



*Ministry of Economic Development*

DEPARTMENT OF ENERGY

**Directorate-General for Nuclear Energy, Renewable Forms of Energy and Energy Efficiency**

**ANNUAL REPORT  
ON COGENERATION IN ITALY**

**PRODUCTION YEAR 2011**

**April 2013**

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## **Introduction**

This document<sup>1</sup>, drawn up pursuant to Article 24(6) of Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency, aims to present and analyse the 2011 statistics on Italy's power and heat production through high- and low-efficiency cogeneration. Moreover, the document provides information on the power-generating capacity of the cogeneration units, the fuels used and the power, heat and overall output for each type of cogeneration technology, with particular emphasis on the contribution of cogeneration units connected to district heating networks.

The document also covers primary energy savings achieved in the 2011 production year through high-efficiency cogeneration (HEC) as well as simultaneous power and heat generation that does not qualify as HEC.

More specifically, the first chapter of the report describes the scope of the analysis and the main assumptions used in processing the data, whereas the second chapter illustrates and examines the statistical data obtained in the analysis. The main definitions and calculation criteria used are set out in the Appendices.

## **1 Scope of the analysis and assumptions**

### **1.1 Scope of the analysis**

This report has been drawn up on the basis of data collected from applications submitted by operators to the Energy Services Operator (ESO) to obtain high-efficiency cogeneration (HEC) status for the 2011 production year. Cogeneration units connected to district heating networks are referred to as CHP/DHN below.

### **1.2 Assumptions used in drawing up the report**

#### **1.2.1 Technologies and fuels taken into account**

The following cogeneration technologies, also listed in Annex I to Directive 2012/27/EU, have been taken into account in this report:

- combined-cycle gas turbine with heat recovery (CC);
- steam back-pressure turbine (SBT);
- steam-condensing extraction turbine (SCET);
- gas turbine with heat recovery (GT);
- internal combustion engine (ICE);
- other (microturbines, stirling engines, fuel cells, steam engines, organic Rankine cycles and any other type of technology or combination of technologies not covered by the previous points).

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<sup>1</sup> The Energy Services Operator (ESO) contributed to the preparation of this report.

Fuels are broken down as follows, based on their main use in cogeneration technologies:

- natural gas;
- oil (including diesel oil, distillate fuel oil, etc.) and LPG;
- hard coal/coke;
- ‘renewable sources’, i.e. wood fuels, agricultural biomass, biofuels and biogas;
- ‘waste’, i.e. non-renewable (urban/industrial) waste;
- ‘other’, i.e. the following fuels used by a small number of cogeneration units with a high power-generating capacity installed at the premises of energy-consuming users (e.g. refineries): refinery gas, hydrogen, coke oven gas, blast furnace gas, other gaseous waste and recovered waste heat.

### 1.2.2 Methodological assumptions used in the calculations

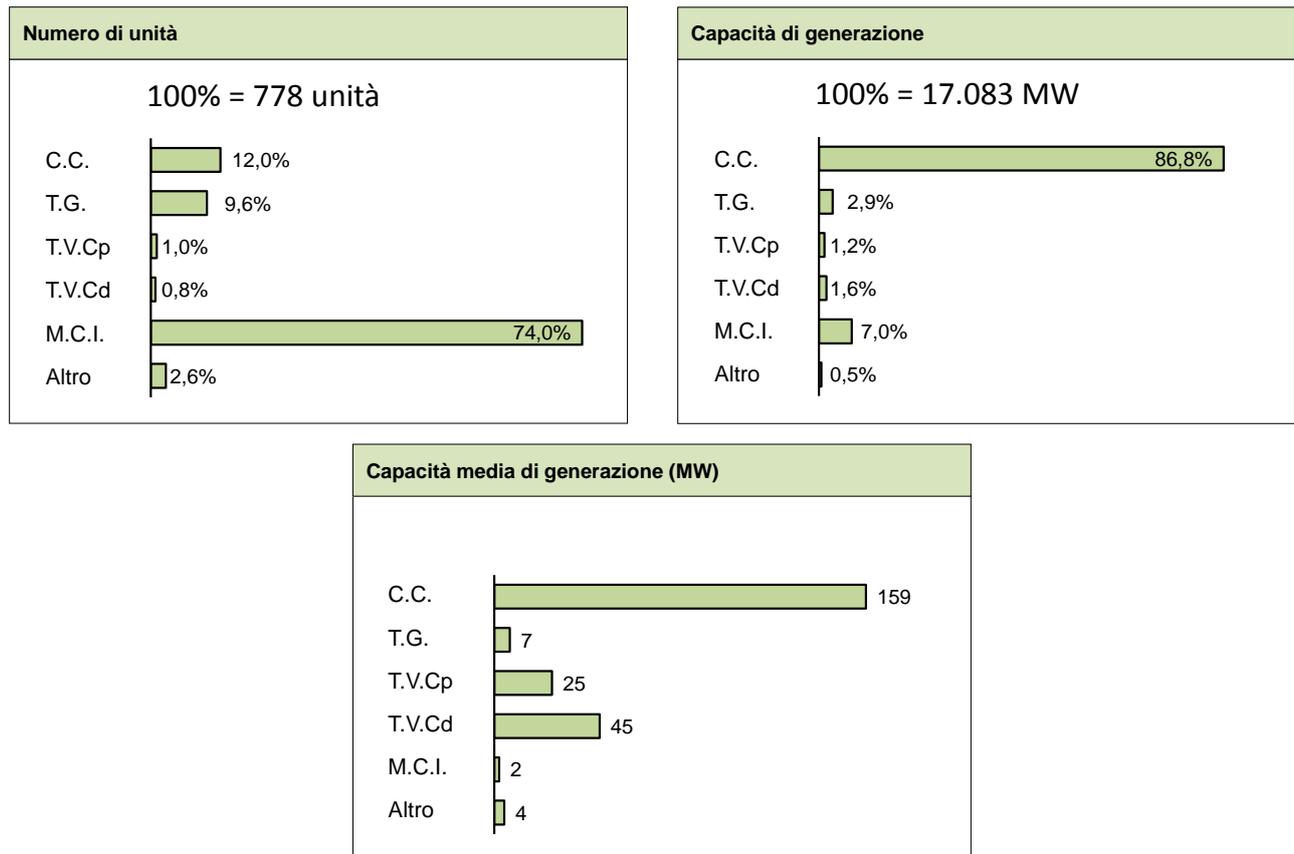
Units connected to a district heating network have been identified by examining declarations on the exploitation of useful heat submitted by operators in the context of obtaining HEC status, or by examining applications to obtain CHP/DHN status. To determine output and district heating capacity, the following assumptions were made:

- useful heat produced by cogeneration ( $H_{\text{CHP}}$ ) and supplied to a district heating network by units that have simultaneously submitted HEC and CHP/DHN applications has been considered equal to the ‘civil non-industrial heat’ share of the total ‘useful heat’ value (the sum of ‘civil non-industrial’ and ‘industrial’ heat) declared in the enclosures to CHP/DHN applications;
- the share of useful heat produced by cogeneration ( $H_{\text{CHP}}$ ) and supplied to a district heating network by units that have submitted HEC applications without simultaneously submitting CHP/DHN applications has been considered equal to the total useful heat supplied to the district heating network;
- for the purpose of verifying compliance with Annex II to Directive 2004/8/EC for units that have submitted CHP/DHN applications without simultaneously submitting HEC applications, the following assumptions were made:
  - where a steam-condensing extraction turbine is used, also in a combined cycle with a gas turbine, and the overall efficiency of the unit is below the threshold value, the default power to heat ratio ( $C_{\text{default}}$ ) has been used to calculate electricity from cogeneration ( $E_{\text{CHP}}$ ) and fuel input to cogeneration ( $F_{\text{CHP}}$ ) values instead of the effective power to heat ratio ( $C_{\text{eff}}$ ) recommended for statistical purposes by Annex II to Directive 2004/8/EC.

## 2 National cogeneration data for 2011

### 2.1 Number of units, power-generating capacity, power and heat output

Figures 1 and 2 illustrate the contribution made by each cogeneration technology used in combined heat and power production, in terms of the number of units, total and average power-generating capacity, total gross power and useful heat output and the average gross power to heat ratio.



