3 GWh	4 GWh	1 MWt	1 Mwe
Non-Ferrous Metals	19 GWh	32 GWh	4 MWt	6 MWe	122 GWh	173 GWh	31 MWt	44 MWe
Non-Metallic Minerals	325 GWh	269 GWh	109 MWt	91 MWe	1 080 GWh	1 392 GWh	369 MWt	475 MWe
Non-specified (Industry)	328 GWh	333 GWh	110 MWt	102 MWe	1 137 GWh	1 022 GWh	1 229 MWt	983 MWe
Paper, Pulp and Print	5 188 GWh	3 299 GWh	1 493 MWt	944 MWe	4 127 GWh	3 040 GWh	1 078 MWt	827 MWe
Textile and Leather	217 GWh	180 GWh	75 MWt	75 MWe	1 608 GWh	1 459 GWh	715 MWt	638 MWe
Transport Equipment	308 GWh	301 GWh	196 MWt	209 MWe	299 GWh	377 GWh	182 MWt	230 MWe
Wood and W. Products	103 GWh	124 GWh	35 MWt	40 MWe	469 GWh	531 GWh	229 MWt	259 MWe
Total	**23 239 GWh**	**18 327 GWh**	**9 361 MWt**	**8 773 MWe**	**41 579 GWh**	**31 897 GWh**	**16 113 MWt**	**12 310 MWe**

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	7 084 GWh	5 415 GWh	1 711v MWt	309 MWe
Coke Ovens	-	-	-	-
Refineries	853 GWh	-	219 MWt	-
Food and Tobacco	2 736 GWh	2 482 GWh	912 MWt	882 MWe
Iron and Steel	1 658 GWh	1 321 GWh	-	-
Machinery	4 330 GWh	2 911 GWh	2 172 MWt	1 467 MWe
Mining and Quarrying	-	-	-	-
Non-Ferrous Metals	103 GWh	141 GWh	27 MWt	37 MWe
Non-Metallic Minerals	754 GWh	1 123 GWh	260 MWt	385 MWe
Non-specified (Industry)	809 GWh	689 GWh	1 119 MWt	881 MWe
Paper, Pulp and Print	-	-	-	-
Textile and Leather	1 391 GWh	1 279 GWh	640 MWt	563 MWe
Transport Equipment	-	75 GWh	-	21 MWe
Wood and W. Products	365 GWh	407 GWh	194 MWt	219 MWe
Total	**20 083 GWh**	**15 843 GWh**	**7 254 MWt**	**4 764 MWe**

5.4.3 Analysis of costs and economic potential in the industrial sector

The typical companies in the industrial sub-sectors 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[68] 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.

As concerns commodities, the final consumer prices of the gas and electricity absorbed by users have been drawn from Eurostat, reference year 2014[69]. 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 the power off-taken 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.

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)[70].

The self-consumed electricity is charged an excise duty on electricity just as 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

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[68] Gambini M. Vellini. M. "Illustrazione dei principali processi industriali rilevanti ai fini CAR" 2015

[69] "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

[70] 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.

capacity of less than 20 KWe with and connected in low voltage. SEU installations connected in low voltage with a capacity of more than 20 kWe (e.g. the CHP scenario considered for small hotels) are instead charged a fixed excise duty of 36 €/year (in 2015), while non-energy intensive customers 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.[71] Lastly, energy-intensive high and medium voltage systems are charged 5% of the variable system charged on the self-produced/self-consumed share of power.

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 the statistical data of GME on the average prices of the centralised market for EEC/WC in 2014[72].

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[73]. 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 cost-effectiveness of investing in some of the sub-sectors having 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.).

For more energy-intensive sectors (refineries, iron and steel, basic chemicals, pulp and paper), despite the cost-effectiveness shown by the economic simulations, the economic potential seems on average to be already covered by the installations currently in operation in these sectors.
On the other hand, incremental economic potential seems to be concentrated especially in the food sector (about 2 TWht from almost all its various sub-sectors), in the manufacture of building materials (about 0.5 TWht mainly from ceramic industries), in the chemical and petrochemical sectors (about 5TWh) and in the textile sector (about 0.2 TWht, largely in tanneries).

[71] 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 a x rate. The rate is 0.273 EURc/kWh while the factor a and the hours are, in the case of HE CHP systems, respectively 0.6 and 5000.
[72] http://www.mercatoelettrico.org/It/Statistiche/EEC/StatisticheTEE.aspx
[73] This approach reflects the JRC guidelines "Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level" 2015.

Table 76 - Economic potential for the development 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	4 725 GWh	4 573 GWh	2 145 MWt	3 185 MWe	9 809 GWh	8 082 GWh	3 140 MWt	2 578 MWe
Coke Ovens	49 GWh	50 GWh	27 MWt	28 MWe				
Refineries	9 311 GWh	6 959 GWh	3 733 MWt	2 807 MWe	10 097 GWh	5 239 GWh	3 915 MWt	2 032 MWe
Food and Tobacco	1 882 GWh	1 496 GWh	471 MWt	407 MWe	2 916 GWh	2 614 GWh	917 MWt	835 MWe
Iron and Steel	620 GWh	565 GWh	825 MWt	778 MWe	1 793 GWh	1 459 GWh	598 MWt	486 MWe
Machinery	152 GWh	131 GWh	136 MWt	98 MWe				
Mining and Quarrying	12 GWh	16 GWh	3 MWt	4 MWe				
Non-Ferrous Metals	19 GWh	32 GWh	4 MWt	6 MWe	53 GWh	75 GWh	12 MWt	17 MWe
Non-Metallic Minerals	325 GWh	269 GWh	109 MWt	91 MWe	890 GWh	1 147 GWh	284 MWt	366 MWe
Non-specified (Industry)	328 GWh	333 GWh	110 MWt	102 MWe				
Paper, Pulp and Print	5 188 GWh	3 299 GWh	1 493 MWt	944 MWe	4 127 GWh	3 040 GWh	1 078 MWt	827 MWe
Textile and Leather	217 GWh	180 GWh	75 MWt	75 MWe	125 GWh	94 GWh	73 MWt	55 MWe
Transport Equipment	308 GWh	301 GWh	196 MWt	209 MWe	11 GWh	14 GWh	6 MWt	8 MWe
Wood and W. Products	103 GWh	124 GWh	35 MWt	40 MWe	53 GWh	60 GWh	21 MWt	23 MWe
Total	**23 239 GWh**	**18 327 GWh**	**9 361 MWt**	**8 773 MWe**	**29 873 GW**	**21 824 GWh**	**10 044 MWt**	**7 227 MWe**

Table 77 - Incremental economic potential for HE CHP development 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	5 101 GWh	3 528 GWh	1 001 MWt	64 MWe
Coke Ovens				
Refineries	786 GWh		182 MWt	
Food and Tobacco	2 006 GWh	1 799 GWh	580 MWt	525 MWe
Iron and Steel				
Machinery				
Mining and Quarrying				
Non-Ferrous Metals	34 GWh	43 GWh	8 MWt	11 MWe
Non-Metallic Minerals	565 GWh	878 GWh	176 MWt	276 MWe
Non-specified (Industry)				
Paper, Pulp and Print				
Textile and Leather	120 GWh	89 GWh	44 MWt	20 MWe
Transport Equipment				
Wood and W. Products				
Total	**8 612 GWh**	**6 338 GWh**	**1 991 MWt**	**895 MWe**

The incremental potential for heat and power from HE CHP in the industrial sector is estimated to be respectively 8.6 TWht and 6.3 TWhe and, in terms of electrical capacity, about 0.9 GWe and 2 GWt.

For those sectors in which the economic potential is lower than that already achieved (e.g. refineries, iron and steel) the factors already discussed in the analysis of technical potential[74], together with the fact that the investment costs on the systems have largely been recovered[75], currently justify the apparent excess capacity and overproduction by HE CHP systems in the industrial sector. However, should the current demand conditions and market trend persist, it is reasonable to assume that in some of these sectors, at the end of the systems' useful life, partial reduction of their electrical capacity and increase in their heat recovery could be considered, given the changed economic context.

[74] The main factors are: fall in consumption due to the crisis, higher return of the electricity market in the previous years when the investments were made, diversification of the business of energy-intensive industrial companies that have also decided to operate in the electricity sector etc.

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

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 in accordance with the Ministerial Decree of 4 August 2011. GHG emission savings were calculated with the GSE method used to monitor the GHG emissions saved through RES energy efficiency, as explained in detail in the section on method 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 784 ktoe and 365 ktoe.

Overall, exploitation of the technical and economic incremental potential would make it possible to reduce GHG emissions by the industrial sector by about 3.3 and 1.5 $MtCO_2$ respectively.

