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High Efficiency Cogeneration: Performance Assessment of Industrial Cogeneration Power Plants

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Abstract

In 2004, the European Parliament and the Council of the European Union adopted the Directive 2004/8 EC whose purpose is to increase energy efficiency and develop high efficiency cogeneration of heat and power. Italy brought into force this law by means of the Legislative Decree February 8, 2007, n. 20: from January 1, 2011, the high efficiency cogeneration is the cogeneration that meets the requirements of Directive 2004/8/EC. Then, Italy adopted two ministerial decrees: the ministerial decree of Environment Ministry (August 4, 2011), that integrates the Decree n.20, and the ministerial decree of Ministry of Economic Development (September 5, 2011), that lays down the conditions and procedures for access to the support system of cogeneration: for each year in which the requirements of high efficiency cogeneration are met, the cogeneration units are entitled to energy efficiency certificates (White Certificates), whose number is proportional to the energy saving achieved.

Therefore, from January 1, 2011 the legislative and incentive cogeneration context is radically changed and, consequently, new boundary conditions must be taken into account for feasibility studies and performance assessments of cogeneration plants. So, in this paper we want to evaluate the impact of this new legislative context on the competitiveness of the various cogeneration technologies. To this end, after an illustration of the new criteria to meet the qualifications of the high efficiency cogeneration, a comparison between different generation technologies will be developed by highlighting the impact of the new incentive context.

Keywords: high efficiency cogeneration; primary energy savings, electricicity from cogeneration; power to heat ratio; Directive 2004/8/EC

Nomenclature

CHP Eη	electrical efficiency of the cogeneration production
CHP Hη	heat efficiency of the cogeneration production
E_{CHP}	electricity from cogeneration
$E_{non-CHP}$	non-CHP electrical/mechanical energy

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F_{CHP}	fuel input used to produce the sum of useful heat output and electricity from cogeneration
$F_{non-CHP,E}$	fuel energy for non-CHP electrical/mechanical energy
$F_{non-CHP,H}$	fuel energy for non-combined generation of useful heat energy
H_{CHP}	useful heat from cogeneration
$H_{non-CHP}$	non-combined useful heat energy
Ref Eη	efficiency reference value for separate electricity production
Ref Hη	efficiency reference value for separate heat production

1. High efficiency cogeneration : European directives and Italian transposition

In 2004, the European Union adopted the Directive 2004/8 EC [1] whose purpose is to develop *high efficiency cogeneration* of heat and power based on useful heat demand and primary energy savings.

The Annex II of the Directive introduces the concept of "*Electricity from Cogeneration*" (E_{CHP}) :

$$E_{CHP} = C * H_{CHP} \tag{1}$$

where:

- E_{CHP} is the electricity from cogeneration
- C is the "*power to heat ratio*"
- H_{CHP} is the useful heat from cogeneration (calculated for this purpose as total heat production minus any heat produced in separate boilers or by live steam extraction from the steam generator before the turbine and so on).

The Annex III of the Directive defines the "High Efficiency Cogeneration" as the cogeneration production from cogeneration units that provides *primary energy savings* (PES, see below) at least 10% compared with the references for separate production of heat and electricity (small scale cogeneration units, installed capacity below 1 MWe, and micro cogeneration units, installed capacity below 50 kWe, must provide *primary energy savings*, that is PES>0).

The *primary energy savings*, in accordance with Annex II, shall be calculated using the following formula:

$$PES = 1 - \frac{1}{\dfrac{CHP\ H\eta}{REF\ H\eta} + \dfrac{CHP\ E\eta}{REF\ E\eta}} \tag{2}$$

where:

- PES is primary energy savings;
- CHP Hη is the heat efficiency of the cogeneration production defined as annual useful heat output (H_{CHP}) divided by the fuel input (F_{CHP}) used to produce the sum of useful heat output and electricity from cogeneration;
- Ref Hη is the efficiency reference value for separate heat production;
- CHP Eη is the electrical efficiency of the cogeneration production defined as annual electricity from cogeneration (E_{CHP}) divided by the fuel input (F_{CHP}) used to produce the sum of useful heat and electricity from cogeneration;
- Ref Eη is the efficiency reference value for separate electricity production.