**Figure 1 – Number of units, total and average power-generating capacity**

#### Legend

numero di unità = number of units

capacità di generazione = generating capacity

capacità media di generazione = average generating capacity

C.C. = CC

T.G. = GT

T.V.Cp = SBT

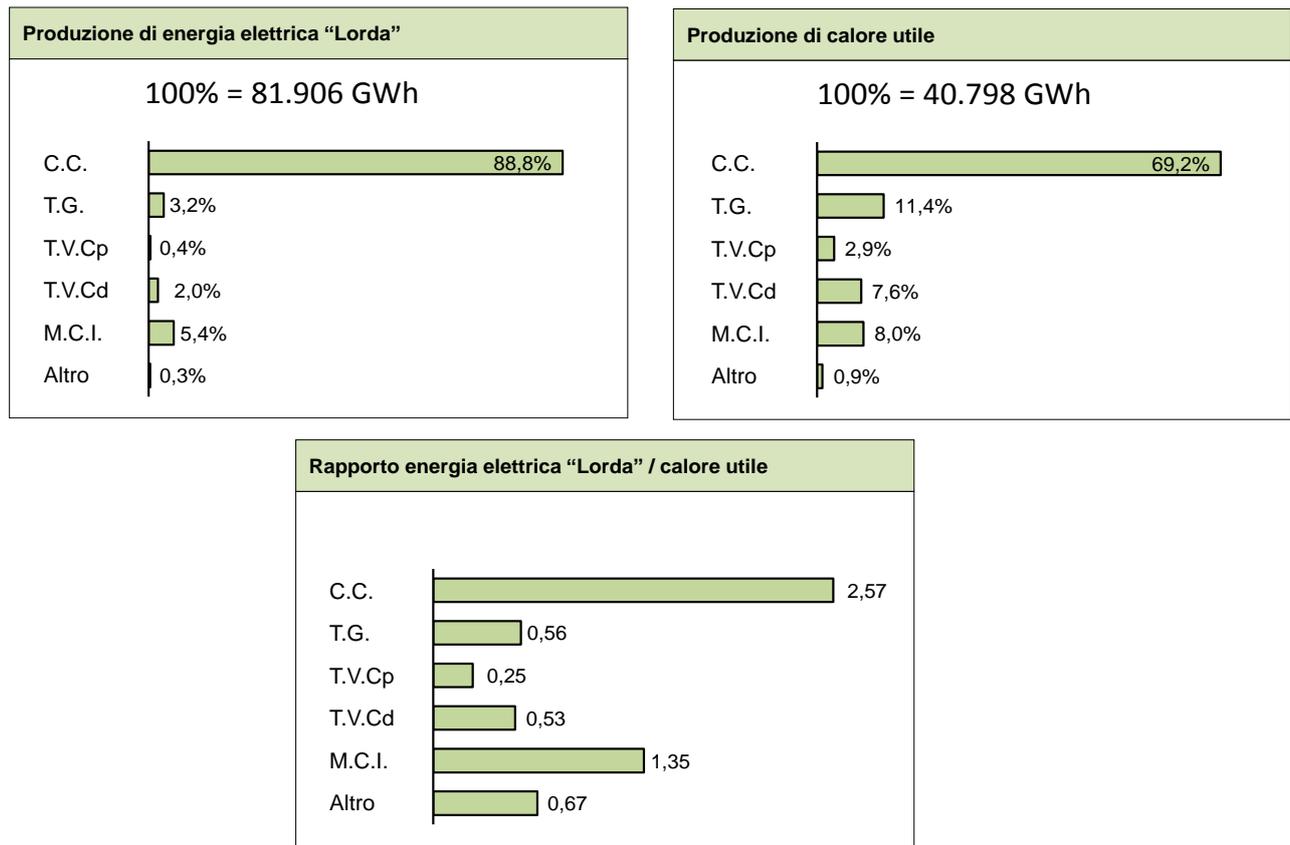
T.V.Cd = SCET

M.C.I. = ICE

altro = other

Combined-cycle gas turbines with heat recovery proves to be the technology with the largest installed power-generating capacity, whereas the internal combustion engine is the most widely used in terms of the number of plants, albeit with a considerably lower average generating capacity.

The small number of steam turbines (steam back-pressure or condensation turbines) not coupled with gas turbines shows that operators increasingly opt for combined cogeneration units, sometimes changing the configuration of existing units based on steam turbines only by installing one or more gas turbines upstream together with heat-recovery generators.



**Figure 2 – Power and heat output; gross power to useful heat ratio**

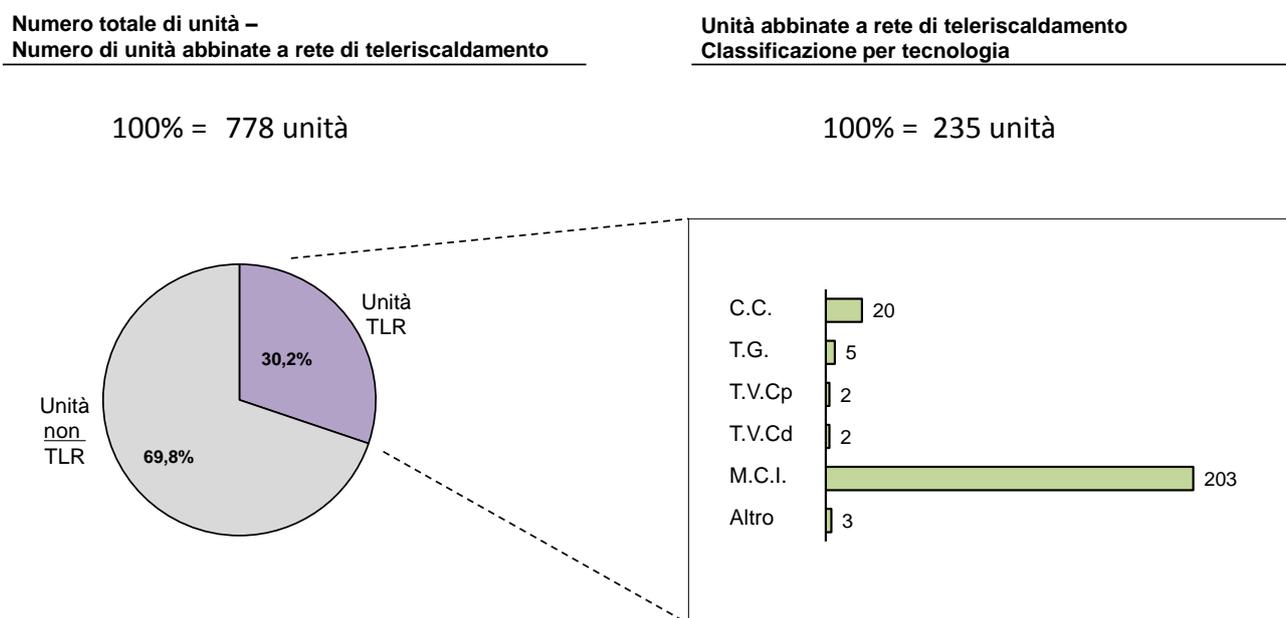
Legend

- produzione di energia elettrica 'lorda' = gross power output
- produzione di calore utile = useful heat output
- rapporto energia elettrica 'lorda'/calore utile = gross power to useful heat ratio
- C.C. = CC
- T.G. = GT
- T.V.Cp = SBT
- T.V.Cd = SCET
- M.C.I. = ICE
- altro = other

In line with the above, the combined-cycle gas turbine with heat recovery is the technology that accounts for the largest overall output of power and useful heat. The gross power to useful heat ratio is considerably lower for both gas turbines with heat recovery and simple steam turbines than for combined-cycle gas turbines with heat recovery.

## 2.2 Contribution from district heating units

Figures 3 to 6 illustrate the contribution to the total value, in terms of the number of units, total power-generating capacity and total gross power and useful heat output, of the units analysed, i.e. units connected to a district heating network.



**Figure 3 – Number of district heating units as a share of the total of all cogeneration units**

### Legend:

numero totale di unità = total number of units

numero di unità abbinato a rete di teleriscaldamento = number of units connected to district heating networks

unità abbinato a rete di teleriscaldamento = units connected to district heating networks

classificazione per tecnologia = breakdown by technology

unità non TLR = non-DHN units

unità TLR = DHN units

C.C. = CC

T.G. = GT

T.V.Cp = SBT

T.V.Cd = SCET

M.C.I. = ICE

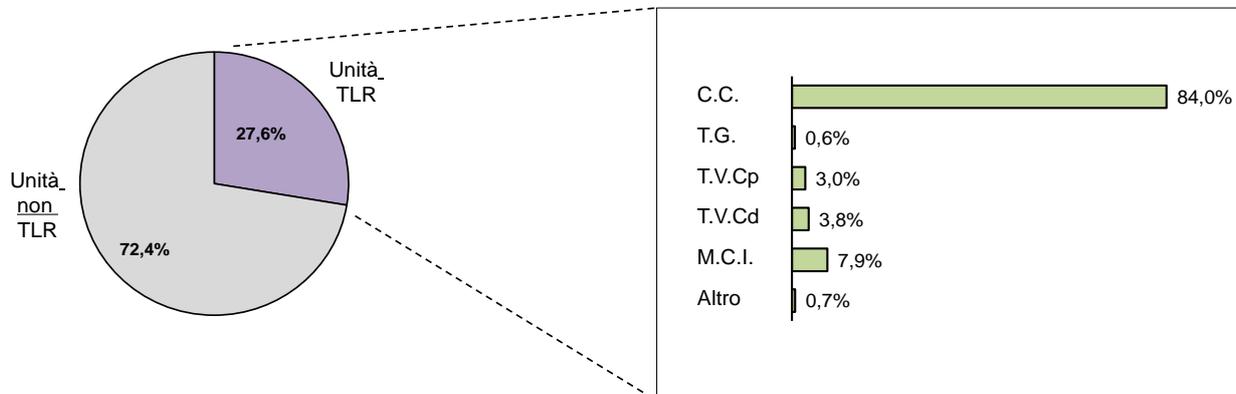
altro = other

Capacità di generazione totale –  
 Capacità di generazione di unità abbinata a  
 rete di teleriscaldamento

Capacità di generazione di unità abbinata a rete  
 di teleriscaldamento  
 Classificazione per tecnologia