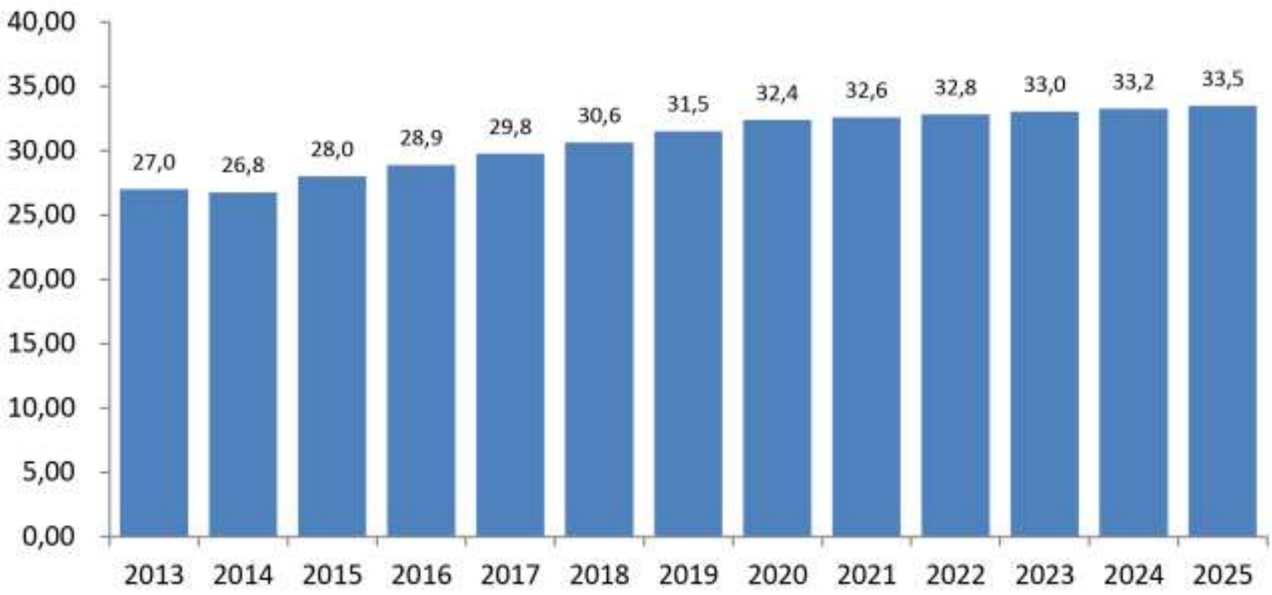
Table 78 - Primary energy savings linked to the incremental technical and economic potential in the industrial sector

	CO_2 savings Incremental technical potential	CO_2 savings Incremental economic potential	PES savings Incremental technical potential	PES savings Incremental economic potential
Chemical and Petrochemical	1 122 $ktCO_2$	729 $ktCO_2$	249 ktoe	161 ktoe
Coke Ovens				
Refineries	195 $ktCO_2$	179 $ktCO_2$	82 ktoe	75 ktoe
Food and Tobacco	522 $ktCO_2$	377 $ktCO_2$	117 ktoe	84 ktoe
Iron and Steel				
Machinery	683 $ktCO_2$		167 ktoe	
Mining and Quarrying				
Non-Ferrous Metals	29 $ktCO_2$	9 $ktCO_2$	6 ktoe	2 ktoe
Non-Metallic Minerals	224 $ktCO_2$	174 $ktCO_2$	48 ktoe	37 ktoe
Non-specified (Industry)	153 $ktCO_2$		36 ktoe	
Paper, Pulp and Print				
Textile and Leather	265 $ktCO_2$	21 $ktCO_2$	59 ktoe	5 ktoe
Transport Equipment	13 $ktCO_2$		2 ktoe	
Wood and W. Products	80 $ktCO_2$		17 ktoe	
Total	3 286 $ktCO_2$	1 489 $ktCO_2$	784 ktoe	365 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 60 - Final consumption evolution scenario 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 - Incremental economic potential of the industrial sector on the basis of demand in 2023

	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	8 130 GWh	6 024 GWh	1 971 MWt	195 MWe
Coke Ovens	-	-	-	-
Refineries	1 318 GWh	-	388 MWt	-
Food and Tobacco	2 142 GWh	1 921 GWh	620 MWt	564 MWe
Iron and Steel	-	-	-	-
Machinery	-	-	-	-
Mining and Quarrying	-	-	-	-
Non-Ferrous Metals	50 GWh	66 GWh	12 MWt	16 MWe
Non-Metallic Minerals	811 GWh	1 196 GWh	254 MWt	377 MWe
Non-specified (Industry)	-	-	-	-
Paper, Pulp and Print	-	507 GWh	-	92 MWe
Textile and Leather	126 GWh	94 GWh	48 MWt	23 MWe
Transport Equipment	-	-	-	-
Wood and W. Products	-	-	-	-
Total	**12 578 GWh**	**9 808 GWh**	**3 293 MWt**	**1 266 MWe**

5.4.6 Analytical Appendix - detailed tables for the industrial sector

Table 80 - demand by 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	Total thermal demand by medium-large	Electricity demand by a typical medium-large	Thermal demand by a typical medium-large
			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			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									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 (cocoa. sugar etc.)	Manufacture of other food products and tobacco	Production of animal feeds	Manufacture of bakery products and farinaceous products	Manufacture of basic iron and steel manufacture of tubes. pipes. hollow profiles 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	manufacture of luggage. handbags. saddlery and harness;	Preparation and spinning of textile fibres	Textiles. manufacture of other textiles. manufacture of wearing apparel and	Manufacture of motor vehicles and accessories	Manufacture of wooden. cork and wickerwork goods
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	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]	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	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	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	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-	CCGT - NG	ICE - NG	ICE - 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	ICE - NG	ICE - NG	CCGT - 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	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]	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	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	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	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%	39%	40%	38%	34%	38%	37%	36%	38%	35%	37%	40%	39%	41%	36%	34%	41%	44%	42%	42%	37%	38%	33%	35%	38%	37%	42%	40%
Thermal efficiency of CHP system [%]	44%	36%	35%	37%	46%	37%	41%	44%	37%	40%	40%	37%	36%	35%	44%	46%	34%	31%	33%	33%	48%	38%	49%	47%	37%	37%	33%	35%
Share of electricity produced by High- Efficiency CHP [%]	50%	75%	56%	49%	57%	66%	86%	90%	88%	82%	79%	75%	68%	72%	50%	83%	57%	67%	64%	64%	100%	83%	81%	100%	63%	83%	58%	47%
Share of self-produced electricity [%]	53%	91%	92%	98%	53%	82%	90%	89%	92%	100%	79%	81%	88%	82%	53%	70%	99%	94%	85%	85%	100%	87%	75%	100%	67%	77%	87%	98%
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	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%	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	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 [%]	44%	45%	60%	15%	36%	25%	23%	40%	10%	25%	40%	25%	25%	15%	6%	50%	15%	6%	8%	3%	55%	44%	77%	41%	24%	28%	50%	55%
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	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]	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	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]	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	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]	51 929	329	441	466	45 781	532	321	315	124		2 066	79	528	167	7 805	239	3	94	948	685	0	106	15 637		343	256	295	69
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	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]	14 580	-	-	-	3 804	2 697	6 146	3 192	7 278	8 666	7 231	470	3 592	1 949	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]	14 580	-	-	-	3 804	532	321	315	124		2 066	79	528	167	7 805	239	3	94	948	685	0	106	15 637		343	256	295	69
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	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]	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	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]	96 485	3 665	4 235	139 497	423 8668	6 145	11 167	5 505	12 539	17 297	14 371	989	9 129	3 750	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]	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	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]	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	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 industrial companies (10-50 workers)

Industry	Chemical and Petrochemical			Coke ovens	Oil&Gas	Food									Iron and steel	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	Oil extraction and refining	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	Manufacture of basic iron and steel manufacture of tubes, pipes, hollow profiles 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, paper, paperboard,	travel accessories, bags, leather goods and saddlery;	Preparation and spinning of textile fibres	textile, other textile industries, manufacture of wearing apparel and	Manufacture of motor vehicles and accessories	Manufacture of wooden, cork and wickerwork goods
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	1 443	210	283	1 914	5 631	3 025	137	173	17 778	204	738	282	99	244
Electricity demand [MWh/year]	961	75	830	14 028	506	368	799	281	982	2 340	360	291	2 106	239	693	240	324	1 024	1 214	652	760	956	11 843	146	530	202	359	461
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	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	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		0.1			0.1	0.3		0.2		4.1	0.1	0.1		0.1	0.1
Thermal capacity of CHP system [MWt]	0.4	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	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 []	0.9	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	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 [%]	40%	39%	40%	38%	41%	38%	37%	36%	38%	35%	37%	40%	39%	41%	44%	34%	41%	44%	42%	42%	37%	38%	40%	35%	38%	37%	42%	40%
Thermal efficiency of CHP system [%]	36%	36%	35%	37%	37%	37%	41%	44%	37%	40%	40%	37%	36%	35%	31%	46%	34%	31%	33%	33%	48%	38%	35%	47%	37%	37%	33%	35%
Share of electricity produced by High-Efficiency CHP [%]	69%	75%	56%	49%	82%	66%	86%	90%	88%	82%	79%	75%	68%	72%	67%	83%	57%	67%	64%	64%	100%	83%	78%	100%	63%	83%	58%	47%
Share of self-produced electricity [%]	95%	91%	92%	98%	97%	82%	90%	89%	92%	100%	79%	81%	88%	82%	94%	70%	99%	94%	85%	85%	100%	87%	88%	100%	67%	77%	87%	98%
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	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%	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	87	105	43	115	451	76	75	76	10 446	84	177	79	50	134
Share of demand for CHP heat [%]	44%	45%	60%	15%	36%	25%	23%	40%	10%	25%	40%	25%	25%	15%	6%	50%	15%	6%	8%	3%	55%	44%	77%	41%	24%	28%	50%	55%
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	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]	961	75	830	14 028	506	140	240	126	148	752	185	113	852	60	123	71	50	163	581	97	58	75	11 843	63	182	73	63	152
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	182	86	88	242	912	153	58	90	15 122	63	290	88	108	321
Electricity injected into the grid [MWh]	64	9	117	466	21	39	29	16	14		50	28	147	15	12	26	1	16	134	22	0	12	1 842		97	20	14	7
Self-consumed electricity [MWh]	1 323	91	1 362	28 219	600	173	252	123	154	921	185	124	1 108	68	171	60	87	226	778	131	58	78	13 280	63	193	68	94	313
Electricity off-taken from the grid [MWh]						196	546	158	828	1 419	176	167	998	170	522	180	237	798	436	522	703	878		84	336	134	265	148
Electricity exchanged with the grid [MWh]						39	29	16	14		50	28	147	15	12	26	1	16	134	22	0	12			97	20	14	7
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	277	213	123	367	1 371	230	154	196	29 318	178	477	196	149	379
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	411	250	216	546	2 154	362	154	237	37 558	178	759	235	258	801
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	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]	961	75	830	14 028	506	368	799	281	982	2 340	360	291	2 106	239	693	240	324	1 024	1 214	652	760	956	11 843	146	530	202	359	461
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	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 EH 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	Manufacture of basic iron and steel manufacture of tubes, pipes, hollow profiles 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	textile, other textile industries, manufacture of wearing apparel 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	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

unit [€/MWh]																												
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 EH CHP in small and medium 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	Manufacture of other food products and tobacco	Production of animal feeds	Manufacture of bakery products and farinaceous products
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
WACC [%]	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

Industry	Iron and steel	Mechanical Engineering	Mining	Other metals	Ceramics and glass		Other industries		Paper	Textile			Automotive	Wood
Industrial subsector	Manufacture of basic iron and steel manufacture of tubes, pipes, hollow profiles 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	Textiles, manufacture of other textiles, manufacture of wearing apparel and	Manufacture of motor vehicles and accessories	Manufacture of wooden, cork and wickerwork goods
Cost of specific investment in a CHP system [€/kWe]	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]	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	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	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	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]	48.20	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	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
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
Excise duty on consumption of gas for civil use [€/MWh]	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
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
Excise duty on gas applied to the CHP unit [€/MWh]	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	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
WACC [%]	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%

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.