The efficiency reference values must be calculated according to the following main principles: (i) the comparison with separate electricity production shall be based on the principle that the same fuel categories are compared; (ii) each cogeneration unit shall be compared with the best available and economically justifiable technology for separate production of heat and electricity on the market in the year of construction of the cogeneration unit. These reference values were first published in 2006 in the Commission Decision 2007/74/EC [2] and they are differentiated by year of construction and types of fuel. Then, these values were reviewed in 2011 in the Commission Decision 2011/877/EC [3].

The methodology for determining the *Electricity from Cogeneration* and the others parameters involved in PES calculation was postponed to successive Decisions. After the publication of the Directive 2004/8 EC, the Decision of November 19, 2008 (2008/952/EC) [4], establishing detailed guidelines for the implementation and application of Annex II to Directive 2004/8/EC, stated that a cogeneration unit, operating with maximum technically possible heat recovery from the cogeneration unit itself, is said to be operating in *full cogeneration mode* and all electricity is considered combined heat and power (CHP) electricity (Fig. 1). For cases in which the plant does not operate in full

cogeneration mode, it is necessary to identify the electricity and heat not produced under cogeneration mode, and to distinguish it from the CHP production. The energy input and output of the heat-only-boilers which in many cases are part of the on-site technical installations are to be excluded.
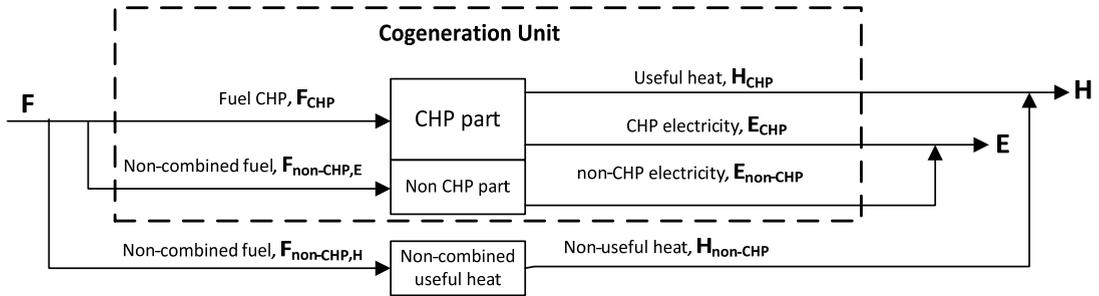

Fig. 1. Cogeneration unit

To distinguish which part of the electricity produced is not recognized as electricity from cogeneration, it is first necessary to calculate the overall efficiency of the cogeneration unit, that is the ratio of energy output of the cogeneration plant (electricity, mechanical energy and useful heat) to the fuel input. All the cogeneration unit is CHP part if the overall efficiency is equal or higher than:

- 80% for combined cycle gas turbines with heat recovery and steam condensing extraction turbines-based plants;
- 75% for the other types of cogeneration units (steam backpressure turbine, gas turbine with heat recovery, internal combustion engine, microturbines, stirling engines, fuel cells).

If the overall efficiency of the cogeneration unit is lower than the threshold values (75% - 80%), non-CHP electricity generation takes place and the unit must be split into two virtual parts, the CHP part and the non-CHP part (Fig. 1). For the CHP part, the plant operator shall check the load pattern (useful heat demand) and evaluate whether the unit operates in *full cogeneration mode* during certain periods. If this is the case, the plant operator shall measure actual heat and electrical energy output from the cogeneration unit for this situation and during these periods. These data will allow him to determine the actual "*power to heat ratio*" (C_{actual}). This actual power to heat ratio will allow the operator to calculate which part of the electricity measured during the reporting period is recognised as CHP electricity according to the formula:

$$E_{CHP} = C_{actual} * H_{CHP} \tag{3}$$

In order to calculate the primary energy savings, in addition to H_{CHP} and E_{CHP}, it is necessary also to determine the CHP fuel consumption (F_{CHP}). This fuel consumption is evaluated as the difference between the total fuel input to the cogeneration unit and the non-CHP fuel consumption: it is the non-CHP electricity divided by the plant specific efficiency value for electricity production.