100% = 17.083 MW

100% = 4.718 MW



**Figure 4 – Power-generating capacity of district heating units as a share of the total of all cogeneration units**

Legend:

capacità di generazione totale = total generating capacity

capacità di generazione di unità abbinata a rete di teleriscaldamento = generating capacity of units connected to district heating networks

classificazione per tecnologia = breakdown by technology

unità non TLR = non-DHN units

unità TLR = DHN units

C.C. = CC

T.G. = GT

T.V.Cp = SBT

T.V.Cd = SCET

M.C.I. = ICE

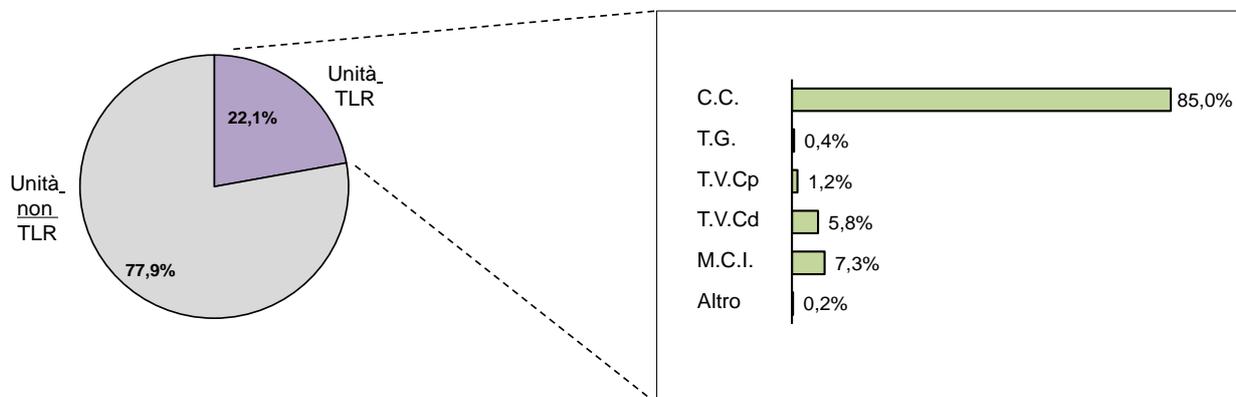
altro = other

Produzione totale di energia elettrica "lorda" –  
Produzione di energia elettrica "gross" di unità  
abbinate a rete di teleriscaldamento

Produzione di energia elettrica "lorda" di unità  
abbinate a rete di teleriscaldamento  
Classificazione per tecnologia

100% = 81.906 GWh

100% = 18.113 GWh



**Figure 5 – Power output of district heating units as a share of the total of all cogeneration units**

Legend:

produzione totale di energia elettrica "lorda" = total gross power generation

produzione di energia elettrica "gross" di unità abbinate a rete di teleriscaldamento = gross power generation of units connected to district heating networks

classificazione per tecnologia = breakdown by technology

unità non TLR = non-DHN units

unità TLR = DHN units

C.C. = CC

T.G. = GT

T.V.Cp = SBT

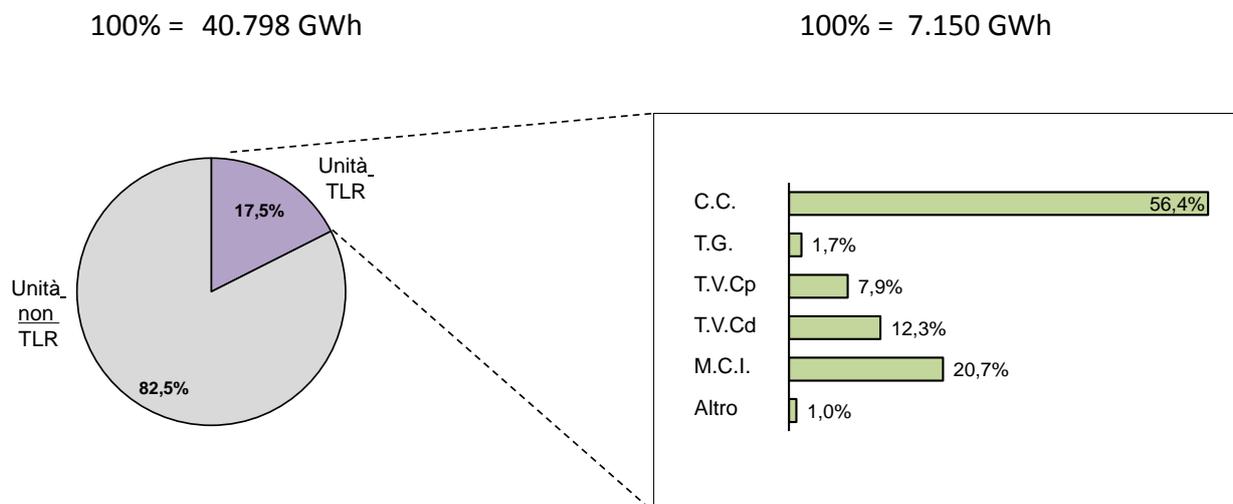
T.V.Cd = SCET

M.C.I. = ICE

altro = other

**Produzione totale di calore utile –  
Produzione di calore utile di unità abbinata a rete di  
teleriscaldamento**

**Produzione di calore utile di unità abbinata a rete di  
teleriscaldamento  
Classificazione per tecnologia**



**Figure 6 – Total useful heat output of district heating units as a share of the total of all cogeneration units**

Legend:

produzione totale di calor utile = total useful heat generation

produzione di calore utile di unità abbinata a rete di teleriscaldamento = useful heat generation of units connected to district heating networks

classificazione per tecnologia = breakdown by technology

unità non TLR = non-DHN units

unità TLR = DHN units

C.C. = CC

T.G. = GT

T.V.Cp = SBT

T.V.Cd = SCET

M.C.I. = ICE

altro = other

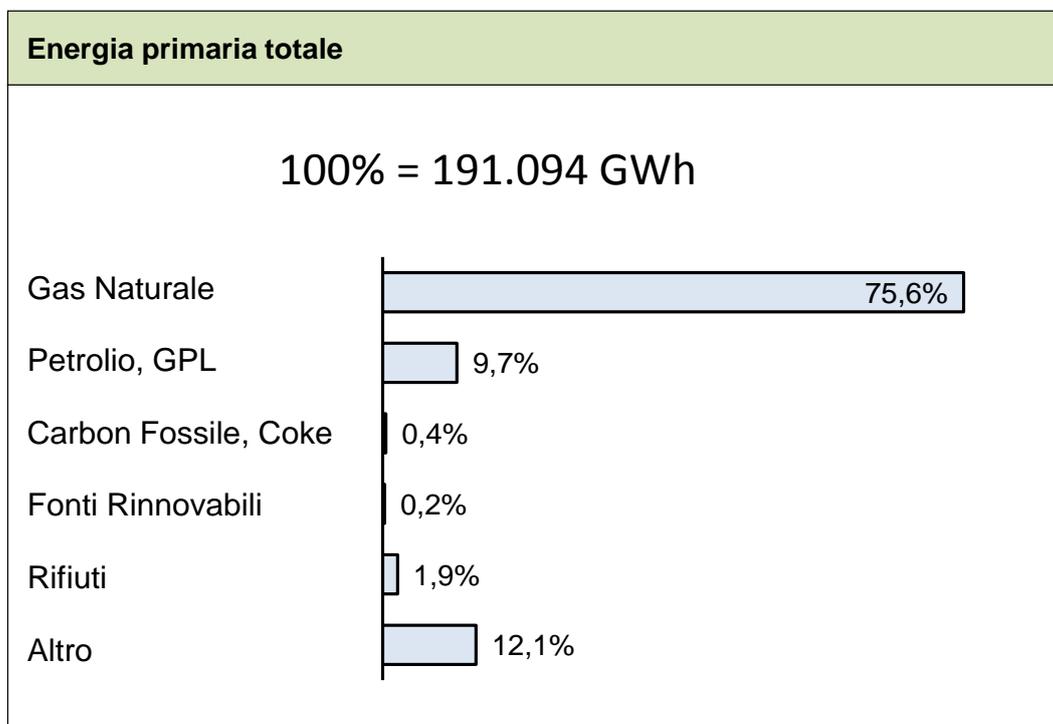
The development of district heating has mainly taken place in large urban areas with a high concentration of users. Such densely populated areas have seen the development of networks with a high distribution capacity, supplied on the basis of combined-cycle or other ‘centralised’ production technologies.

The analysis made shows that most of the units that are connected to district heating networks operate with internal combustion engines (around 90%); their output accounts for 20% of the total useful heat supplied to the networks.

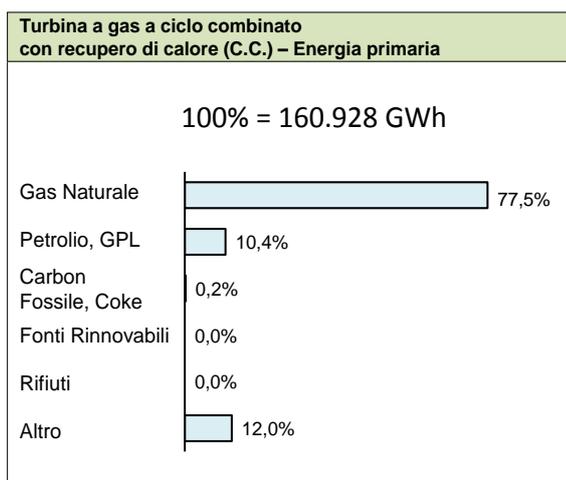
Thanks to their higher installed capacity, combined-cycle gas turbines, which is the second technology in terms of volume with less than 10% of the installed units, generate around 60% of the total useful heat supplied to the district heating networks.