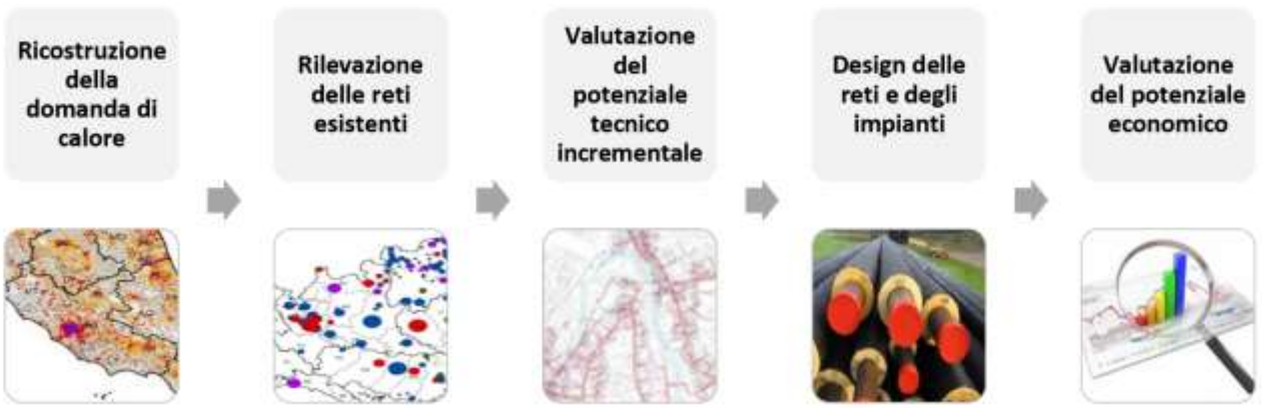
The development potential of district heating in Italy was assessed on the basis of a detailed estimate of the demand for heat by sector, type of use and geographical zone, described in Chapter 1, and of parametric estimates, derived from analysis of the district heating networks already existing in 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 61 Diagram of the method for assessing the potential for efficient DH



Ricostruzione della domanda di calore	Reconstruction of heat demand
Rilevazione delle reti esistenti	Survey of existing networks
Valutazione del potenziale tecnico incrementale	Assessment of incremental technical potential
Design delle reti e degli impianti	Design of networks and plants
Valutazione del potenziale economico	Assessment of economic potential

The method used to build the scenario included the following steps:

- Characterisation of heat demand:
  - reconstruction of the national heat demand at municipality level, broken down 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- 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 the heat demand at municipal level currently covered by district heating networks was obtained by processing the data from the AIRU annual report 2014.

The main driver used to identify the areas with technical potential for development of DH was heat demand for space heating from the residential sector, which is the main driver of development of DH networks to date. This choice is supported by earlier statistics on the district heating sector in Italy which show that:

- 67% 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;
- 97% of the energy supplied by DH networks is located in areas with colder winters (climate condition areas E-F).

The contribution of heat demand from the services sector to development of DH networks has been considered secondarily. This means it has not been considered as a driver for identifying the areas most suited for DH, but it was factored in only when sizing the demand which can be covered by a DH network. The contribution of heat demand from industrial customers to development of district heating networks (currently about 6% 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, 66% 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 (2.6% of the national total).

Table 85 Heat demand in the residential sector and share covered by district heating in 2013

Area	Number of municipalities	Consumption for space heating in the residential sector (GWh)	Heat demand for space heating in the residential sector (GWh)	Share of climate condition area demand	Energy from district heating in 2013 in the residential sector (GWh)	Share of demand covered by district heating (2013)
A	2	-	-	-	-	-
B	157	3 732	2 985	1%	-	0.0%
C	986	28 412	22 730	10%	-	0.0%
D	1 582	67 177	53 742	23%	156	0.3%
E	4 263	176 791	141 433	61%	5 052	3.6%
F	1 102	13 489	10 791	5%	719	6.7%
Total	**8 092**	**289 601**	**231 680**	**100%**	5 927	**2.6%**

Table 86 Heat demand in the residential sector and share covered by district heating in 2013 in municipalities served by the methane network

Area	Number of municipalities with methane supply	Consumption for space heating in the residential sector (GWh)	Heat demand for space heating in the residential sector (GWh)	Share of climate condition area demand	Energy from district heating in 2013 in the residential sector (GWh)	Share of demand covered by district heating (2013)
A	1	-	-	0%	-	-
B	93	3 366	2 693	1%	-	0.0%
C	677	24 147	19 318	9%	-	0.0%
D	1 248	63 836	51 069	23%	156	0.3%
E	3 978	174 283	139 427	63%	4 952	3.6%
F	595	10 314	8 251	4%	439	5.3%
Total	6 592	275 946	220 757	100%	5 547	2.5%

Table 87 Heat demand in the residential sector and share covered by district heating in 2013 in municipalities not served by the methane network

Area	Number of municipalities without methane supply	Consumption for space heating in the residential sector (GWh)	Heat demand for space heating in the residential sector (GWh)	Share of climate condition area demand	Energy from district heating in 2013 in the residential sector (GWh)	Share of demand covered by district heating (2013)
A	1	-	-	0%	-	-
B	64	365	292	3%	-	0.0%
C	309	4 265	3 412	31%	-	0.0%
D	334	3 342	2 673	24%	-	0.0%
E	285	2 507	2 006	18%	100	5.0%
F	507	3 175	2 540	23%	280	11.0%
Total	**1 500**	13 654	**10 923**	**100%**	381	3.5%

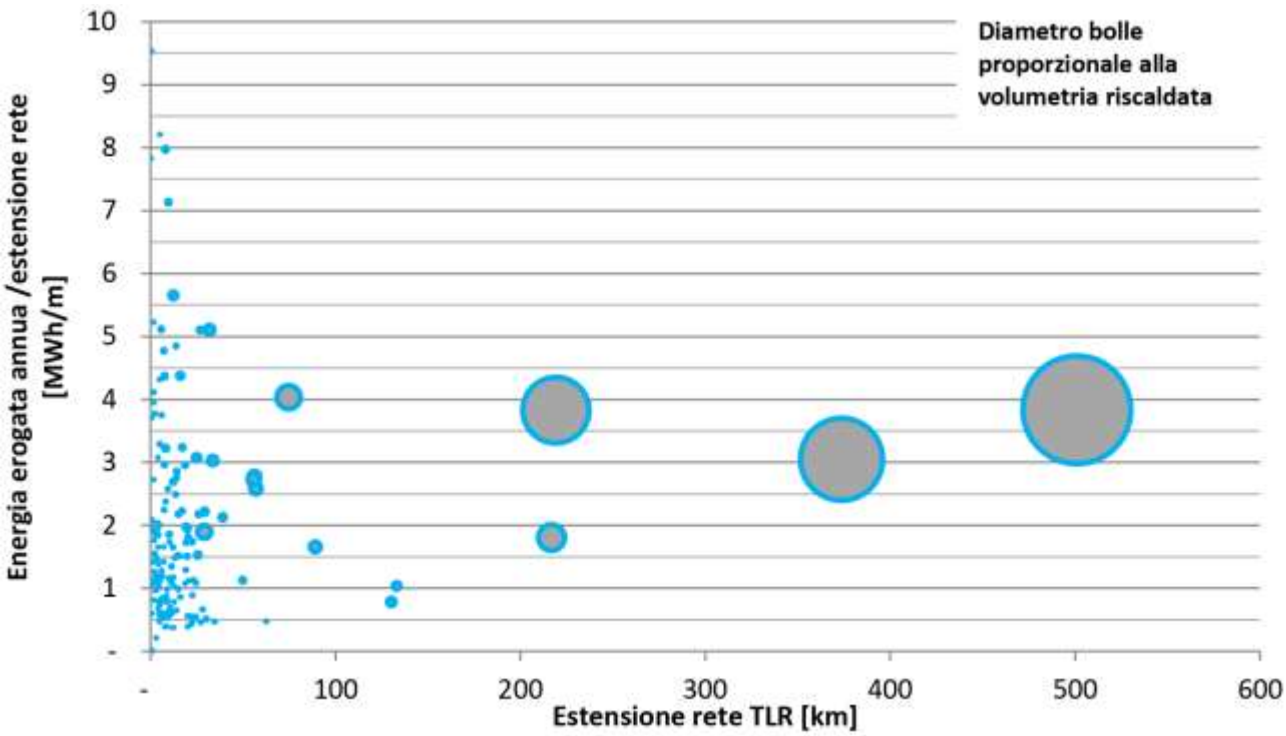
6.2 Technical potential for district heating

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 (SWD2013 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[76], 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 weighed 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 have in many cases values well below 2 MWh/m.

Figure 62. District heating networks in Italy in 2013. Distribution with respect to: network length, linear density and heated space



Energia erogata annua/estensione rete [MWh]	**Energy supplied per year/network length [MWh]**
Estensione rete TLR [km]	**Length of DH network [km]**
Diametro bolle proporzionale alla volumetria riscaldata	**Diameter of bubbles proportionate to heated volume**

[76] 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 from natural gas

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 threshold value for identifying technical potential the linear heat density value suggested by the European Commission, which is of 2.5 MWh/m.