Italy brought into force these laws by means of the following decrees: Legislative Decree February 8, 2007, n. 20, ministerial decree of Environment Ministry (August 4, 2011) and ministerial decree of Ministry of Economic Development (September 5, 2011) [5, 6, 7]. The second ministerial decree [7] provides the following national support mechanisms: the white certificates (in Italian "*Certificati Bianchi*"). Their value amounts to about 100 €/TOE per certificate and they are issued to the plant for every year in which it will demonstrate to be an high efficiency cogeneration plant. In order to calculate the number of with certificates, first of all saving (in Italian "*Risparmio*") must be evaluated:

$$RISP = \frac{H_{CHP}}{\eta_{H,ref}} + \frac{E_{CHP}}{\eta_{E,ref}} - F_{CHP} \tag{4}$$

where all energies are measured in MWh, $\eta_{E,\,ref}$ is 0.46 and $\eta_{H,\,ref}$ is 0.82 when the useful heat is provided by exhaust gases (directly use) and 0.9 when useful heat is provided by water/steam. The number of white certificates, CB, is then calculated as follows:

$$CB = RISP * 0.086 * K \tag{5}$$

where 0.086 is the conversion factor (from MWh in TOE) and K is a parameter that depends on the size of power plants.

2. Criteria for evaluating the high efficiency cogeneration parameters

The Commission Decision 2008/952/EC is not very clear regarding the definition of parameters of CHP part and non CHP part and about the definition of the "power to heat ratio" (C, C_{actual}, etc.). But there is available an interesting manual, entitled "Manual for determination of Combined Heat and Power (CHP)" [8], elaborated by CEN/CENELEC Workshop Agreement (CWA), whose scope was to provide guidance for the implementation of Annex II of the European Directive 2004/8/EC. On 2004-06-16 the CEN/CENELEC Workshop Agreement (CWA) was drafted and approved by a Workshop of representatives of interested parties.

In Italy, in February 2012 the Italian Ministry of Economic Development published detailed guidelines entitled "Guidelines for the implementation of ministerial decree of Ministry of Economic Development (September 5, 2011)" [9]. These guidelines are very similar to the "Manual for determination of Combined Heat and Power (CHP)" so in the following we will refer to the Italian guidelines in order to explain the criteria for evaluating the high efficiency cogeneration parameters. Therefore we will use the Italian nomenclature in the expression of these parameters.

First of all, the guidelines give rules to calculate overall efficiency. To determine the overall efficiency (η_g) of a CHP plant in a reporting period, the following parameters must be known (fig.1):

- total useful heat energy (H)
- total electrical/mechanical energy (E)
- total fuel energy (F)
- non-combined useful heat energy ($H_{non\text{-}CHP}$)
- non-combined fuel energy for non-combined generation of useful heat energy ($F_{non\text{-}CHP,H}$)

CHP useful heat energy must be determined as follows:

$$H_{CHP} = H - H_{non-CHP} \tag{6}$$

The overall efficiency is:

$$\eta_g = \frac{E + H_{CHP}}{F - F_{non-CHP,H}} \tag{7}$$

If the overall efficiency (η_g) achieves or exceeds the values in Annex II of the CHP-Directive (η_{CHP}=0,80 for combined cycle gas turbines with heat recovery and steam condensing extraction turbines-based plants or η_{CHP}=0,75 for the other types of cogeneration units, i.e. steam backpressure turbine, gas turbine with heat recovery, internal combustion engine, microturbines, stirling engines, fuel cells), the CHP plant does not generate non-CHP electrical/mechanical energy ($E_{non\text{-}CHP}$) and then:

$$H_{CHP} = H - H_{non-CHP}$$
$$E_{CHP} = E \tag{8}$$
$$F_{CHP} = F - F_{non-CHP,H}$$

Otherwise the non-CHP electrical/mechanical energy ($E_{non-CHP}$) and the referring fuel energy ($F_{non-CHP,E}$) have to be determined (Fig. 1). To determine the non-CHP electrical/mechanical energy ($E_{non-CHP}$) and the referring fuel energy ($F_{non-CHP,E}$) of a CHP plant and to isolate the CHP part, the following steps have to be done:

1) determination of power loss coefficient (β). This parameter must be calculated for steam condensing extraction turbine-based plants. It gives the electricity loss due to steam extraction for heat production and so it is:

$$\beta = \frac{h_{estr} - h_{cond}}{h_{estr} - h_{ref}} \cdot K_p \tag{9}$$

where:
- h_{estr} is the enthalpy of the steam extraction;
- h_{cond} is the steam enthalpy at the condenser inlet;
- h_{ref} is reference enthalpy (evaluated as the water enthalpy at 15°C e 1 bar abs)
- K_p is given by the Guidelines where there is a matrix of values differentiated by power of the steam turbine; this parameter takes into account mechanical and electric losses.