### 2.3 Primary energy and fuel input

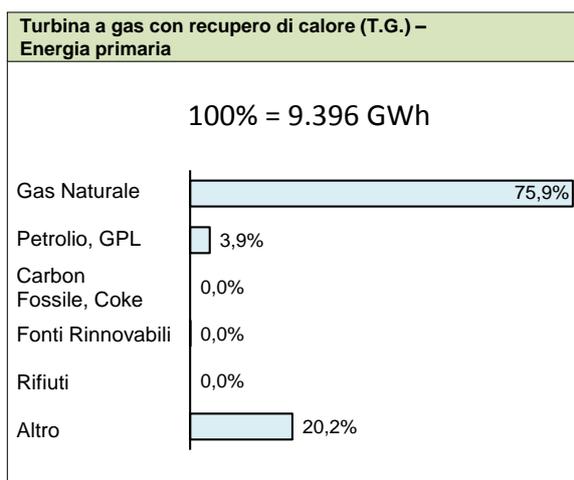
Figures 7-13 show the total primary energy used for cogeneration in 2011, broken down by type of fuel, and the contribution of each cogeneration technology used, also broken down by type of fuel.



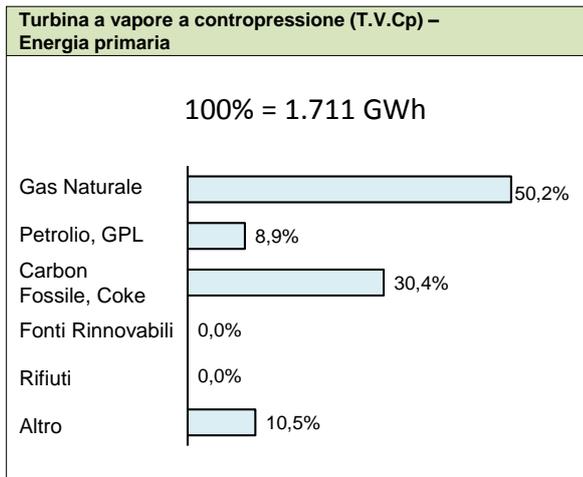
**Figure 7 – Primary energy broken down by fuel**



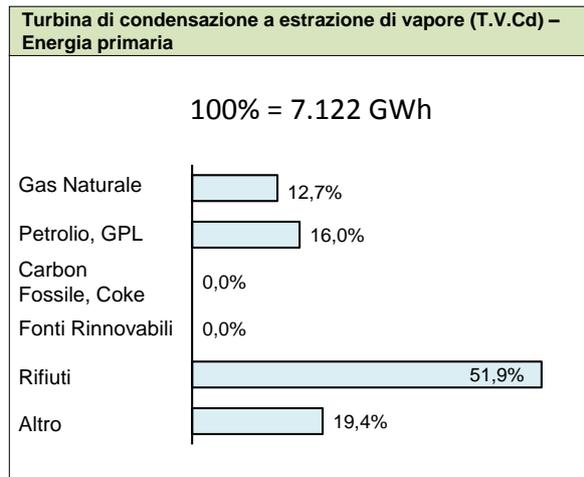
**Figure 8: Primary energy - combined-cycle gas turbines with heat recovery (CC), broken down by fuel**



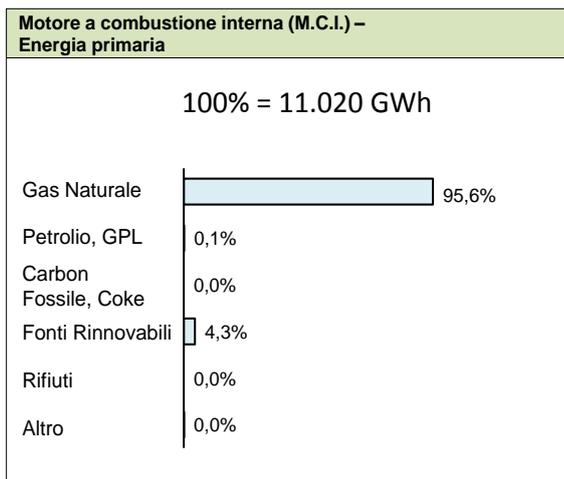
**Figure 9: Primary energy - gas turbines with heat recovery (GT), broken down by fuel**



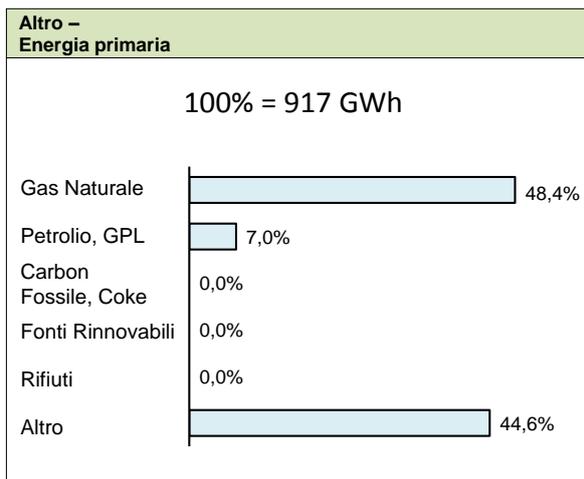
**Figure 10: Primary energy - steam back-pressure turbines (SBT), broken down by fuel**



**Figure 11: Primary energy - steam-condensing extraction turbines (SCET), broken down by fuel**



**Figure 12: Primary energy - internal combustion engines (ICE), broken down by fuel**



**Figure 13: Primary energy - other technologies, broken down by fuel**

Legend (figures 7-13):

energia primaria totale = total primary energy  
 gas naturale = natural gas  
 petrolio, GPL = oil, LPG  
 carbon fossile, coke = hard coal, coke  
 fonti rinnovabili = renewable sources  
 rifiuti = waste  
 altro = other

As can be seen from Figure 7, natural gas is the main source of primary energy supply for cogeneration. The breakdown by technology shows that for internal combustion engines natural gas is virtually the only fuel used and that it is also particularly important for gas turbines of both the ‘simple’ and combined-cycle type. Waste, on the other hand, is used exclusively by cogeneration units operating with steam-condensing extraction turbines.

## 2.4 Average output efficiency

Figure 14 shows the average energy performance of each cogeneration technology, highlighting in particular the power, heat and primary principle ( $\eta_{I \text{ principio}}$ ) efficiency recorded for the 2011 production year.

	Rendimento elettrico medio	Rendimento termico medio	Perdite medie di conversione	$\eta_{I \text{ principio}}$ (%)
TOTAL	42,9%	21,3%	35,8%	64,2
C.C.	45,2%	17,6%	37,3%	62,7
T.G.	27,9%	49,5%	22,6%	77,4
T.V.Cp	17,6%	69,3%	13,1%	86,9
T.V.Cd	22,8%	43,4%	33,8%	66,2
M.C.I.	39,9%	29,5%	30,6%	69,4
Altro	27,3%	40,8%	31,9%	68,1

**Figure 14 – Average power and heat efficiency**

Legend:

rendimento elettrico medio = average power efficiency  
 rendimento termico medio = average heat efficiency  
 perdite medie di conversione = average conversion losses  
 C.C. = CC  
 T.G. = GT  
 T.V.Cp = SBT  
 T.V.Cd = SCET

M.C.I. = ICE  
altro = other

The data in Figure 14 show up the considerable difference between the various technologies in terms of their heat to power output ratio. Combined-cycle gas turbines are characterised by a high power to heat ratio, confirming the common practice among operators to install this type of technology near consumers with low heat requirements in relation to electricity, or where electricity generation for supply to the network is the main objective and advantage can be taken of heat consumers situated in the area to optimise efficiency. The performance figures recorded for all the other technologies show that their use is efficient if they are installed near users with high heat requirements relative to their electricity needs.

## 2.5 Low-efficiency and high-efficiency power output

Electricity produced by cogeneration units covered by this document can be classified as follows:

- *gross* power: total electricity from cogeneration;
- *high-efficiency* power: electricity that meets the cogeneration criteria laid down in Annex II to Directive 2004/8/EC;
- *low-efficiency* power: electricity from cogeneration accounting for the difference between gross and high-efficiency power (i.e. electricity generated by units that fail to satisfy the criteria of Annex II to Directive 2004/8/EC.