To estimate linear heat density, the calculation method suggested by Persson was used[77]:

$$\frac{Q_S}{L} = e \cdot q \cdot w$$

Where:

$\frac{Q_S}{L}$: linear heat density

e : plot ratio, i.e. fraction of total building space area in a given land area

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 $w = 61. \bullet e^{-0,15}$

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 technical potential for increasing district heating has been calculated using this formula:

$$P_{INCR-DH} = \sum_{i=0}^{8092} P_{i\ INCR-DH} = \sum_{i=0}^{8092} [(P_{i\ L-DH} \cdot K_{i\ SAT} - E_{i\ DH}) \cdot K_{SWITCH} \cdot K_{INCR} \cdot K_{i\ MAX}]$$

Where

P_i ***INCR_DH:*** technical potential for increasing district heating in the nth municipality

E_i ***DH***: heat supplied by the existing DH in the residential sector in the nth municipality

P_i ***L-DH:***- gross demand that can be covered by district heating in the nth municipality, considered equal to the demand for residential heating in the municipalities having a linear heat density greater than the threshold value of 2.5 MWh/m. Although the demand for residential heating makes up the largest use of the heat distributed by district heating networks, considering residential heating demand as a first approximation equal to the total heat demand that can be covered by district heating networks may lead to partial underestimation of the potential supply from DH. However, this cautionary assumption is balanced by other assumptions which overestimate potential, e.g. the proximity of high-density areas and the lack of physical obstacles to construction of the network. Moreover, to calculate the incremental technical potential more precisely a correction factor K_{INCR} has been introduced, to include the demand for heat by demand points different from residential heating.

K_i ***SAT:***- saturation rate, the ratio of the municipal heat demand from those municipal areas (identified by the individual census areas of the municipality) that have linear heat density >2.5 MWh/m to overall demand in the municipality, assuming that all the areas in the municipality are technically able to be served by district heating. Thus, this assumption fails to consider the presence of physical obstacles to construction of the networks (too narrow roads, 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 lie in non-adjoining areas which cannot be served by a single network.

K_{SWITCH}: district heating acquisition rate, i.e. the % share of potential customers which would connect to

[77] Urban Persson 'Realize the Potential! Cost effective and Energy Efficient District Heating in European Urban Areas', 2011

the network out of all those reached by it. This factor has been assessed at municipal level as being equal to the share of consumption of expensive energy sources (diesel, LPG, etc.) plus 50% of the share of consumption for central heating.

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 at national level the share of district heating energy delivered for non-process and non-residential thermal uses is of 30%, the incremental factor has been set at 140%.

$K_i MAX$: factor establishing the annual growth limit of municipal built space connected to the sector: the value set for the limit is of 3 million m^3 per year per municipality. This value corresponds to the maximum value of annual growth of spaces connected to DH, recorded in a single municipality within the time series of development of existing networks.

The technical potential for increase of district heating in the areas served by methane pipelines has been calculated at about 10.7 TWh. Comparing this value with the current 9.2 TWh it is felt that, net of economic and financial consideration, a maximum increase of about 2.2 time the demand currently met by district heating may be achieved.

Table 88 Incremental technical potential for efficient DH fuelled by natural gas

	Nm	P_L-DH	K_{sat}	K_{switch}	K_{incr}	E_{DH}	$P_{INCR-DH}$
	Number of municipalities with potential for DH	**Gross technical potential for DH**	**Saturation rate**	**Switch rate**	**Incremental rate other customers**	**Heat supplied to the residential sector by existing DH networks[78]**	**Incremental technical potential[79]**
	n°	(GWh/year)	%	%	%	(GWh/year)	(GWh/year)
B	1	1	0%	-	140%	-	-
C	5	37	3%	37%	140%	-	-
D	150	9 063	46%	29%	140%	12	1 488
E	804	50 062	55%	36%	140%	4 184	9 028
F	204	2 425	16%	47%	140%	67	217
Italy	**1 164**	**61 588**	**52%**	**35%**	**140%**	**4 262**	10 733

[78] The heat from district heating does not match the national total in 2013 because it considers sonly the energy supplied by district heating in the municipalities served by methane pipelines having a linear heat density >2.5MWh/m.

[79] In aggregate terms, the formula used is not applicable precisely. This formula may yield a negative result in some networks where development exceeded the gross technical potential. In these cases, the incremental technical potential of the municipality has been considered to be nil.

6.2.2 Technical potential for efficient DH from waste incineration

In 2013 5 million tonnes of waste were incinerated for energy purposes, with an input energy content of 13.3 TWh (1.15 Mtoe)[80], of which 6.8 TWh are used for district heating[81].

To assess the role of waste in the potential for increase of DH it is also important to estimate availability of waste in the near future. To this end, analysis of the technical potential for district heating fuelled by waste is based on estimates of the availability of waste for waste-to-energy use, projected to be 9.77 million tonnes in 2023, with a thermal equivalent of 2.25 Mtoe (26 TWh)[82]. Thus, in 2023 the incremental availability of input energy in incineration plants would be of 12.7 TWh, corresponding (applying a thermal efficiency of 20% and 15% of heat distribution losses) to 2.1 TWh.

Analysis of exploitation of this availability for district heating purposes has assumed the use of these resources in each provincial capital (in the case of provinces with more than one capital, the capital with the largest population was selected). For the purposes of the analysis, the local availability of waste for energy use was assessed by considering the resident population of each province; this assumption, while introducing an approximation, is felt to be fit for the purposes of this study. It has been assumed that the DH networks currently fuelled by incineration plants use primarily waste produced in the province in which they are located, secondarily in other provinces of the same region and, lastly, for any excess consumption, waste uniformly taken from the other regions.

[80] Source: ISPRA data

[81] Source: AIRU annual report

[82] The estimates of waste to be used for waste to energy are based on the scenarios supplied by ISPRA in 2015

Table 89 Assessment of the use for DH of the waste intended for energy use in 2023

Region	Province	Resident population as at 31/12/2010	Share of the region's resident population	Consumption of waste in the Region 2013 [GWh]	Consumption by province 2013[GWh]	Consumption of waste by province for district heating in 2013 [GWh]	Availability in the region 2023 [GWh]	Availability by province 2023 [GWh]	Gross residual availability 2023 [GWh]	Excess in the region 2023 [GWh]	Residual availability by province 2023 [GWh]	Thermal efficiency	Heat obtainable from waste [GWh]	Incremental demand for DH RES +Ther (GWh/year)	Actual heat obtainable from waste [GWh]
ABRUZZO	L'Aquila	309 820	23.08%	300	69		582	134	134		84	20%	14	16	14
	Teramo	312 239	23.26%		70			135	135		85	20%	14		
	Pescara	323 184	24.08%		72			140	140		88	20%	15		
	Chieti	397 123	29.58%		89			172	172		108	20%	18		
BASILICATA	Potenza	383 791	65.32%	136	89		233	152	152		95	20%	16	50	16
	Matera	203 726	34.68%		47			81	81		51	20%	9	-	
CALABRIA	Cosenza	734 656	36.52%	436	159		814	297	297		187	20%	32	-	
	Catanzaro	368 597	18.33%		80			149	149		94	20%	16	-	
	Reggio di Calabria	566 977	28.19%		123			229	229		144	20%	24	-	
	Crotone	174 605	8.68%		38			71	71		44	20%	8	-	
	Vibo Valentia	166 560	8.28%		36			67	67		42	20%	7	-	
CAMPANIA	Caserta	916 467	15.71%	1 294	203		2 559	402	402		252	20%	43	-	
	Benevento	287 874	4.93%		64			126	126		79	20%	13	-	
	Napoli	3 080 873	52.81%		683			1 351	1 351		848	20%	144	-	
	Avellino	439 137	7.53%		97			193	193		121	20%	21	-	
	Salerno	1 109 705	19.02%		246			487	487		306	20%	52	-	
EMILIA-ROMAGNA	Piacenza	289 875	6.54%	967	63		1 861	122	59		37	20%	6	114	6
	Parma	442 120	9.97%		96			186	90		56	20%	10	140	10
	Reggio nell'Emilia	530 343	11.97%		116			223	108		68	20%	11		
	Modena	700 913	15.81%		153			294	142		89	20%	15	241	15
	Bologna	991 924	22.38%		216	604		416	0			20%		674	
	Ferrara	359 994	8.12%		79	391		151	0			20%		90	
	Ravenna	392 458	8.85%		86			165	80		50	20%	8	88	8
	Forlì-Cesena	395 489	8.92%		86	321		166	0			20%			
	Rimini	329 302	7.43%		72			138	67		42	20%	7	89	7
FRIULI-VENEZIA GIULIA	Udine	541 522	43.82%	272	119		582	255	255		160	20%	27		
	Gorizia	142 407	11.52%		31			67	67		42	20%	7		
	Trieste	236 556	19.14%		52			111	111		70	20%	12	372	12
	Pordenone	315 323	25.52%		69			148	148		93	20%	16		
LAZIO	Viterbo	320 294	5.59%	1 239	69		2 442	137	137		86	20%	15		
	Rieti	160 467	2.80%		35			68	68		43	20%	7		
	Roma	4 194 068	73.21%		907			1 788	1 788		1 122	20%	191		
	Latina	555 692	9.70%		120			237	237		149	20%	25		
	Frosinone	498 167	8.70%		108			212	212		133	20%	23		
LIGURIA	Imperia	222 648	13.77%	354	49		698	96	96		60	20%	10		
	Savona	287 906	17.81%		63			124	124		78	20%	13	105	13
	Genoa	882 718	54.60%		193			381	381		239	20%	41	863	41
	La Spezia	223 516	13.82%		49			96	96		61	20%	10	90	10
LOMBARDY	Varese	883 285	8.91%	2 165	193		4 303	383		-1 052		20%			
	Como	594 988	6.00%		130	214		258				20%			
	Sondrio	183 169	1.85%		40			79				20%		79	
	Milan	3 156 694	31.83%		689	2 180		1 370				20%		1 109	
	Bergamo	1 098 740	11.08%		240	316		477				20%		181	
	Brescia	1 256 025	12.66%		274	2 166		545				20%			
	Pavia	548 307	5.53%		120			238				20%		132	
	Cremona	363 606	3.67%		79	186		158				20%		60	
	Mantua	415 442	4.19%		91			180				20%			
	Lecco	340 167	3.43%		74			148				20%		58	
	Lodi	227 655	2.30%		50			99				20%			
	Monza and Brianza	849 636	8.57%		185	294		369				20%		183	
MARCHE	Pesaro e Urbino	366 963	23.44%	340	80		698	164	164		103	20%	17	75	17
	Ancona	481 028	30.73%		105			214	214		135	20%	23	62	23
	Macerata	325 362	20.79%		71			145	145		91	20%	15		
	Ascoli Piceno	214 068	13.68%		47			95	95		60	20%	10	31	10
	Fermo	177 914	11.37%		39			79	79		50	20%	8		-