The value of h_{estr} is calculated by using pressure and temperature of the steam extraction. The value of h_{cond} is calculated by using the procedure illustrated in the guidelines: briefly it consists of an energy balance of the steam turbine, known the power of the steam turbine and the mass flow-rate and the enthalpy of all extractions and all inlets in the turbine. If the steam turbines has more than one extraction, the parameter β is calculated as a weighted average of the different extractions.

For all the other types of cogeneration units, it is $\beta = 0$.

2) determination of the efficiency of non-combined electrical/mechanical energy generation:

$$\eta_{non-CHP,E} = \frac{E + \beta \cdot H_{CHP}}{F - F_{non-CHP,H}} \tag{10}$$

It important to underline that the efficiency of non-combined electrical/mechanical energy generation represents a conventional efficiency of the power plant in "full electrical load".

3) determination of the power-to-heat ratio (named C_{eff} in Italian legislation. This parameter is the C_{actual} of the European legislation):

$$C_{eff} = \frac{\eta_{non-CHP,E} - \beta \cdot \eta_{CHP}}{\eta_{CHP} - \eta_{non-CHP,E}} \tag{11}$$

where η_{CHP} is equal to 0.8 for combined cycle gas turbines with heat recovery and steam condensing extraction turbines-based plants and 0.75 for the other types of cogeneration units.

4) determination of CHP electricity/mechanical energy:

$$E_{CHP} = C_{eff} * H_{CHP} \tag{12}$$

5) determination of non-CHP electricity/mechanical energy:

$$E_{non-CHP} = E - E_{CHP} \tag{13}$$

6) determination of fuel energy for non-CHP electricity/mechanical energy generation:

$$F_{non-CHP,E} = \frac{E_{non-CHP}}{\eta_{non-CHP,E}}$$ (14)

7) determination of fuel energy for CHP electricity/mechanical energy generation:

$$F_{CHP} = F - F_{non-CHP,H} - F_{non-CHP,E}$$ (15)

Using such a procedure, the CPH part of a cogeneration plant will achieve an overall efficiency exactly equal to the overall efficiency (η_{CHP}=0.8 or η_{CHP}=0.75) established in Annex II of the CHP-Directive.

Known all the energies of the CHP part of the cogeneration unit (E_{CHP}, H_{CHP}, F_{CHP}), it is possible to calculate all the other performance parameters (PES, RISP and CB) using the procedure illustrated at par. 2.

3. Evaluation of high efficiency cogeneration parameters for industrial cogeneration power plants

Now high efficiency cogeneration parameters will be evaluated taking into account different industrial cogeneration power plants (>1 MWe). The following technologies have been analysed:

- steam condensing extraction turbine-based plants (SC)
- steam back-pressure turbine-based plants
- combined cycle power plants with heat recovery (CC)
- gas turbines with heat recovery (GT)
- internal combustion engines with heat recovery (ICE)

The power plant layouts are shown in Figg. 2-6; because the aim of this paper is to provide a general overview of the different types of cogeneration units in the new legislative context, we have chosen generic schemes, able to represent a great number of installations. Consequently, also input parameters of these power plants were chosen as average values, representative of actual operating technologies. More in details, for steam turbine-based plants live steam pressure and temperature are respectively 90 bars and 490°C, deaerator pressure is 5 bar, extraction pressure is variable from 5 bar to 20 bar and the condenser pressure is 0.05 for the steam condensing extraction turbine-based plants. For combined cycle power plants, the gas turbine has a net efficiency of 36% and the temperature of exhaust gases at the heat recovery steam generator (HRSG) inlet is 520°C; the HRSG has two pressure levels (90 bar and 5 bar) and the steam turbine is a condensing extraction turbine where the extraction pressure is variable from 5 bar to 20 bar and the condenser pressure is 0.05 bar. The gas turbine with heat recovery has the same performance of the gas turbine of the combined cycle power plant; HRSG has only one pressure level, variable from 5 to 20 bar, while the steam temperature for the heat consumer is the same of the other power plants. The internal combustion engine has a net efficiency of 45% and the temperature of exhaust gases at the HRSG inlet is 435°C; the HRSG is the same of the gas turbine with heat recovery.
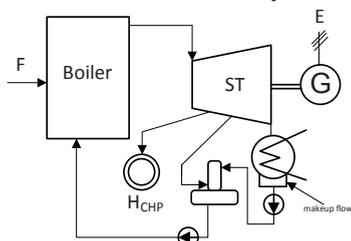