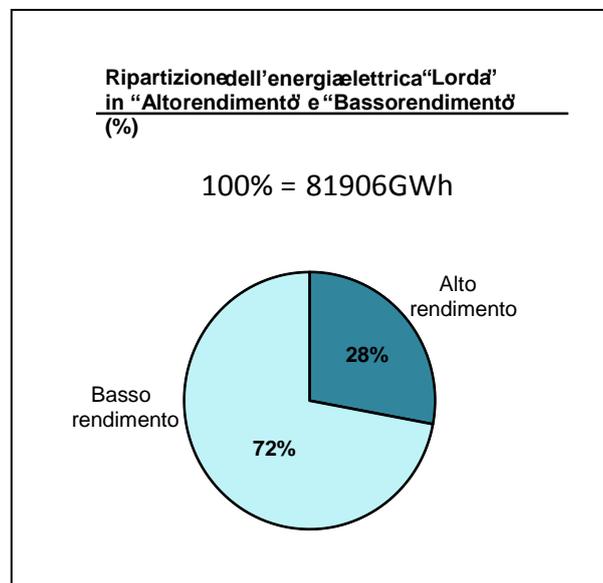


Figure 15 – Low-efficiency and high-efficiency power

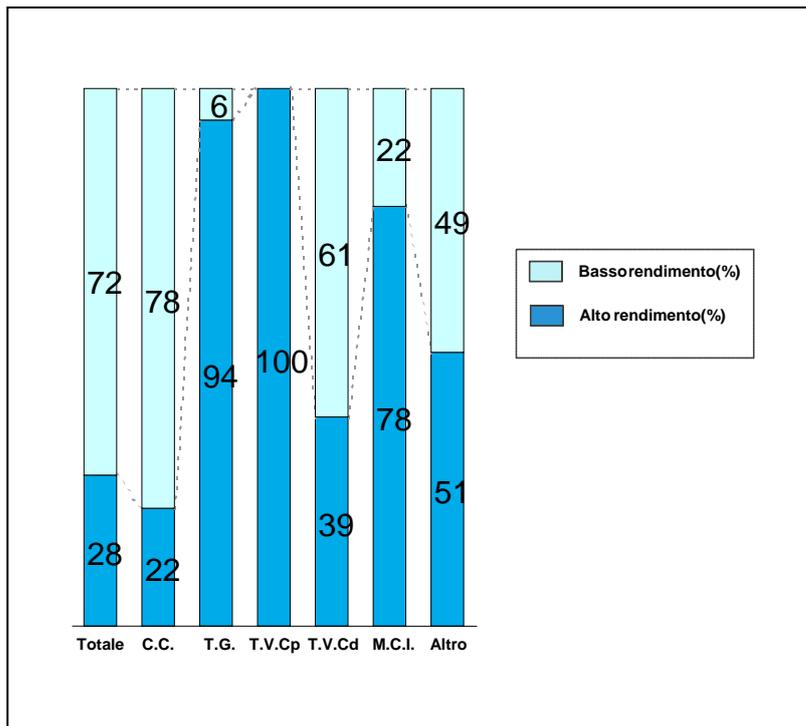


Figure 16 – Low-efficiency and high-efficiency power

Legend (Figures 15-16):

ripartizione dell'energia elettrica "Lorda" in "Alto rendimento" e "Basso rendimento" = Gross power broken down into high efficiency and low efficiency

basso rendimento = low efficiency

alto rendimento = high efficiency

The data collected show that, for combined-cycle gas turbines with heat recovery, the high-efficiency power output accounted for a relatively small share of the overall output.

The high impact of combined cycles on the power to useful heat ratio largely explains the low share of high-efficiency power of the overall output.

For the other technologies the following can be noted:

- steam-condensing extraction turbines are characterised by low efficiency output, thus contributing to the small share of high-efficiency power of the overall power generation;
- the low-efficiency output that also characterises steam back-pressure turbines is compensated by the high-efficiency heat output which is a feature of that technology;
- for gas turbines and internal-combustion engines, the high share of the overall output of high-efficiency power is due, for the former, to a high-efficiency heat output (combined with a relatively high-efficiency power output compared with 'simple' steam turbines), and for the latter to a medium-to-high-efficiency power output (combined with a medium-efficiency heat output which is significantly higher than for combined-cycle gas turbines).

Figure 17 illustrates the energy balance of the cogeneration units covered by this report.

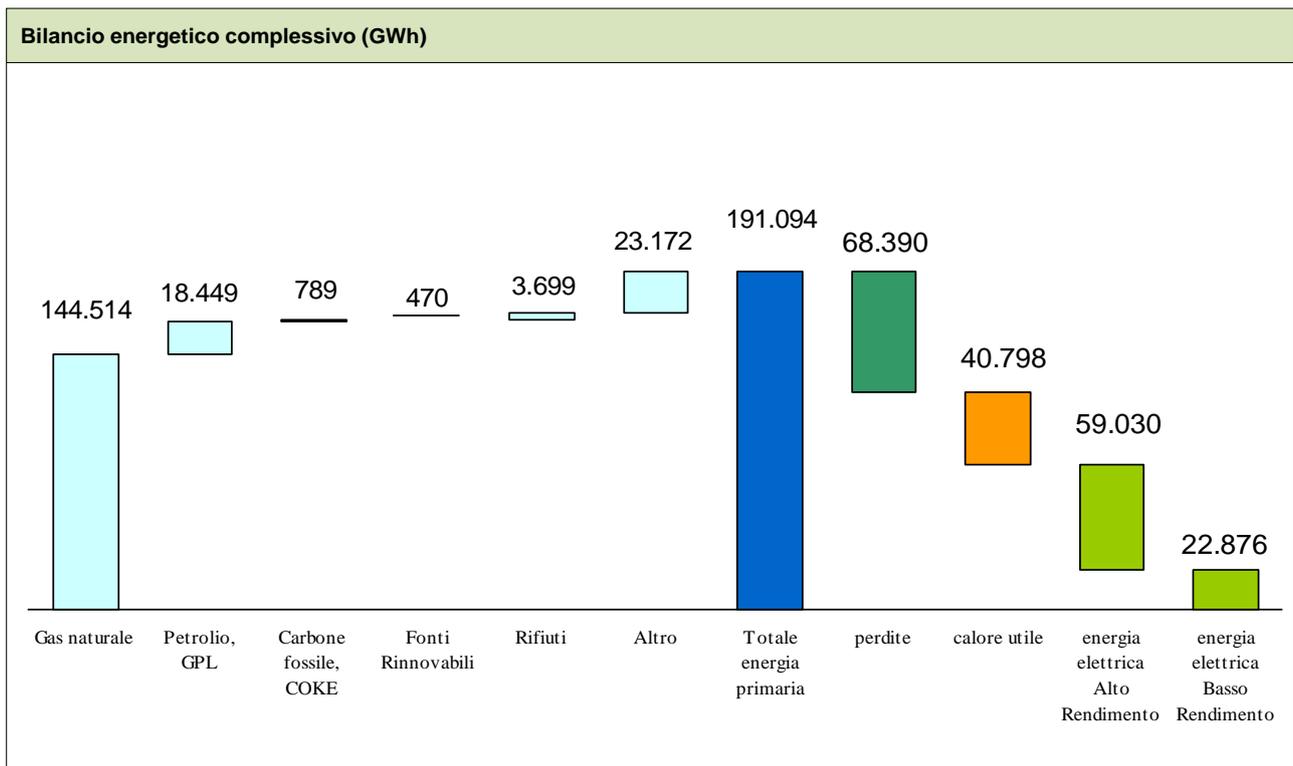


Figure 17 – Energy balance of cogeneration units included in report on the 2011 production year

Legend:

bilancio energetico complessivo = overall energy balance

gas naturale = natural gas

petrolio, GPL = oil, LPG

carbon fossile, coke = hard coal, coke

fonti rinnovabili = renewable sources

rifiuti = waste

altro = other

totale energia primaria = total primary energy

perdite = losses

calore utile = useful heat

energia elettrica alto rendimento = high-efficiency power

energia elettrica basso rendimento = low-efficiency power

## 2.6 Primary energy savings: Analysis of the results

Figure 18 illustrates the overall primary energy savings, calculated using the method described in Appendix B, associated with the generation of total power ( $E_{UNITA}$ ) and useful heat ( $H_{CHP}$ ). It also shows the contribution of each cogeneration technology used in the combined production of heat and power.

To provide a general overview, Tables 1 and 2 show the values of the main performance indicators both for the analysed units overall and for each of the following categories:

1. cogeneration units with an overall efficiency at or above the threshold (75% or 80%) whose applications for HEC status have been granted;
2. cogeneration units with an overall efficiency below the threshold (75% or 80%) whose applications for HEC status have been granted;
3. cogeneration units whose applications for HEC status have been refused, and cogeneration units having submitted applications for CHP/DHN status without simultaneously submitting a HEC application, combined into one category.

As can be seen from the results, the low primary energy savings of combined-cycle gas turbines compared with other technologies are due to the large contribution (around 50% in terms of gross power output) of cogeneration units that do not satisfy the requirements of Annex II to Directive 2004/8/EC. Indeed, the impact of combined cycles in terms of power and useful heat production is so high that it significantly affects the overall primary energy savings achieved through cogeneration. Compared with other technologies where power and useful heat are produced separately, the primary energy savings achieved are nevertheless considerable, reaching at least 10% in all cases.

