Technical Planning To Reduce Air Pollution By Management Of Energy Supply To "Technological Polo" Of Catania University

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Abstract

Forecasted data of energy consumptions to supply energy needs of Technological Polo (TP) equipped with a "Complex Energy System" (CES) allowed calculating amount of polluting emission yearly expected. With same approach people calculated amount of polluting emission in case of energy, supply with a Conventional System of Technologies (CST). By means of comparison between the two amounts of forecasted polluting data, people focused on as much air pollution could be saved adopting CES that is based on "green energy", CCHP techniques and statements of II Law of Thermodynamics. Firstly, paper shows a short summary of architectural and operational function of TP integrally reported in previous paper [1].

Keywords: Energy, Rationalize, Environmental Control Techniques, Renewable

Short summary of TP

Paper [1] showed characteristics of architecture and building material of TP as depicted in fig.1, fig.2, fig.3, fig.4, fig.5 and fig.6. TP, designed by Author and built in 28 months with a final cost of about € 14.000.000.

Thermodynamic Architecture of CES allows utilizing the same thermal energy coming from a certain source but different and decreasing intervals of temperature to supply plants and various utilities as showed in fig.7 and fig.8.

CES utilizes renewable energies coming from Photovoltaic Installation (PI), Solar Panel (SP) and CCHP techniques that Italian Rules consider “renewable techniques” too under certain conditions.