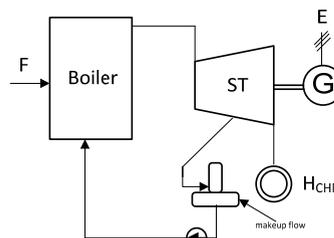Fig. 2. Steam condensing extraction turbine-based plant

Fig. 3. Steam back-pressure turbine-based plant

Another important matter of consideration while evaluating high efficiency cogeneration parameters is the supplementary firing (at HRSG inlet). In gas turbines and internal combustion engines, the supplementary firing does not produce useful heat so there is no influence on H_{CHP} and E_{CHP}. In combined cycle power plants,

supplementary firing produces useful heat if no steam flow, produced in HRSG, is sent directly to heat consumer. Because this is a general discussion of the different cogeneration units, the supplementary firing will not be taken into account.
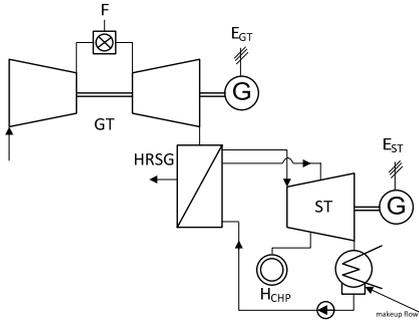
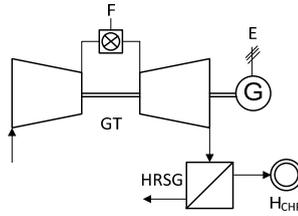

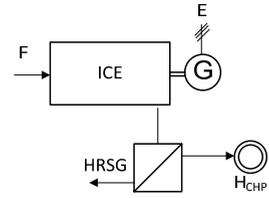Fig. 4. Combined cycle power plant   Fig. 5. Gas turbine with heat recovery   Fig. 6. ICE with heat recovery

3.1. Steam condensing extraction turbine-based plants

In fig. 7 the results are referred to two different extraction pressures (5 bar and 20 bar) in order to highlight the effects of the quality of the heat required by the final user (heat consumer).
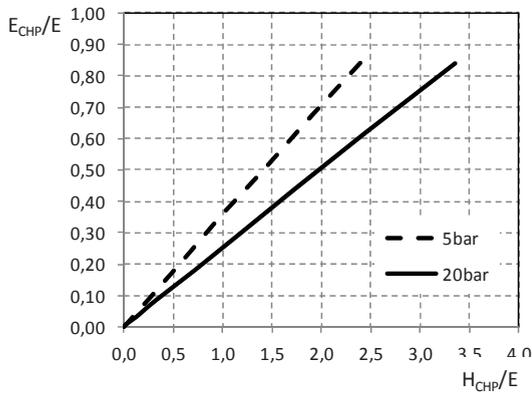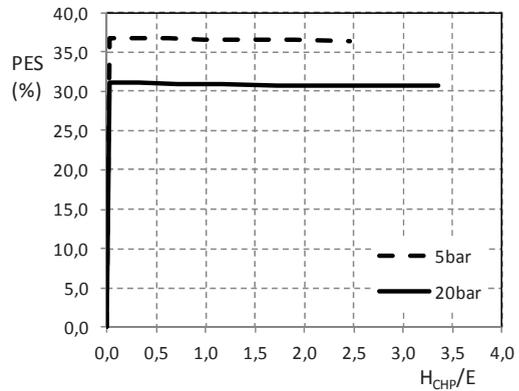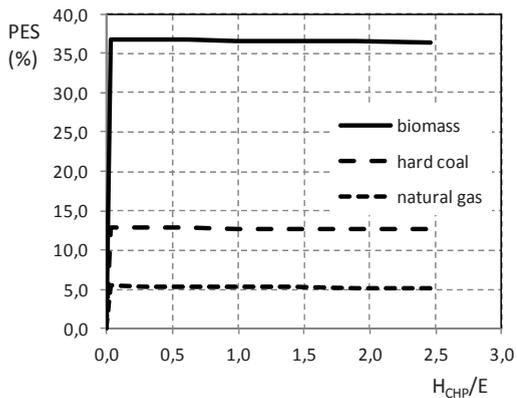