Legend (Figure 18 below):

turbina a gas a ciclo combinato con recupero di calore (C.C.) = combined-cycle gas turbine with heat recovery (CC)

turbina a gas con recupero di calore (T.G.) = gas turbine with heat recovery (GT)

turbina a vapore con contropressione (T.V.Cp) = steam back-pressure turbine (SBT)

turbina a vapore di condensazione a estrazione di vapore (T.V.Cd) = steam-condensing extraction turbine (SCET)

motore a combustione interna (M.C.I.) = internal combustion engine (ICE)

altro = other

energia primaria per produzione separata vs. per produzione combinata (MTep) = primary energy for separate vs. combined production (MTep)

energia primaria = primary energy

produzione separata = separate production

produzione combinata = combined production

totale = total

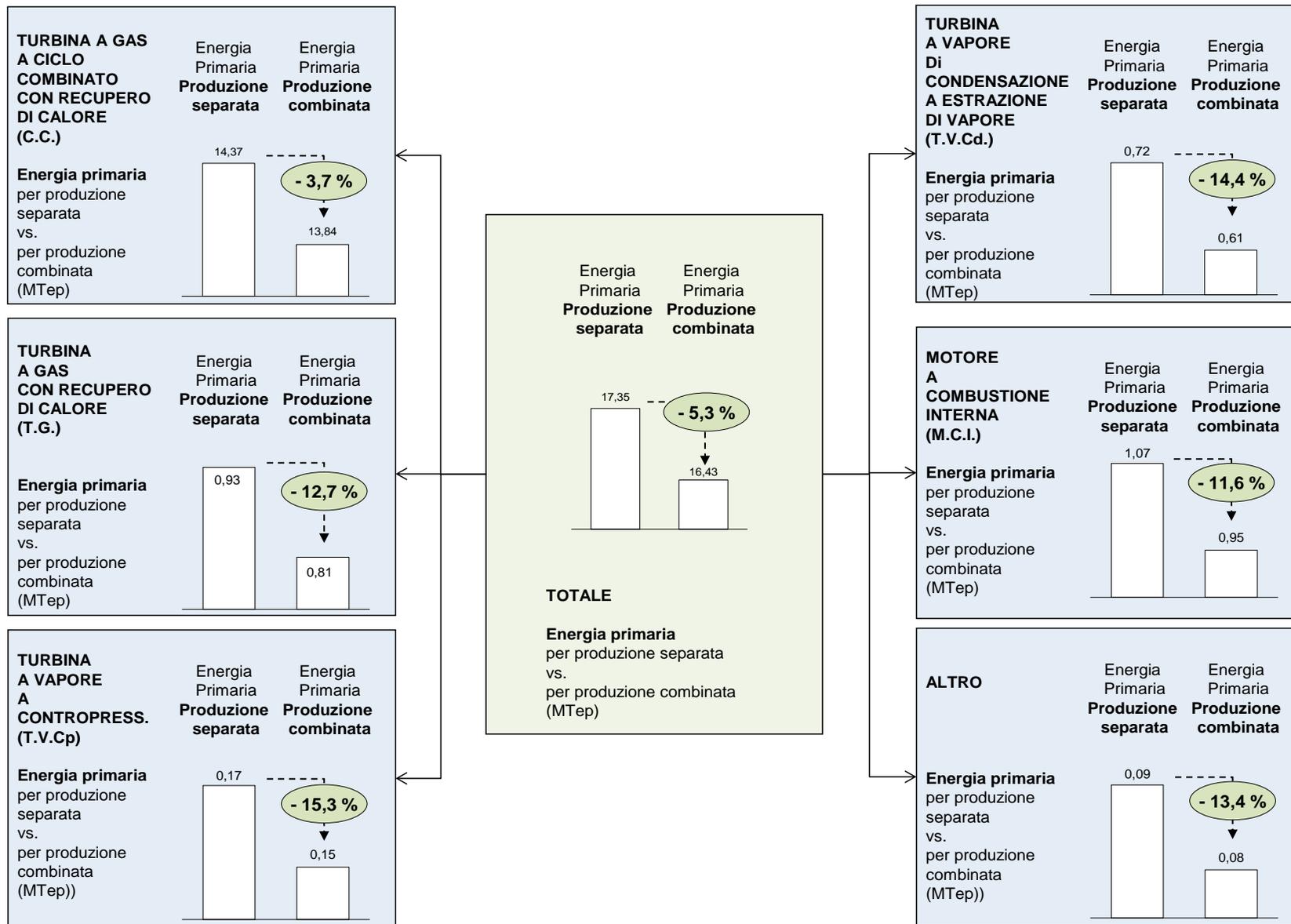


Figure 18 – Primary energy savings overall and for each cogeneration technology

**Table 1 – COGENERATION – MAIN PERFORMANCE INDICATORS (1/2)**

(2011 production year – all units)

Totale Unità																								
Tecnologie di cogenerazione	Numero di unità		Capacità di generazione		Produzione						Energia primaria						Rendimento medio			Risparmio Energia Primaria				
	Totale	di cui TLR	Energia elettrica		Energia elettrica				Calore		Gas naturale	Petrolio, GPL	Carbon fossile /	Fonti Rinnovabili	Rifiuti	Altro	Totale	Elettrico	Termico	Globale	Energia elettrica lorda e calore utile			
			Lorda	di cui TLR	Certificata Alto rendimento	Alto rendimento	Lorda	di cui TLR	Utile Totale	di cui TLR											Lorda	Lorda	Lorda	Lorda
	N.	N.	MW	MW	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	%	%	%	TOE	TOE	TOE	%
C.C.	93	20	14.832	3.963	11.712	15.926	72.702	15.393	28.248	4.033	124.639	16.724	269	0	0	19.296	160.928	45,2%	17,6%	62,7%	14.368.179	13.837.323	530.856	3,7%
T.G.	75	5	500	30	735	2.462	2.624	80	4.652	119	7.130	364	0	0	1.902	9.396	27,9%	49,5%	77,4%	925.492	807.917	117.575	12,7%	
T.V.Cp	8	2	198	141	203	301	301	218	1.186	566	859	152	520	0	0	180	1.711	17,6%	69,3%	86,9%	173.753	147.085	26.668	15,3%
T.V.Cd	6	2	271	177	550	635	1.627	1.058	3.090	880	902	1.139	0	0	3.699	1.382	7.122	22,8%	43,4%	66,2%	715.165	612.401	102.764	14,4%
M.C.I.	576	203	1.198	374	1.886	3.425	4.400	1.328	3.248	1.481	10.539	7	0	470	0	3	11.020	39,9%	29,5%	69,4%	1.072.094	947.529	124.565	11,6%
Altro	20	3	85	32	122	127	251	37	374	71	444	64	0	0	410	917	27,3%	40,8%	68,1%	91.102	78.890	12.212	13,4%	
<b>Totale</b>	<b>778</b>	<b>235</b>	<b>17.083</b>	<b>4.718</b>	<b>15.208</b>	<b>22.876</b>	<b>81.906</b>	<b>18.113</b>	<b>40.798</b>	<b>7.150</b>	<b>144.514</b>	<b>18.449</b>	<b>789</b>	<b>470</b>	<b>3.699</b>	<b>23.172</b>	<b>191.094</b>	<b>42,9%</b>	<b>21,3%</b>	<b>64,2%</b>	<b>17.345.785</b>	<b>16.431.145</b>	<b>914.640</b>	<b>5,3%</b>

Legend: (Tables 1 and 2)

totale unità = all units

tecnologie di cogenerazione = cogeneration technologies

C.C. = CC

T.G. = GT

T.V.Cp = SBT

T.V.Cd = SCET

M.C.I. = ICE

altro = other

numero di unità = number of units

totale N. = total number

di cui TLR = of which DHN

capacità di cogenerazione = cogeneration capacity

lorda = gross

di cui TLR = of which DHN

produzione = production

energia elettrica = electricity

certificata alto rendimento = certified as high-efficiency

alto rendimento = high efficiency

lorda = gross

di cui TLR = of which DHN

calore = heat

utile totale = total useful

di cui TLR = of which DHN

energia primaria = primary energy

gas naturale = natural gas

petrolio, GPL = oil, LPG

carbon fossile/coke = hard coal/coke

fonti rinnovabili = renewable sources

rifiuti = waste

altro = other

totale = total

lordo = gross

rendimento medio = average efficiency

elettrico = power

termico = heat

globale = overall

produzione lorda = gross output

calore utile = useful heat

risparmio energia primaria = primary energy savings

energia elettrica lorda e calore utile = gross power and useful heat

produzione separata = separate production

produzione in cogenerazione = cogeneration

risparmio = savings

totale = total

unità interamente CAR = units with full HEC status

unità parzialmente CAR = units with partial HEC status

rendimento  $\geq 75\%$  ( $\geq 80\%$  per unità con turbina di condensazione a estrazione di vapore) = efficiency  $\geq 75\%$  (or  $\geq 80\%$  for units with steam-condensing extraction turbines)

unità non CAR = units without HEC status

**Table 2 – COGENERATION – MAIN PERFORMANCE INDICATORS**

2011 production year – Units classified according to recognised status)

Unità interamente CAR rendimento ≥ 75% (o ≥ 80%, per unità con turbina di condensazione a estrazione di vapore)																								
Tecnologie di cogenerazione	Numero di unità		Capacità di generazione		Produzione						Energia primaria						Rendimento medio			Risparmio Energia Primaria				
	Totale	di cui TLR	Energia elettrica		Energia elettrica				Calore		Gas naturale	Petrolio, GPL	Carbon fossile / Coke	Fonti Rinnovabili	Rifiuti	Altro	Totale	Elettrico	Termico	Globale	Energia elettrica lorda e calore utile			
			Lorda	di cui TLR	Certificata Alto rendimento	Alto rendimento	Lorda	di cui TLR	Utile Totale	di cui TLR											Lorda	Lorda	Lorda	Lorda
	N.	N.	MW	MW	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	%	%	%	TOE	TOE	TOE	%
C.C.	6	0	193	0	1.098	1.098	1.098	0	2.896	0	2.832	127	269	0	0	1.365	4.593	23,9%	63,0%	87,0%	484.816	394.944	89.871	18,5%
T.G.	16	3	132	20	585	585	585	77	941	105	1.876	0	0	0	0	1.876	31,2%	50,2%	81,4%	191.286	161.339	29.947	15,7%	
T.V.Cp	1	1	121	121	203	203	203	203	522	522	329	0	520	0	0	849	23,9%	61,5%	85,4%	90.184	72.995	17.189	19,1%	
T.V.Cd	1	0	75	0	219	219	219	0	862	0	146	587	0	0	0	588	16,6%	65,2%	81,8%	126.987	113.641	13.346	10,5%	
M.C.I.	225	95	354	144	744	744	744	492	780	519	1.887	0	0	0	0	1.887	39,4%	41,3%	80,8%	203.735	162.265	41.470	20,4%	
Altro	5	1	59	32	87	87	87	37	331	70	417	64	0	0	0	481	18,0%	68,8%	86,8%	46.922	41.346	5.576	11,9%	
<b>Totale</b>	<b>254</b>	<b>100</b>	<b>933</b>	<b>317</b>	<b>2.937</b>	<b>2.937</b>	<b>2.937</b>	<b>808</b>	<b>6.331</b>	<b>1.215</b>	<b>7.488</b>	<b>778</b>	<b>789</b>	<b>0</b>	<b>0</b>	<b>1.953</b>	<b>11.008</b>	<b>26,7%</b>	<b>57,5%</b>	<b>84,2%</b>	<b>1.143.930</b>	<b>946.530</b>	<b>197.400</b>	<b>17,3%</b>