Region	Province	Resident population as at 31/12/2010	Share of the region's resident population	Consumption of waste in the region 2013 [GWh]	Consumption by province 2013 [GWh]	Consumption of waste by province for district heating in 2013 [GWh]	Availability in the region 2023 [GWh]	Availability by province 2023 [GWh]	Gross residual availability 2023 [GWh]	Excess in the region 2023 [GWh]	Residual availability by province 2023 [GWh]	Thermal efficiency	Heat obtainable from waste [GWh]	Incremental demand for DH RES + Ther (GWh/year)	Actual heat obtainable from waste [GWh]
MOLISE	Campobasso	231 086	72.26%	68	49		116	84	84		53	20%	9	40	9
	Isernia	88 694	27.74%		19			32	32		20	20%	3		
PIEDMONT	Torino	2 302 353	51.65%	981	506		1 977	1 021	1 021		641	20%	109	1 134	109
	Vercelli	179 562	4.03%		39			80	80		50	20%	9	103	9
	Novara	371 802	8.34%		82			165	165		104	20%	18	187	18
	Cuneo	592 303	13.29%		130			263	263		165	20%	28	129	28
	Asti	221 687	4.97%		49			98	98		62	20%	10	135	10
	Alessandria	440 613	9.89%		97			195	195		123	20%	21	152	21
	Biella	185 768	4.17%		41			82	82		52	20%	9	87	9
	Verbano-Cusio-Ossola	163 247	3.66%		36			72	72		45	20%	8		
PUGLIA	Foggia	640 836	15.66%	912	143		1 745	273	273		172	20%	29		
	Bari	1 258 706	30.77%		281			537	537		337	20%	57		
	Taranto	580 028	14.18%		129			247	247		155	20%	26		
	Brindisi	403 229	9.86%		90			172	172		108	20%	18		
	Lecce	815 597	19.94%		182			348	348		218	20%	37		
	Barletta-Andria-Trani	392 863	9.60%		88			168	168		105	20%	18		
SARDINIA	Sassari	337 237	20.13%	368	74		698	140	140		88	20%	15		
	Nuoro	160 677	9.59%		35			67	67		42	20%	7		
	Cagliari	563 180	33.61%		124			235	235		147	20%	25		
	Oristano	166 244	9.92%		36			69	69		43	20%	7		
	Olbia-Tempio	157 859	9.42%		35			66	66		41	20%	7		
	Ogliastra	57 965	3.46%		13			24	24		15	20%	3		
	Medio Campidano	102 409	6.11%		22			43	43		27	20%	5		
	Carbonia-Iglesias	129 840	7.75%		28			54	54		34	20%	6		
SICILY	Trapani	436 624	8.64%	1 130	98		2 210	191	191		120	20%	20		
	Palermo	1 249 577	24.74%		280			547	547		343	20%	58		
	Messina	653 737	12.94%		146			286	286		180	20%	31		
	Agrigento	454 002	8.99%		102			199	199		125	20%	21		
	Caltanissetta	271 729	5.38%		61			119	119		75	20%	13		
	Enna	172 485	3.41%		39			75	75		47	20%	8		
	Catania	1 090 101	21.58%		244			477	477		299	20%	51		
	Ragusa	318 549	6.31%		71			139	139		87	20%	15		
	Siracusa	404 271	8.00%		90			177	177		111	20%	19		
TOSCANA	Massa-Carrara	203 901	5.44%	803	44		1 628	89	89		56	20%	9		
	Lucca	393 795	10.50%		84			171	171		107	20%	18		
	Pistoia	293 061	7.82%		63			127	127		80	20%	14		
	Florence	998 098	26.62%		214			433	433		272	20%	46		
	Livorno	342 955	9.15%		73			149	149		93	20%	16		
	Pisa	417 782	11.14%		90			181	181		114	20%	19		
	Arezzo	349 651	9.32%		75			152	152		95	20%	16	72	16
	Siena	272 638	7.27%		58			118	118		74	20%	13		
	G rosseto	228 157	6.08%		49			99	99		62	20%	11		
	Prato	249 775	6.66%		54			108	108		68	20%	12		
TRENTINO-ALTO ADIGE	Bolzano	507 657	48.95%	232	113	150	465	228	78		49	20%	8	287	8
	Trento	529 457	51.05%		118			237	237		149	20%	25		
UMBRIA	Perugia	671 821	74.11%	204	151		349	259	259		162	20%	28		
	Terni	234 665	25.89%		53			90	90		57	20%	10		
VALLE D'AOSTA	Valle d'Aosta	128 230	100.00%	27	27							20%		155	
VENETO	Verona	920 158	18.63%	1 089	203		2 093	390	390		245	20%	42	281	42
	Vicenza	870 740	17.63%		192			369	369		232	20%	39		
	Belluno	213 474	4.32%		47			91	91		57	20%	10	88	10
	Treviso	888 249	17.99%		196			377	377		236	20%	40		
	Venice	863 133	17.48%		190			366	366		230	20%	39	394	39
	Padua	934 216	18.92%		206			396	396		249	20%	42	340	42
	Rovigo	247 884	5.02%		55			105	105		66	20%	11		
Grand total		**60 626 442**	**100.00%**	**13 319**	**13 319**	**6 821**	**26 051**	**26 051**	**20 282**	**-1 052**	**12 733**		**2 165**	**8 490**	**573**

6.2.3 Technical potential for efficient DH from biomass

The potential for efficient district heating fuelled by biomass was assessed for all the municipalities not reached by the natural gas network.

The analysis applied some specific assumptions, linked to the peculiar features of these areas and to the characteristics found in the existing district heating infrastructure.

Thus, the technical potential for increasing district heating was calculated using the same formula adopted in paragraph 6.2.1, with the following specifications:

- $P_{i\ G\text{-}DH}$:- gross demand that can be covered by district heating in the nth municipality, considered to be equal to the demand for residential heating in the municipalities having a linear heat density greater than the threshold value of 1.5 MWh/m;
- $K_{i\ SAT}$: the saturation rate was assessed as being equal to 70%, in line with the penetration rate of district heating in the residential sector currently found in areas not served by methane pipelines;
- K_{SWITCH}: the district heating acquisition phase was assumed to be homogeneous for the different municipalities and equal to 70% of the municipal residential customers.

Table 90 Incremental technical potential for efficient DH from biomass

	N_m	$P_{L\text{-}DH}$	K_{sat}	K_{switch}	K_{incr}	E_{DH}	$P_{INCR\text{-}DH}$
	Number of municipalities with potential for DH	**Gross technical potential for DH**	**Saturation rate**	**Switch rate**	**Incremental rate other customers**	**Heat supplied to the residential sector by existing DH networks[83]**	**Incremental technical potential**
	No	(GWh/year)	%	%	%	(GWh/year)	(GWh/year)
C	10	129	70%	70%	140%	-	86
D	149	1 221	70%	70%	140%	-	787
E	231	1 625	70%	70%	140%	82	952
F	356	1 498	70%	70%	140%	118	728
Italy	**746**	4 474	**70%**	**70%**	**140%**	**200**	2 552

[83] The heat from district heating does not match the national total because it considers only the energy supplied by district heating in the municipalities served by methane pipelines having a linear heat density >2.5MWh/m.

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 every 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[84].

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 as it was not possible do 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) based on market surveys carried out by the Italian Competition Authority (AGCM)[85] and set out below:

Table 91 Linear cost of pipelines

Pipeline costs (minor networks)	**200 €/m**
Pipeline costs (mountain area networks)	**500 €/m**
Pipeline costs (urban area networks)	**500 €/m**

The demand point substations have been sized by multiplying the average specific capacity[86] by the incremental volumes which 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/m^3**
Climate condition area E	**29.0 W/m^3**
Climate condition area F	**35.6 W/m^3**

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.

[84] For networks fuelled by biomass this index was considered to be 1.5.
[85] AGCM ‘Indagine conoscitiva sul settore del teleriscaldamento’ 2013.
[86] 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[87].

Network operating costs were taken from the JRC guidelines [88] which state costs of:

- 250 €/TJ for the part on network operation and maintenance;
- 1.5 €/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

[87] Prices of electricity net of VAT and other recoverable charges, billed in 2014 to industries with consumption between 70 and 150 GWh

[88] 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[89], 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 set the size of plants using 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,[90] obtaining average values of:

Table 94 Parameters K_{base} and K_{peak}

K_{base}	1
K_{peak}	1.3

For each municipality served by the methane pipelines, average capacity was estimated and, consequently, the capacity of the baseload systems and that of the peak systems were derived through parameters Kbase and Kpeak.

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 - Electricity 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

[89] Value in line with the con current average losses of Italian DH networks which are of 16%, and with the main studies in the sector's literature, which place it in the range 10%-20%

[90] Estimated as the ratio of energy supplied by the network to hours of heating by climate condition area as set out in 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}	$R_{ele\ winter\ chp}$	$R_{ele\ only\ summer\ ele}$
	€/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}	$R_{ele\ winter\ chp}$	$R_{ele\ only\ summer\ ele}$
Large ICE	Università Torvergata 2015	Università Torvergata 2015	Università Torvergata 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 2015	GSE based on MPG data 2014	GSE based on MPG data 2014
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
50.6	82.1

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 a 4.6

Table 100 Parameters K_{base} and K_{peak}

$K_{H/CHP}$	2.9
H/E_{CHP}	4.6

The technical efficiency parameters for CHP plants are listed below:

Table 101 Technical parameters for CHP internal combustion engines

	(H/E)max	Fuel/E - EE only	E CHP
Organic Rankine Cycle (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 operation of the ORC cycle:

Table 102 Equivalent operating hours adopted for the ORC cycle

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	€/WC
ORC	**6 500**	**468**		**0.020**	**140**	**115**	-
Boiler using 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 (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[91].