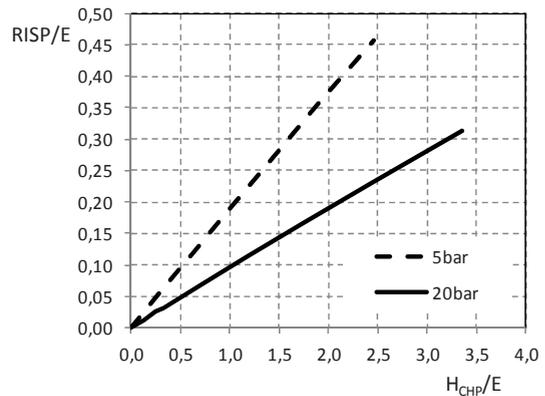Fig. 7a

Fig. 7b

Fig. 7c

Fig. 7d

Fig. 7a shows the trend of the ratio of the CHP electricity to the total electricity: the heat demand at higher quality, that is at a higher temperature, penalizes this parameter because an higher extraction pressure involves an increases of the value of β and thus a decrease of the power to heat ratio (C_{eff}) while the efficiency of non-combined electrical energy generation remains approximately constant. In this analysis the main average results are:

- β=0.19 for p_{extr}=5 bar; β=0.25 for p_{extr}=20 bar
- $η_{non-CHP,E}$=32.3% for p_{extr}=5 bar; $η_{non-CHP,E}$=32.4% for p_{extr}=20 bar
- C_{eff}=0.357 for p_{extr}=5 bar; C_{eff}=0.255 for p_{extr}=20 bar

Fig. 7b shows the trend of the PES. Varying the ratio H_{CHP}/E, the PES remains almost constant and well above the threshold limit of 10%. This evaluation was elaborated under the most favorable condition for the power plant: in fact in these cases the fuel is a biomass which involves efficiency reference values for separate heat and electricity production extremely low (respectively 80% and 25%). Fig. 7c shows the values of PES (when the extraction pressure is 5 bar) for different fuels: biomass, solid fuel (coal) and natural gas. Using coal, the PES falls to values close to the threshold value (when the extraction pressure is 20 bar, the PES is lower than the threshold value); using natural gas, the power plant cannot be considered as a cogeneration plant because the PES is always lower than 10%. Fig. 7d shows the trend of the RISP and thus of the white certificates. The quality of the heat required by the user greatly influences the value of the RISP: when the extraction pressure is 20 bar, the RISP values are approximately halved compared with those obtainable when the extraction pressure is 5 bar.

3.2. Steam back-pressure turbine-based plants

In this case, the graphs of the results are not very expressive because the overall efficiency is always higher than the threshold value and thus the ratio E_{CHP}/E is always unitary when the backpressure varies from 5 to 20 bar; the PES decreases as the quality of the heat required increases but it is always greater than the threshold value with wide margins (for biomass it decreases from 40% to 30% when the extraction pressure is respectively 5 bar and 20 bar); the ratio RISP/E remains constant and close to the unitary value and thus it is far higher than those of the previous case (steam condensing extraction turbine-based plant), fixed the ratio H_{CHP}/E.

3.3. Combined cycle power plants

Figure 8 show the results of the analysis carried out for this type of cogeneration plants. In each figure the results are referred to two different extraction pressures (5 bar and 20 bar) in order to highlight the effects of the quality of the heat required by the final user (heat consumer).
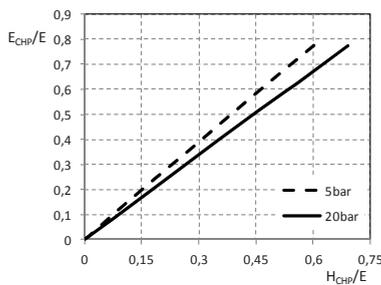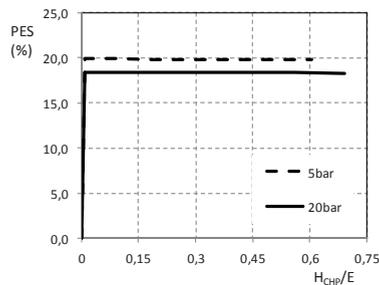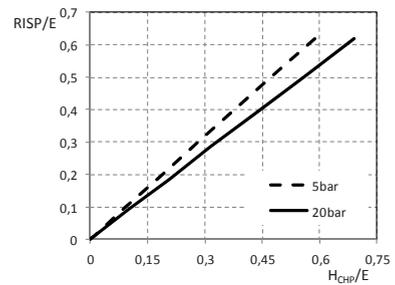