Unità parzialmente CAR rendimento < 75% (o < 80%, per unità con turbina di condensazione a estrazione di vapore)																								
Tecnologie di cogenerazione	Numero di unità		Capacità di generazione		Produzione						Energia primaria						Rendimento medio			Risparmio Energia Primaria				
	Totale	di cui TLR	Energia elettrica		Energia elettrica				Calore		Gas naturale	Petrolio, GPL	Carbon fossile / Coke	Fonti Rinnovabili	Rifiuti	Altro	Totale	Elettrico	Termico	Globale	Energia elettrica lorda e calore utile			
			Lorda	di cui TLR	Certificata Alto rendimento	Alto rendimento	Lorda	di cui TLR	Utile Totale	di cui TLR											Lorda	Lorda	Lorda	Lorda
	N.	N.	MW	MW	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	%	%	%	TOE	TOE	TOE	%
C.C.	51	15	7.309	2.523	10.614	10.614	33.770	10.061	10.152	2.553	66.306	0	0	0	0	6.390	72.696	46,5%	14,0%	60,4%	6.660.395	6.250.723	409.672	6,2%
T.G.	6	0	48	0	149	149	176	0	213	0	563	0	0	0	0	563	31,3%	37,8%	69,0%	51.066	48.396	2.671	5,2%	
T.V.Cp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	n.d.	n.d.	n.d.	0	0	0	0,0%
T.V.Cd	1	1	118	118	331	331	664	664	735	735	36	0	0	0	2.229	0	2.264	29,3%	32,5%	61,8%	321.399	194.695	126.704	39,4%
M.C.I.	124	44	308	100	1.141	1.141	1.579	458	973	320	3.885	1	0	2	0	3	3.891	40,6%	25,0%	65,6%	363.395	334.581	28.814	7,9%
Altro	5	1	25	0	35	35	159	0	36	0	11	0	0	0	0	410	420	37,8%	8,5%	46,3%	42.599	36.143	6.456	15,2%
<b>Totale</b>	<b>187</b>	<b>61</b>	<b>7.808</b>	<b>2.741</b>	<b>12.271</b>	<b>12.271</b>	<b>36.348</b>	<b>11.183</b>	<b>12.109</b>	<b>3.608</b>	<b>70.800</b>	<b>1</b>	<b>0</b>	<b>2</b>	<b>2.229</b>	<b>6.802</b>	<b>79.835</b>	<b>45,5%</b>	<b>15,2%</b>	<b>60,7%</b>	<b>7.438.854</b>	<b>6.864.538</b>	<b>574.316</b>	<b>7,7%</b>

Unità non CAR																								
Tecnologie di cogenerazione	Numero di unità		Capacità di generazione		Produzione						Energia primaria						Rendimento medio			Risparmio Energia Primaria				
	Totale	di cui TLR	Energia elettrica		Energia elettrica				Calore		Gas naturale	Petrolio, GPL	Carbon fossile / Coke	Fonti Rinnovabili	Rifiuti	Altro	Totale	Elettrico	Termico	Globale	Energia elettrica lorda e calore utile			
			Lorda	di cui TLR	Certificata Alto rendimento	Alto rendimento	Lorda	di cui TLR	Utile Totale	di cui TLR											Lorda	Lorda	Lorda	Lorda
	N.	N.	MW	MW	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	GW h	%	%	%	TOE	TOE	TOE
C.C.	36	5	7.329	1.440	0	0	37.834	5.331	15.200	1.481	55.501	16.597	0	0	0	11.541	83.639	45,2%	18,2%	63,4%	7.222.968	7.191.656	31.312	0,4%
T.G.	53	2	319	10	0	1.727	1.863	3	3.498	14	4.691	364	0	0	1.902	6.957	26,8%	50,3%	77,1%	683.139	598.182	84.957	12,4%	
T.V.Cp	7	1	77	20	0	99	99	15	664	44	530	152	0	0	180	862	11,4%	77,0%	88,5%	83.569	74.090	9.479	11,3%	
T.V.Cd	4	1	79	60	0	85	744	394	1.493	145	720	551	0	0	1.471	794	3,536	21,0%	42,2%	63,3%	266.779	304.065	-37.286	-14,0%
M.C.I.	227	64	536	131	0	1.539	2.077	377	1.495	642	4.767	6	0	468	0	5.241	39,6%	28,5%	68,2%	504.964	450.683	54.282	10,7%	
Altro	10	1	1	0	0	5	5	0	8	1	16	0	0	0	0	16	29,3%	47,6%	76,9%	1.580	1.401	180	11,4%	
<b>Totale</b>	<b>337</b>	<b>74</b>	<b>8.342</b>	<b>1.660</b>	<b>0</b>	<b>7.668</b>	<b>42.621</b>	<b>6.121</b>	<b>22.358</b>	<b>2.327</b>	<b>66.226</b>	<b>17.670</b>	<b>0</b>	<b>468</b>	<b>1.471</b>	<b>14.416</b>	<b>100.251</b>	<b>42,5%</b>	<b>22,3%</b>	<b>64,8%</b>	<b>8.763.001</b>	<b>8.620.077</b>	<b>142.924</b>	<b>1,6%</b>

## Appendix A: Definitions

For the purpose of this document the following definitions apply:

- a) Useful heat produced by a cogeneration unit ( $H_{\text{CHP}}$ ): heat produced during the reporting period by a cogeneration unit (i.e. combined with electrical/mechanical energy production) to meet economically justifiable demand for heating or cooling in a consumer area.
- b) Production capacity ( $P_n$ ): a unit's rated active power, determined as the sum of the rated active power of the generators that make up the unit. A generator's rated active power is the maximum active power obtained by multiplying the rated apparent power by the rated power factor, both of which are marked on the generator plate.
- c) Gross power: electrical power as measured by the meters fitted on the output terminals of electric generators.
- d) Total electrical/mechanical energy produced by a cogeneration unit ( $E_{\text{UNITA}}$ ): gross electrical/mechanical energy produced by a cogeneration unit during the reporting period. This means, for example, that any electricity produced by standby generating sets inside the cogeneration plant where that unit is located is not included in the total electrical/mechanical energy produced by the plant.
- e) Electrical/mechanical energy from cogeneration ( $E_{\text{CHP}}$ ): gross electrical/mechanical energy produced during the reporting period in the cogeneration part of the cogeneration unit (i.e. produced in combination with useful heat).
- f) Non-cogenerated electrical/mechanical energy ( $E_{\text{NONCHP}}$ ): gross electrical/mechanical energy produced during the reporting period by the non-cogeneration part (if any) of the cogeneration unit (i.e. not produced in combination with useful heat).
- g) Fuel input to the cogeneration unit ( $F_{\text{UNITA}}$ ): total fuel input to a cogeneration unit during the reporting period.
- h) Fuel input to the cogeneration unit for cogeneration ( $F_{\text{CHP}}$ ): fuel input to the cogeneration part of the cogeneration unit, used for combined production of electrical/mechanical energy and useful heat.
- i) Fuel input to the cogeneration unit not for cogeneration ( $F_{\text{nonCHP,E}}$ ): fuel input to the non-cogeneration part of the cogeneration unit, used 'virtually' for the production of useful electrical/mechanical energy.
- j) Cogeneration part ('CHP part') of the cogeneration unit: where the cogeneration unit's overall efficiency is below the overall efficiency threshold for the cogeneration technology in question, this means the part of the 'virtual' cogeneration unit which consumes fuel input ( $F_{\text{CHP}}$ ) for the combined production of electrical/mechanical energy ( $E_{\text{CHP}}$ ) and useful heat ( $H_{\text{CHP}}$ ), with an overall efficiency equal to the threshold value.
- k) Non-cogeneration part ('non-CHP part') of the cogeneration unit: where the cogeneration unit's overall efficiency is below the overall efficiency threshold for the cogeneration technology in question, this means the part of the 'virtual' cogeneration unit which consumes fuel input not for

cogeneration ( $F_{\text{nonCHP,E}}$ ) for the production of non-cogenerated electrical/mechanical energy ( $E_{\text{NONHP}}$ ) with a 'virtual' efficiency equal to  $\eta_{\text{nonchp,E}}$ .