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.

[91] 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.

In particular, as concerns the municipalities served by methane pipelines, the average annualised generation cost of the heat supplied by cost-effective networks is of 82 €/MWh, against an average sales price of 94.8 €/MWh.[92]. This margin, which includes investment and operating costs and financial charges, is strongly influenced not only by the sales price of gas to domestic customers, but also by the different tax rates (reduced VAT at 10% is applied to DH from HE CHP and renewable sources for residential customers) and excise duties (the duty for industrial use applied to DH is lower than the excise for civil uses applied 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	**100**	**€/WC**

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 2.2 TWh of heat supplied to customers per year. This involves an increase in network length of 375 km and 57 million m^3 of heated space.

[92] 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:

$$\mathbf{P_{TLR}} = [P_{CH4}\ (9{,}6 \times \boldsymbol{eff})] \times (1{,}22/1{,}1) + 10\%\ \mathbf{VAT}$$

$\mathbf{P_{TLR}}$: DH sales price

$\mathbf{P_{CH4}}$: sales price of methane for residential heating, before VAT at 9.6: LHV of methane (KWh/m^3)

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 for district heating for municipalities served by methane pipelines (based on consumption in 2013)

Climate condition area	E	F	Grand total
Incremental economic potential [GWh]	2 141	119	**2 260**
Incremental length of networks [km]	354	21	375
Incremental heated space [million m^3]	54.4	2.5	56 9
Incremental thermal capacity HE CHP [MWt]	983	41	1 025
Incremental supplemental thermal capacity [MWt]	1 278	54	**1 332**
Incremental heat output HE CHP supplied[GWh]	1 713	95	**1 808**
Incremental supplemental heat output [MWt]	428	24	**452**
Incremental electrical capacity HE CHP [MWel]	1 125	47	**1 172**
Incremental electricity output HE CHP produced [GWh]	2 305	128	**2 433**
Incremental non-HE CHP electricity produced [GWh]	477	20	**497**
LCOH [€/MWh]	82.6	69.2	**82.1**
Saved emissions [ton CO2eq]	521 634	28 898	**550 532**
Primary energy savings [toe]	115 464	6 395	**121 859**

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 1.7 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 for district heating for municipalities served by methane pipelines (based on consumption in 2023)

Climate condition area	E	F	Grand total
Incremental economic potential [GWh]	1 605	85	**1 690**
Incremental length of networks [km]	279	16	295
Incremental heated space [million m^3]	43.6	1.9	45.5
HE CHP thermal capacity [MWt]	737	29	767
Supplemental thermal capacity [MWt]	958	38	997
HE CHP heat output (GWh)	1 284	68	1 352
Supplemental heat output [GWh]	321	17	338
HE CHP electrical capacity [MWel]	843	33	**876**
HE CHP electricity produced [GWh]	1 727	90	**1 817**
Non-HE CHP electricity produced [GWh]	357	14	371
LCOH [€/MWh]	83.8	72.7	**83.21**
Saved emissions [ton CO2eq]	390 910	20 338	**411 248**
Primary energy savings [toe]	86 532	4 496	**91 028**

6.5.2 Economic potential for efficient DH from waste incineration

This analysis has assessed the energy obtainable from incineration of the quantity of waste predicted by ISPRA's scenarios over the coming years as energy available at zero cost for incineration. This assumption considers the incineration plants (and their construction and operating costs) as investment in the waste management sector.

The availability of energy from waste incineration, determined on the basis of assessed technical potential, was then compared with the potential heat demand that can be met by district heating in each provincial capital: after this subtraction, the effectively usable heat from waste is equal to 573 GWh.

The following table breaks down this estimate by region but, even though the presence of a technical-economic potential for gas-fuelled DH in the areas identified has been verified, this distribution should be seen as indicative, as it was obtained through approximation for the purpose of national-level assessment (firstly by assuming local availability of waste for energy generation through a breakdown by province based on population figures, then by assuming that DH networks would use primarily waste produced in the same province and only secondarily waste from other areas[93]).

Table 107 Economic potential for efficient DH from waste incineration [GWh]

Abruzzo	14
Basilicata	16
Emilia Romagna	47
Friuli Venezia Giulia	12
Liguria	64
Marche	51
Molise	9
Piedmont	203
Tuscany	16
Trentino Alto Adige	8
Veneto	133
Total	573

Exploitation of the economic potential for efficient DH from waste incineration yields savings of primary energy from fossil fuels (based on 90% heat efficiency of the replaced plants) of 55 ktoe and of avoided emissions of 18.7 kton of CO_2eq (assessed on the basis of the difference in emission factors of natural gas, which is equal to 57 $kgCO_2eq/GJ$, and of CDR, of 48.86 $kgCO_2/GJ$[94]).

6.5.3 Economic potential for efficient DH from biomass

As to the networks located in municipalities not served by methane pipelines, using biomass and which have been determined to be cost-effective, the average value of the annualised cost of heat supply to customers was calculated to be 104 €/MWh, against an average sales price of the heat supplied of 140.1 €/MWh[95]. This margin, which includes both investment and operating costs and financial charges, is

[93] See paragraph 6.2.2

[94] Source: ISPRA data, 2013

[95] 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:

$$P_{TLR} = [P_{LPG}/(eff)] \times (1{,}22/1{,}1) + IVA\ 10\%$$

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 HE DH using biomass (prices before VAT)

Retail price of LPG	109.2	€/MWh
Price of wood chips	20	€/MWh
Price of CHP electricity[96]	115	€/MWh
Wholesale price of heat	33.2	€/MWh
Sales price DH	140.1	€/MWh
Price of white certificates	100	€/WC

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 1.3 TWh of heat supplied to customers per year. This involves an increase in network length of 408 km and 29 million m^3 of heated space.

P_{DH}: DH sales price

P_{LPG}: sales price of LPG for residential heating, before IVA

eff = average seasonal efficiency of boilers

(1.22/1.1) = VAT difference between LPG and residential DH from HE CHP or renewable sources.

[96] 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 for efficient DH using biomass (based on consumption in 2013)

Climate condition area	D	E	F	Grand total
Incremental economic potential [GWh]	149	657	533	**1 338**
Incremental length of networks [km]	44	196	168	**408**
Incremental heated space [million m^3]	4.5	13.9	10.6	**29**
Incremental thermal capacity HE CHP [MWt]	39	133	82	**254**
Incremental supplemental thermal capacity [MWt]	113	386	236	**735**
Incremental heat output HE CHP supplied[GWh]	66	291	236	**592**
Incremental supplemental heat output [MWt]	83	366	297	**746**
Incremental electrical capacity HE CHP [MWel]	8	29	18	**55**
Incremental electricity output HE CHP produced [GWh]	17	74	60	**150**
Incremental non-HE CHP electricity produced [GWh]	-	-	-	-
LCOH [€/MWh]	119.9	100.6	96.4	**104**
Saved emissions [ton CO2eq]	8 521	37 559	30 458	**76 538**
Primary energy savings [toe]	17 057	75 178	60 965	**153 200**

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 just 1.7 TWh of heat supplied to customers per year.

Table 110 Economic potential for efficient DH using biomass (based on consumption in 2023)

Climate condition area	D	E	F	Grand total
Incremental economic potential [GWh]	143	593	466	1 202
Incremental length of networks [km]	43	183	150	**377**
Incremental heated space [million m^3]	4.5	13.0	9.5	**27**
HE CHP thermal capacity [MWt]	37	121	72	**229**
Supplemental thermal capacity [MWt]	108	349	207	**664**
HE CHP heat output (GWh)	63	263	206	**532**
Supplemental heat output [GWh]	80	331	260	**670**
HE CHP electrical capacity [MWel]	8	26	15	**50**
HE CHP electricity produced [GWh]	16	67	52	**135**
Non-HE CHP electricity produced [GWh]	-	-	-	-
LCOH [€/MWh]	120.0	100.8	96.8	**105**
Saved emissions [ton CO2eq]	8 157	33 933	26 672	**68 763**
Primary energy savings [toe]	16 328	67 921	53 388	**137 637**

6.6 Potential increase in the efficiency of existing district heating networks

During 2013 heat losses during heat distribution by district heating networks amounted to 1.7 TWh, or 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 would go down to 10%. The reduction of losses in the existing networks would yield a saving of 673 GWh of heat.

Table 111 Potential for improving the efficiency of existing DH networks (source of the data on heat supplied and losses: AIRU report 2013)

Municipality	Heat supplied [MWh]	Heat losses in the DH network [MWh]	Losses [%]	Potential for efficiency improvement [MWh]
Total	**8 744 345**	**1 685 614**	**16%**	**672 746**
Torino	1 923 064	389 175	17%	157 951
Brescia	1 139 691	240 596	17%	102 567
Milan	839 786	95 671	10%	2 125
Reggio Emilia	391 666	66 145	14%	20 364
Verona	301 470	45 012	13%	10 364
San Donato Milanese	162 108	21 421	12%	3 068
Mantua	155 937	32 770	17%	13 899
Ferrara	153 073	29 231	16%	11 001
Rivoli	151 640	24 624	14%	6 998
Bergamo	150 214	19 780	12%	2 781
Parma	147 599	26 047	15%	8 682
Cremona	146 786	26 312	15%	9 002
Brunico	137 665	25 744	16%	9 403
Imola	102 286	22 456	18%	9 982
Alba	101 607	29 413	22%	16 311
Settimo Torinese	81 043	16 223	17%	6 496
Roma	76 573	19 687	20%	10 061
Varese	70 040	6 334	8%	-
Genoa	69 096	1 821	3%	-
Bardonecchia	67 797	9 599	12%	1 859
Sestriere	66 506	5 401	8%	-
Legnano	64 859	12 960	17%	5 178
Bologna	63 657	5 159	7%	-
Rovereto	57 285	25 719	31%	17 419
Dobbiaco	56 754	14 160	20%	7 069
Val di Vizze	56 229	17 805	24%	10 402
Cinisello Balsamo	55 108	6 462	10%	305
Rho	55 030	10 192	16%	3 670
Bolzano	54 954	5 285	9%	-
Milan	51 248	2 562	5%	-
Castelnuovo di Val di Cecina	41 048	-	0%	-
Riva del Garda	40 509	9 270	19%	4 292
Bologna	40 189	9 024	18%	4 103
Seregno	39 394	10 719	21%	5 708
Morbegno	38 994	15 210	28%	9 790
Tirano	38 877	10 714	22%	5 755
Desio	38 574	10 901	22%	5 954
Varna	37 944	361	1%	-
Vicenza	37 865	6 777	15%	2 313
Saluzzo	37 024	7 286	16%	2 855