Fig. 8a   Fig. 8b   Fig. 8c

Fig. 8a shows the trend of the ratio of the CHP electricity to the total electricity: the considerations are quite similar to those carried out for the steam condensing extraction turbine-based plants. However, in this case the values of the ratio E_{CHP}/E are significantly higher than the previous ones, fixed the ratio H_{CHP}/E, because, even if the value of β is very similar, the efficiency of non-combined electrical energy generation is now much higher and consequently the power to heat ratio (C_{eff}) becomes very high. In this analysis the main average results are:

- β: 0.18 for p_{extr}=5 bar and 0.25 for p_{extr}=20 bar
- $η_{non-CHP,E}$: 51.9% for p_{extr}=5 bar and 51.3% for p_{extr}=20 bar

- C_{eff}: 1.30 for p_{extr}=5 bar and 1.13 for p_{extr}=20 bar

Fig. 8b shows the trend of the PES. Varying the ratio H_{CHP}/E, the PES remains almost constant and well above the threshold limit of 10% even if the fuel, in this case natural gas, involves efficiency reference values for separate heat and electricity production quite high and thus penalising.

Fig. 8c shows the trend of the RISP and thus of the white certificates. In this case, the values are far higher than those of the previous case (steam condensing extraction turbine-based plant), fixed the ratio H_{CHP}/E.

3.4. Gas turbines and internal combustion engines with heat recovery

In gas turbines and internal combustion engines, heat production doesn't cause electrical power loss and thus $\beta=0$ and $\eta_{non-CHP,E}=\eta_E$ (electric efficiency). In order to compare the results of the different power plants here analysed, these power plants are equipped with a HRSG that produces steam at variable pressure from 5 to 20 bar (heat recovery only from exhaust gases). The analyses carried out show, obviously, that the pressure level of the HRSG doesn't influence on power plant performance. For this reason, all the results here shown are referred to a steam pressure of 20 bar. Furthermore, as the two typologies of power plants are fed by natural gas, the results have been represented together in these graphs.
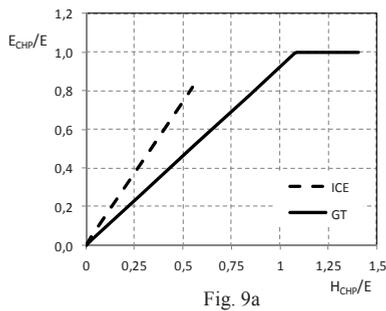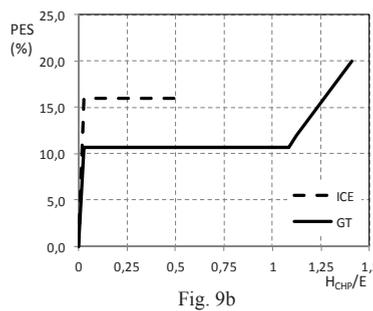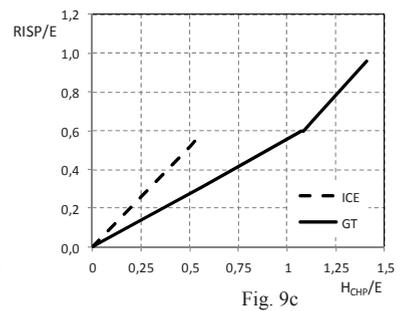

Fig. 9a   Fig. 9b   Fig. 9c

Fig. 9a shows the trend of the ratio of the CHP electricity to the total electricity: fixed the ratio H_{CHP}/E, the ratio E_{CHP}/E is higher for the ICE because the electric efficiency is higher and thus the heat to power ratio (C_{eff}) is higher. But the GT exhibits excellent performance for high ratios H_{CHP}/E where it is not possible to use an ICE; indeed there is a value of the ratio H_{CHP}/E beyond which the GT achieves an overall efficiency greater than the threshold value (75%) and therefore the ratio E_{CHP}/E becomes unitary. Fig. 9b shows the trend of the PES. For the ICE, the PES remains almost constant and well above the threshold limit of 10%; for the GT, the PES is constant and very similar to the limit value when overall efficiency is lower than the limit value, but it increases considerably when overall efficiency becomes greater than the limit value. Fig. 9c shows the trend of the RISP and thus of the white certificates. Also in this case, fixed the ratio H_{CHP}/E, the ratio $RISP/E$ is higher for the ICE but the GT exhibits excellent performance for high H_{CHP}/E where it is not possible to use an ICE.