- l) Reporting period: timeframe set for reporting the parameters that determine whether a cogeneration unit qualifies as HEC (and/or issuing corresponding white certificates to the units), usually a calendar year.
- m) Power to heat ratio ( $C_{\text{eff}}$ ): ratio between electricity from cogeneration ( $E_{\text{CHP}}$ ) and useful heat ( $H_{\text{CHP}}$ ) produced by specific unit operating in full cogeneration mode, based on its operational data for the reporting period.
- n) Default power to heat ratio ( $C_{\text{default}}$ ): if the effective power to heat ratio of a specific cogeneration unit is not known, the operator of the plant may use the default power to heat ratio ( $C_{\text{default}}$ ) as set out in the table in Annex II to the Ministerial Decree of 4 August 2011. In this case, however, the operator must inform the ESO of the reasons for the absence of an effective power to heat ratio figure for which data are lacking, and of the measures taken to remedy the situation.
- o) Ref  $E\eta$ : reference value for separate production of electricity according to the parameters set out in Annex IV to the Ministerial Decree of 5 September 2011. The reference value must be corrected for mean ambient temperature at the site of the plant, mains voltage and the ratio between energy consumed on-site and energy supplied to the grid as set out in Annexes VI and VII to the Ministerial Decree of 5 September 2011.
- p) Ref  $H\eta$ : reference efficiency value for separate production of heat according to the parameters set out in Annex V to the Ministerial Decree of 5 September 2011.
- q) Overall efficiency ( $\eta_{\text{globale}}$ ): ratio where the numerator is the sum of the total useful heat ( $H_{\text{CHP}}$ ) and electrical/mechanical energy produced by the cogeneration unit ( $E_{\text{UNITÀ}}$ ), and the denominator is the total energy of the fuel input to the cogeneration unit ( $F_{\text{UNITÀ}}$ ).
- r) Overall efficiency threshold ( $\bar{\eta}_{\text{globale,soglia}}$  o  $\bar{\eta}_{\text{globale}}$ ):  $\mathbf{v}$ ): minimum overall efficiency value that must be met in order for the entire cogeneration unit to be considered high efficiency; depending on the cogeneration technology the threshold is 75% or 80%.
- s) Power efficiency in non-cogeneration mode ( $\eta_{\text{non chp,E}}$ ): efficiency of the electrical/mechanical energy production of a cogeneration unit assumed to be in non-cogeneration mode. Such efficiency is attributed to the 'virtual', non-cogeneration part of the cogeneration unit in order to identify power generation not associated with the production of useful heat during the reporting period.
- t) Cogeneration unit: a distinct part of a cogeneration plant which, under normal operating conditions, functions independently of any other part of the plant.
- u) Virtual cogeneration unit: if the cogeneration unit's overall efficiency is below the overall efficiency threshold applicable to the cogeneration technology in question, the cogeneration unit is divided into two 'virtual' parts, the 'CHP part' and the 'non-CHP' part, in order to identify, based on the known  $H_{\text{CHP}}$  value for useful heat, the other main values needed ( $E_{\text{CHP}}$ ,  $F_{\text{CHP}}$ ) to calculate the primary energy savings.



## Appendix B: Criteria for calculating primary energy savings

### 1. Criteria for calculating the primary energy savings achieved through cogeneration of power and useful heat – High-efficiency cogeneration

The primary energy savings achieved through cogeneration of power ( $E_{CHP,u}$ ) and useful heat ( $H_{CHP,u}$ ), as opposed to separate production, is calculated using the following formula set out in Annex III to Directive 2004/8/EC and in the Ministerial Decree of 4 August 2011:

$$PES, u = 1 - \frac{F_{CHP,u}}{\frac{H_{CHP,u}}{REFH_{\eta,u}} + \frac{E_{CHP,u}}{REFE_{\eta,u}}}$$

Where:

‘u’ (in subscript) indicates the formulae were applied using the characteristic data of each cogeneration unit;

$PES, u$  is primary energy savings;

$H_{CHP,u}$  is useful heat supplied to the consumer area during the reporting period;

$E_{CHP,u}$  is gross electrical/mechanical energy produced during the reporting period by the cogeneration part of the cogeneration unit;

$F_{CHP,u}$  is fuel input to the cogeneration part of the cogeneration unit used for the combined production of electrical/mechanical energy and useful heat;

$Ref E_{\eta,u}$  is the reference value for separate production of power according to the parameters. The reference value set out in Annex I to Decision 2007/74/EC must be corrected for mean ambient temperature at the site of the plant, mains voltage and the ratio between energy consumed on-site and energy supplied to the grid as set out in Annex VI to the Ministerial Decree of 4 August 2011 (temperature correction) and Annex IV to Decision 2007/74/EC;

$Ref H_{\eta,u}$  is the efficiency reference value for separate production of heat according to the parameters set out in Annex II to Decision 2007/74/EC.

Primary energy consumed by the systems for separate production of cogenerated electricity and useful heat can be expressed using the following formula:

$$F_{SEPARATA} = \frac{H_{CHP,u}}{REFH_{\eta,u}} + \frac{E_{CHP,u}}{REFE_{\eta,u}}$$

Removing the analytical element from the above formula produces the following:

$$F_{SEPARATA} = \frac{F_{CHP,u}}{1 - PES_u}$$

The summary table below contains formulae for calculating the primary energy consumed, based on a comparison of the two production modes (separate production and cogeneration), for the production of cogenerated electricity ( $E_{CHP}$ ) and useful heat ( $H_{CHP}$ ):

OUTPUT (CHP part of the unit)	PRODUCTION MODE	INPUT (CHP part of the unit)
$E_{CHP,u}$ $H_{CHP,u}$	Separate production	$\frac{F_{CHP,u}}{1 - PES_u}$
	Cogeneration	$F_{CHP,u}$

Accordingly, the primary energy savings achieved by each cogeneration unit through production of  $E_{CHP,U}$  and  $H_{CHP,U}$  is calculated using the following formula:

$$RISPARMIO_u (TEP) = \frac{F_{CHP,u}}{1 - PES_u} - F_{CHP,u} = F_{CHP,u} * \frac{PES_u}{1 - PES_u}$$

The overall primary energy savings achieved by all the cogeneration units through production of  $E_{CHP,U}$  and  $H_{CHP,U}$  is calculated using the following formula:

$$RISPARMIO (TEP) = \sum_{u=1}^N RISPARMIO_u (TEP)$$

The percentage share can be expressed as follows:

$$RISPARMIO (\%) = \frac{RISPARMIO (TEP)}{F_{SEPARATA} (TEP)}$$

2. Criteria for calculating the primary energy savings achieved through cogeneration of power and useful heat – Low-efficiency cogeneration

A cogeneration unit, i.e. a unit producing power and heat simultaneously, does not necessarily qualify for HEC status. In the cases set out below their power output is defined as low-efficiency cogeneration, indicated as  $E_{CHPnoCAR}$ :

- compliance with Annex II to Directive 2004/8/EC but overall efficiency of cogeneration unit below the threshold value. Consequently the unit is divided into two virtual parts, one operating in HEC mode (CHP part) and the other in non-HEC mode ( $C_{HPnoCAR}$  part);
- non-compliance with Annex II to Directive 2004/8/EC. In this case the unit's power output is considered electricity from cogeneration but does not qualify as high-efficiency ( $E_{CHPnoCAR}$ ).

In this latter case the primary energy needs to be quantified as follows:

- for cogeneration the quantity is expressed as  $F_{CHPnoCAR,u}$ , which is equal to the difference between the total fuel input to a cogeneration unit during the reporting period ( $F_{UNITA}$ ) and the fuel input to the cogeneration part of the cogeneration unit ( $F_{CHP,u}$ ), the latter value being equal to zero in the case of non-compliance with Annex III to Directive 2004/8/EC;
- for separate production, power efficiency is assumed on the basis of the 'Efficiency reference values for separate production of electricity' set out in Annex I to Decision 2007/74/EC, irrespective of the correction factors for average climate conditions and prevented grid losses, based on a division of the power output into electricity supplied to the grid and electricity consumed on-site.

The summary table below contains formulae for calculating the primary energy consumed, based on a comparison of the two production modes (separate production and cogeneration), for the total production of electricity ( $E_{UNITA}$ ) and useful heat ( $H_{CHP}$ ):

OUTPUT (unit)	PRODUCTION MODE	INPUT (unit)
$E_{UNITA}$ (= $E_{CHP,u}$ + $E_{CHPnoCAR,u}$ )  $H_{CHP,u}$	Separate production	$\frac{E_{CHPnoCAR,u}}{REFE_{\eta base,u}} + \frac{E_{CHP,u}}{1 - PES}$
	Cogeneration	$F_{CHPnoCAR,u} + F_{CHP,u}$

$$RISPARMIO_u(TEP) = \frac{E_{CHPnoCAR,u}}{REFE_{\eta base,u}} + \frac{E_{CHP,u}}{1 - PES} - (F_{CHPnoCAR,u} + F_{CHP,u})$$

$$INPUT\ PROD.\ SEPARATA_u (TEP) = \frac{E_{CHPnoCAR,u}}{REFE_\eta base,u} + \frac{F_{CHP,u}}{1 - PES_u}$$

$$RISPARMIO (TEP) = \sum_{u=1}^N RISPARMIO_u (TEP)$$

$$INPUT\ PROD.\ SEPARATA (TEP) = \sum_{u=1}^N INPUT\ PROD.\ SEPARATA_u (TEP)$$

$$RISPARMIO (\%) = \frac{RISPARMIO (TEP)}{INPUT\ PROD.\ SEPARATA (TEP)}$$