Fossano	36 698	10 520	22%	5 798
Monza	34 245	4 242	11%	393
Biella	33 605	3 892	10%	142
Como	33 273	13 779	29%	9 074
Acqui Terme	32 920	5 010	13%	1 217
Pomarance	32 800	1 730	5%	-
Lodi	32 712	4 638	12%	903
Monza	32 685	5 787	15%	1 940
Pomarance	29 800	1 900	6%	-
Piacenza	29 670	5 236	15%	1 745
Bologna	29 315	2 608	8%	-
Cavalese	26 090	14 663	36%	10 588
Voghera	26 012	3 020	10%	117
Cassano d'Adda	24 567	2 136	8%	-
Modena	24 102	4 282	15%	1 444
Silandro	23 697	6 447	21%	3 433
Siror	22 807	2 394	10%	-
Santa Fiora	22 588	5 825	21%	2 984
Casale Monferrato	22 429	2 545	10%	48
Casalecchio di Reno	22 010	6 447	23%	3 601
Cesana Torinese	21 122	2 451	10%	94
Temù	20 097	5 403	21%	2 853
Sesto	19 946	3 951	17%	1 561
Rho	19 850	3 515	15%	1 179
Borgaro Torinese	19 264	1 759	8%	-
Busto Arsizio	19 159	2 780	13%	586
Monguelfo	18 627	4 518	20%	2 203
Valdaora	18 565	3 690	17%	1 464
La Thuile	17 722	3 720	17%	1 576
Carmagnola	16 299	2 502	13%	622
Laces	16 295	5 279	24%	3 122
Monza	15 709	1 853	11%	97
Mezzano	15 418	7 624	33%	5 320
Sondalo	15 084	4 980	25%	2 974
Osimo	14 702	5 600	28%	3 570
Leinì	14 279	3 275	19%	1 520
Badia	13 811	4 748	26%	2 892
Cesena	13 449	1 494	10%	-
Sluderno	13 391	7 703	37%	5 593
Chiusa	13 127	2 699	17%	1 116
Lasa	12 426	4 599	27%	2 897
Cairo Montenotte	12 405	1 552	11%	156
Campo Tures	12 232	3 809	24%	2 204
Cesena	12 108	3 937	25%	2 333
Renon	11 671	20 374	64%	17 170
Pragelato	11 642	2 522	18%	1 106
Morgex	11 569	5 845	34%	4 104
Rasun Anterselva	11 267	4 361	28%	2 798
Monterotondo Marittimo	10 017	-	0%	-
Prè Saint Didier	9 977	1 819	15%	639
Sarentino	9 943	3 710	27%	2 345
Prato allo Stelvio	9 629	3 888	29%	2 536
Valle Aurina	9 289	4 554	33%	3 170
Piossasco	9 240	528	5%	-
Forlì	9 124	3 508	28%	2 245
Stelvio	8 915	2 920	25%	1 737
Cesano Boscone	8 148	3 492	30%	2 328
Villa Guardia	7 840	2 974	28%	1 893
Bergamo	7 828	586	7%	-
Brennero	7 768	1 666	18%	723

Rho	7 700	1 911	20%	950
Valle Aurina	7 506	1 875	20%	937
Predazzo	7 316	2 548	26%	1 562
Vandoies	7 250	2 726	27%	1 728
Rio di Pusteria	7 077	1 901	21%	1 003
Modena	7 032	1 050	13%	242
Santa Caterina Valfurva	7 031	3 775	35%	2 695
Ultimo	6 943	2 042	23%	1 143
Sellero	6 717	2 784	29%	1 834
Pomarance	6 620	280	4%	-
Rovereto	5 933	297	5%	-
Racines	5 769	172	3%	-
Fondo	5 684	2 896	34%	2 038
Vicenza	5 670	1 282	18%	587
Malles	5 571	1 504	21%	797
Collio	5 473	2 719	33%	1 900
Bagno di Romagna	5 400	2 390	31%	1 611
Ormea	5 249	2 713	34%	1 917
Arta Terme	5 242	2 413	32%	1 648
Nizza Monferrato	5 013	787	14%	207
Falzes	4 816	1 817	27%	1 154
Pomarance	4 711	-	0%	-
Curon	4 680	1 202	20%	614
Lizzano in Belvedere	4 655	2 315	33%	1 618
Racconigi	4 610	710	13%	178
Mirandola	4 481	1 295	22%	717
Nova Ponente	4 367	331	7%	-
Rimini	4 297	1 468	25%	892
Bomporto	4 143	2 984	42%	2 271
Terento	4 130	781	16%	290
Castel Maggiore	4 068	1 743	30%	1 162
Velturno	4 029	1 471	27%	921
Malles	3 998	1 194	23%	675
Pollein	3 905	1 812	32%	1 240
Rasun Anterselva	3 888	2 896	43%	2 217
Pomarance	3 792	152	4%	-
Naz Sciaves	3 754	826	18%	368
Curon	3 682	1 200	25%	711
Pinerolo	3 641	973	21%	512
Funes	3 553	1 112	24%	646
Laion	3 545	1 546	30%	1 037
Racines	3 523	575	14%	165
Luson	3 512	796	18%	365
Canale	3 500	1 238	26%	764
Rimini	3 432	1 479	30%	988
Trento	3 418	661	16%	253
Casalecchio di Reno	3 386	1 451	30%	967
Sedrina	2 964	1 429	33%	989
Naturno	2 906	462	14%	125
Castegnato	2 893	1 949	40%	1 465
Bologna	2 825	1 000	26%	618
Coredo	2 814	727	21%	373
Malles	2 751	633	19%	294
Selva dei Molini	2 562	546	18%	235
Tires	2 485	199	7%	-
Bologna	2 428	200	8%	-
Santo Stefano di Cadore	2 427	135	5%	-
Terlano	2 416	559	19%	262
San Felice sul Panaro	2 378	1 192	33%	835
Valdaora	2 230	250	10%	2

Castel Bolognese	2 194	482	18%	214
San Pancrazio	2 072	429	17%	179
Cortemilia	1 946	76	4%	-
Chiusa	1 929	674	26%	413
Funes	1 580	593	27%	376
Pomarance	1 573	77	5%	-
Moso in Passiria	1 565	498	24%	291
Castelrotto	1 543	698	31%	474
Verano	1 543	796	34%	562
Rodengo	1 516	583	28%	373
Pomarance	1 418	82	5%	-
Pomarance	1 255	55	4%	-
Modena	1 164	498	30%	332
Monterenzio	836	136	14%	39
San Godenzo	710	290	29%	190
Forlì	640	490	43%	377
Treppo Carnico	479	355	43%	272
Piobesi Torinese	428	112	21%	58

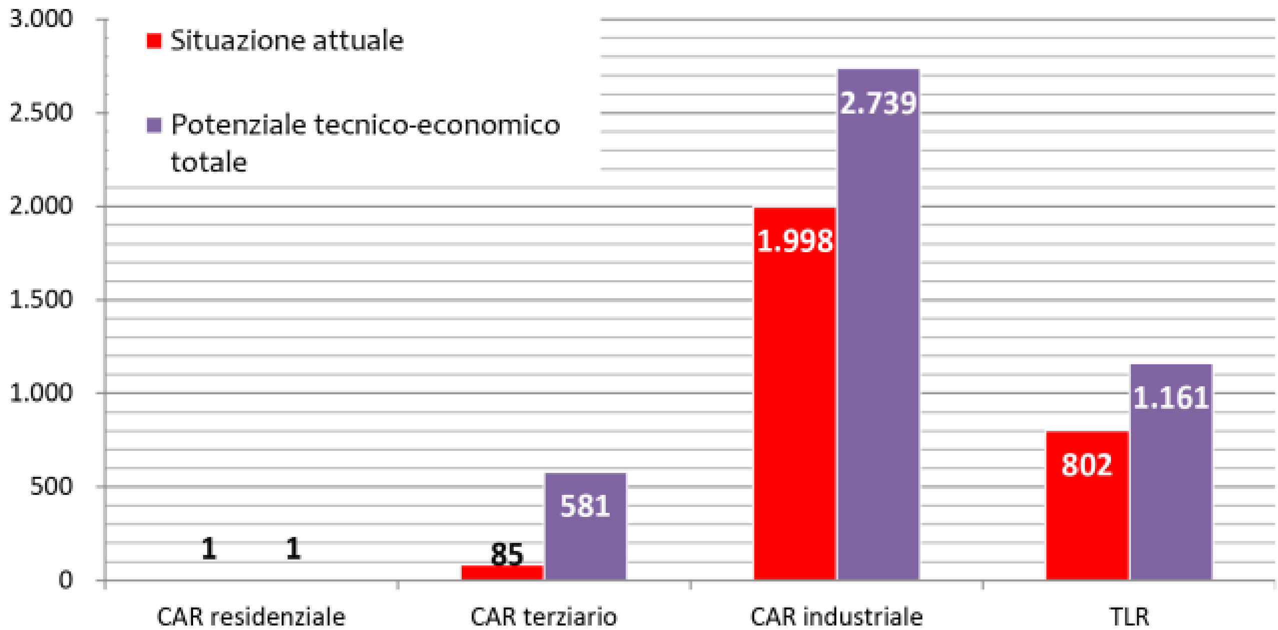
7 Summary of results

The development potential for HE CHP in the final use sectors[97] has been assessed, on the basis of the current economic and consumption conditions, to be 3 320 ktoe. Compared with the production of useful heat from HE CHP in these sectors in 2013, which amounted to 2 084 ktoe, the potential increase is of 1 236 ktoe.

This increase in useful heat produced by HE CHP is driven by the industrial sector and the services sector, which have a potential increase respectively of 740 ktoe and 496 ktoe. The residential sector has no economic potential under the current market conditions and cost of the technologies.