3.5. Comparison between cogeneration technologies

Figg.10 compare the performance of the power plants here analysed. The steam back-pressure turbine-based plants are not shown because they have a field of the ratio H_{CHP}/E that it is not overlapping with that of the other technologies (H_{CHP}/E is generally above 4). For these high values of the ratio H_{CHP}/E, steam back-pressure turbine-based plants exhibit very good performance (E_{CHP}/E=1 and $RISP/E$ is approximately equal to the unitary value) that can not be reached by the other technologies in their fields of H_{CHP}/E. Figures 10 show that for low values of the ratio H_{CHP}/E the ICE stands out (both in terms of E_{CHP}/E and of $RISP/E$). The GT exhibits excellent performance for high H_{CHP}/E where it is not possible to use an ICE or an unfired combined cycle power plant. The steam condensing extraction turbine-based plant exhibits limited performance but it can be adopted for values of the ratio H_{CHP}/E which can not be covered by the other technologies, even if the values of the ratio $RISP/E$ are always less than 0.3.
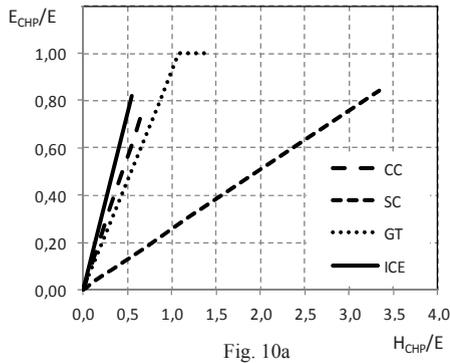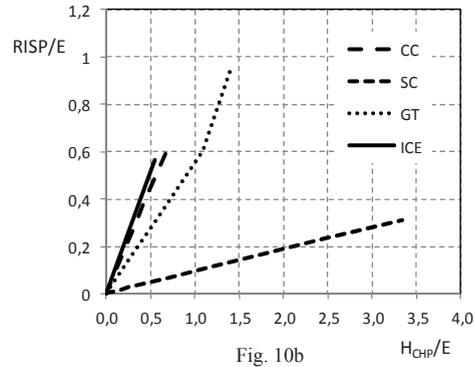
Fig. 10a   Fig. 10b

4. Conclusions

In this paper, performance assessment of industrial cogeneration plants, operating in the new legislative context, was carried out. First of all, the salient features of high efficiency cogeneration legislation were illustrated. Then, the procedure for the calculation of high efficiency cogeneration parameters was presented and finally five different cogeneration technologies were analysed and their high efficiency performance was calculated and compared. The main results are:

- all power plants must be split into two virtual parts, the CHP part and non-CHP part, except steam backpressure turbine-based plants and gas turbines (for these last power plants only when the overall efficiency is higher than the threshold value). Because electricity from cogeneration is produced by the CHP part, the ratio E_{CHP}/E is generally less than the unitary value. For the steam condensing extraction turbine-based plants, this ratio is very low and it reaches a maximum values of 30%;
- when power plants must be split into two virtual parts, the evaluation of the heat to power ratio (C_{eff}) must be carried out in order to quantify electricity from cogeneration, $E_{CHP}=C_{eff}*H_{CHP}$. This parameter, C_{eff}, depends on the efficiency of non-combined electrical/mechanical energy generation and on power loss coefficient, β, only for steam condensing extraction turbine-based plants. The coefficient, C_{eff}, is higher as higher is the efficiency of non-combined electrical/mechanical energy generation and as lower is the quality (temperature) of the steam required by the heat consumer: for this reason, combined cycles power plants have an higher heat to power ratio in comparison with steam cycle power plants, as well as generally an ICE versus a GT, and it is as higher as lower is the extraction pressure;
- the calculation of the PES, whose value determines the possibility of access to the support system, must be carried out using the energies of the CHP part (E_{CHP}, H_{CHP}, F_{CHP}): the cogeneration technologies, that have low E_{CHP}/E values, can have values of the PES below the threshold value (10%) when are fed by high-grade fuels because in this case the efficiency reference values for separate heat and electricity production are very high;
- also the calculation of the RISP, whose value determines the number of white certificates, must be carried out using the energies of the CHP part (E_{CHP}, H_{CHP}, F_{CHP}): the cogeneration technologies, that have low E_{CHP}/E values, will have very limited incentives.

References

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