In the district heating sector, the potential was determined to be 1 161 ktoe. Compared with the heat supplied by DH in 2013, which amounted to 802 ktoe, the potential increase through efficient district heating is estimated to amount to 359 ktoe. A contributor to this potential increase is the production of heat based on biomass exploitation as to 115 ktoe and exploitation of waste incineration as to a further 49 ktoe.

Figure 63 Comparison between heat consumption from HE CHP and DH and the technical economic potential calculated on the basis of consumption levels in 2013 [ktoe]



Situazione attuale	Current situation
Potenziale tecnico-economico totale	Total technical- economic potential
CAR residenziale	Residential HE CHP
CAR terziario	HE CHP service sector
CAR industriale	HE CHP industrial sector
TLR	District heating

[97] The HE CHP systems supplying heat to district heating networks are not included in this estimate.

Table 112 Summary of results on potential

Sector	Measurement	Unit of measurement	Current situation 2013	Total technical-economic potential [98]	Incremental technical-economic potential
Residential HE CHP	Electrical output	MWe	5	5	0
	Heat output	MWt	7	7	0
	HE CHP electrical production	GWh el	6	6	0
	Heat production	GWh t	10	10	0
		ktoe	1	1	0
HE CHP service sector	Electrical output	MWe	287	1 426	1 140
	Heat output	MWt	291	1 925	1 634
	HE CHP electrical production	GWh el	989	5 050	4 061
	Thermal production	GWh t	989	6 752	5 764
		ktoe	85	581	496
HE CHP industrial sector	Electrical output	MWe	8 773	9 668	895
	Heat output	MWt	9 361	11 352	1 991
	HE CHP electrical production	GWh el	18 327	24 665	6 338
	Heat production	GWh t	23 239	31 851	8 612
		ktoe	1 998	2 739	740
District heating	Volumes heated	Mm3	302	402	100
	Km of network	km	3 807	4 685	878
	CHP heat output	MWt	2 825	4 260	1 435
	TOT heat output	MWt	8 056	11 558	3 502
	Heat supplied	GWht	9 331	13 502	4 171
		ktoe	802	1 161	359
	of which from RES	*GWht*	*1 367*	*2 705*	*1 338*
	of which from waste	*GWht*	*1 264*	*1 837*	*573*

[98] The economic technical potential shown in this paragraph is assessed as the sum of the incremental potential identified and current production, excluding possible future decommissioning or downsizing of capacity currently in operation.

8 Appendix

8.1 HE CHP and DH: 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 (SEN) 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 Cogeneration

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 which meet specific requirements in terms of primary energy savings (PES index) and can therefore be considered to operate in a 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, are entitled to 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 subparagraphs.

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;
- the net electricity produced by the HE CHP unit and fed into the grid from biomethane power plants is granted the tariff applying to electricity from biogas under 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 (varying according to consumption and to final use), i.e.: excise of 0.000449 €/m^3 for gas for specific consumption of up to 0.220 m^3/kWh, and excise between 0.007499 €/m^3 and 0.044 €/m^3 (according to end 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 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. Again, this is a requirement for issue of the building permit. This obligation, laid down in paragraph 5, does shall 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.

Paragraph 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.

Article 5(12) of Legislative Decree No 102/2014 has superseded the fund, by establishing that the resources earmarked for it must be paid into the State budget, for an amount of € 5 million in 2014 and € 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 fund for energy efficiency, which is a revolving fund. The Fund provides financing to projects that contribute to the national energy efficiency targets; it promotes the involvement of national and EU financial institutes and of private investors on the basis of appropriate risk sharing. Eligible projects include: a) projects to improve the energy efficiency of public buildings; b) development of district heating and district cooling networks; c) improvement of the energy efficiency of public services and infrastructure, including street lighting; d) improvement of the energy efficiency of whole residential buildings, including social housing buildings; e)improvement of energy efficiency and reduction in energy consumption in the industry and services sector.

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 installations feeding 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 to 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, shall be increased by a premium of 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 2005. 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 64 - Regions whose official documents include assessment of the potential for HE CHP

Figure 65 - 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	✓	Preliminary document for the new PEAR	2015
Valle d'Aosta	✓	PEAR (Regional Energy and Environmental Plan)	2014
Lombardy	✓	PEAR integrated with SEA	2015
Bolzano	✓	Climate and Energy Plan of Alto Adige to 2050	2011
Trento	✓	PEAP (Provincial Environmental and Energy Plan)	2013
Veneto	✓/	PEAR - Proposal for the Regional Assembly	2014
Friuli Venezia Giulia	✓	Adoption of PER (Regional Energy Plan) and consultation	2015
Emilia Romagna		PER - II Implementing plan 2011-2013	2011
Liguria	✓	Draft PEAR	2014
Toscana		PAER (Regional Environmental and Energy Plan)	2015
Umbria		SEAR (Regional Energy and Environmental Strategy)	2013
Marche	✓	PEAR (Regional Energy and Environmental Plan)	2005
Lazio		Policy Document New Energy Plan of Lazio	2015
Abruzzo		PER (Regional Energy Plan)	2009
Molise	✓	Preliminary document for the new PEAR 2015	2015
Campania	✓/	Draft PEAR and launch of SEA	2009
Puglia		Adoption of the updated PEAR and launch of consultation for SEA	2015
Basilicata		PIEAR (Regional Energy and Environmental Plan)	2010
Calabria		PEAR (Regional Energy and Environmental Plan)	2005
Sicily	✓	PEARS (Regional Energy and Environmental Plan of Sicily)	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 di 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: as to 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 in 2016 actions to improve energy efficiency in the industrial sector - through HE CHP - for 6 280 GWh/year, after the 2 493 GWh 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 Proposal for a Regional Energy Plan, put out for consultation in 2015, also included a focus on 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 in investing in this technology. 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 which might concern in particular bioenergies, 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 CHP mode; liquid biofuels in transport and in power generation.

The **Region of Piedmont**, in its proposal for a new PEAR approved in 2015, includes in its plans for the development of district heating systems in urban areas, maximisation of use of the CHP heat produced by existing systems (in particular for use in 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** stresses 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 services 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 about 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 services 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 minimum target, for systems with outputs below MWe and using natural gas, the increase in installed electrical capacity by 50 MWe by 2013 and by 100 MWe by 2020, thereby achieving additional savings of non-renewable primary energy estimated in 25 ktoe/year in 2013 and 50 ktoe/year in 2020.

The Action Plan of **the Sicily Region** contains several sheets describing actions and measures on cogeneration (for self-production but not only), 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 quoted	Year of source
Piedmont	✓	Draft document for the new PEAR The contribution of DH to ES targets	2015 2013
Valle d'Aosta	✓	PEAR (Regional Energy and Environmental Plan)	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 (Provincial Environmental and Energy Plan)	2015 2014 2013
Veneto	✓	PEAR - Proposal for the Regional Assembly	2014
Friuli Venezia Giulia	✓	Adoption of PER (Regional Energy Plan) and consultation	2015
Emilia Romagna	✓	PER (Regional Energy Plan) - Implementing Plan 2011-2013 Preliminary analysis for assessment of the geothermal potential	2011 2010
Liguria	✓	Draft PEAR	2014
Toscana	✓	PAER (Regional Environmental and Energy Plan)	2015
Umbria	✓	SEAR (Regional Energy and Environmental Strategy)	2013
Marche		PEAR (Regional Energy and Environmental Plan)	2005
Lazio		Policy Document - New Energy Plan of Lazio	2015
Abruzzo		PER (Regional Energy Plan)	2009
Molise		Preliminary document for the new PEAR 2015	2015
Campania		Draft PEAR and launch of SEA	2009
Puglia		Adoption of the updated PEAR and launch of consultation for SEA	2015
Basilicata		PIEAR (Regional Energy and Environmental Plan)	2010
Calabria		PEAR (Regional Energy and Environmental Plan)	2005
Sicily		PEARS (Regional Energy and Environmental Plan of Sicily)	2009
Sardinia		Draft PEAR and launch of consultation	2014

The **Valle d'Aosta Region** included in 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 electric output 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 level of census zone has 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 optimum size to maintain a local supply chain within the territory of Lombardy ranges between 1 and 10 MW: considering heat generation only, this means a potential of almost 130 new biomass plants having a size 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. The PEAR 2020 scenarios, high and medium, estimate efficiency increases in the DH networks of 120 ktoe in the residential sector and 80 ktoe in the services sector. As concerns the scenarios for RES penetration and development, biomass for domestic uses, district heating and industrial and agricultural uses reach 1 140 ktoe in the high development scenario at 2020 and 806 in the medium scenario; the geothermal source (direct use or district heating) reaches 30 ktoe in the high scenario and 13 ktoe in the medium scenario; waste RES in district heating reach 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 great interest, thanks to the results of the European project BIO-EN-AREA, which has calculated the quantity used at present, and has estimated the still untapped potential in the territory of 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**, in the framework of the Climate and Energy Plan for Alto Adige 2050 approved in 2011, has planned for the city of Bolzano further expansion of the existing DH, 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 of 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 number of actions to increase the use of DH networks, in the section “potential for energy generation from geothermal sources” of the draft PEAR for approval by the Regional Assembly, made in 2014, 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 for the services 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.

The **Region of Emilia Romagna**, in the three-year period 2011-2013, set the target of network extension by a total of some 35 km and an increase in indoor space served of 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 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 that Lombardy came third in Italy, after Lombardy and Piedmont, in term of 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 investment foreseen by the Plan, a major role for district heating can be played by the actions planned under the multiutility system, local authorities and plant development in areas with waste processing plants.

In the **Region of Liguria,** DH plants are included as contributors to achievement of the energy efficiency target 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, in line with the ROP ERDF resources 2007-2013 already used in past years. In the industrial sector, for example in a steel and iron industry hub 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 a sort of internal district heating system and plans to cool electricity and control stations using absorption equipment. In the civil sector, the focus is mostly on conurbations, the aim being to convert traditional energy generation plants into more sustainable systems (upgrading of the distribution network, smart grids, district heating and storage systems).

Gestore dei Servizi Energetici - GSE S.p.A.

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