Fig.1

Fig.2

Fig.3

Fig.4

Fig.5

Fig.6

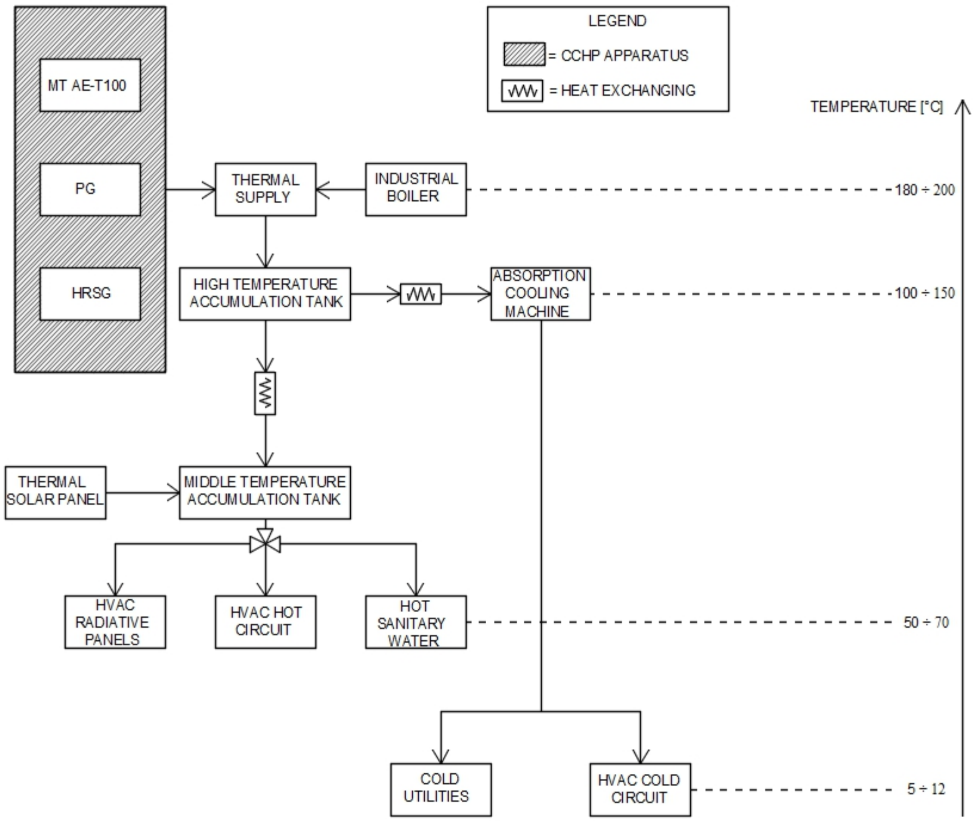

Fig.7 – “Hot” and “Cold” thermal supplies

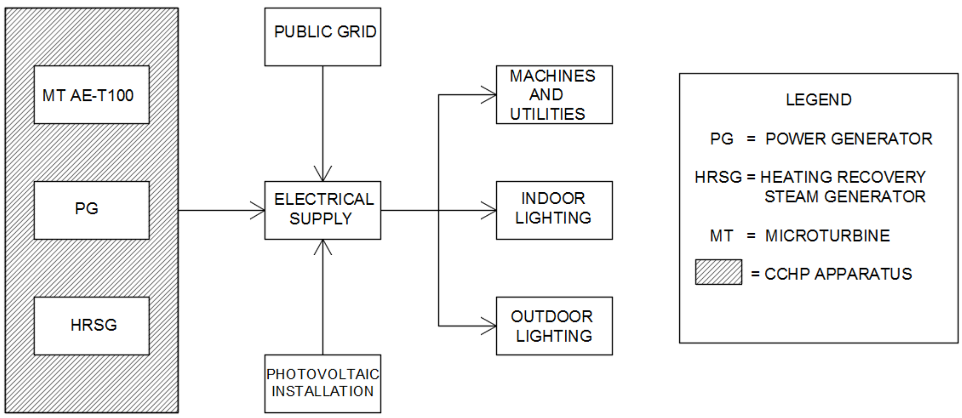

Fig.8 – Electrical supplies

Energy needs and supplyings of operational TP

Previous paper [1] paper showed following tables:

✓ Tab.1 showing thermal loads requested and sources of supplying.

✓ Tab.2 showing electrical loads requested and sources of supplying.

	REQUEST	SOURCE OF SUPPLY		
	kWh_t	CCHP kWh_t	THERMAL SOLAR kWh_t	INDUSTRIAL BOILER kWh_t
January	84,500	76,400	2,600	5,460
February	84,500	76,400	2,600	5,460
March	84,500	76,400	2,600	5,460
April	1,300	Maintenance	3,250	NO (-1,950)
May	77,740	76,400	3,250	NO (-1,950)
June	77,740	76,400	5,200	NO (-3,900)
July	77,740	76,400	5,200	NO (-3.900)
August	35,880	35,280 (50%)	2,400	NO (-1,800)
September	77,740	76,400	3,250	NO (-1,950)
October	77,740	76,400	3,250	NO (-1,950)
November	1,300	Maintenance	2,600	NO (-1,300)
December	84,500	76,440	2,600	5,460
TOTAL	765,180	723,240	38,800	21,840

Tab.1 [1]

	REQUEST	SOURCE OF SUPPLY			
				NETWORK kWh_e	
	KWh_e	CCHP kWh_e	PI kWh_e	GAVE TO NETWORK	SUPPLEMENTARY FROM NETWORK
January	102,960	62,400	711	-.-	-39,849
February	102,960	62,400	782	-.-	-39,778
March	57,200	62,400	1,007	6,270	-.-
April	57,200	Maintenance	1,053	NO	-56,147
May	57,200	62,400	1,189	6,389	-.-
June	45,760	62,400	1,170	17,810	-.-
July	45,760	62,400	1,229	17,869	-.-
August	21,120	28,800	1,179	8,859	-.-
September	57,200	62,400	1,036	6,236	-.-
October	57,200	62,400	967	6,167	-.-
November	102,960	Maintenance	722	-.-	-102,238
December	102,960	62,400	685	-.-	-39,875
TOTAL	810,480	590,400	11,730	69,537	-277,887

Tab.2 [1]

To supply previous energy loads people made use of technologies, plants and system as CCHP system, photovoltaic installations, thermal panels installation, industrial boiler and public national electrical network system.

Renewable or assimilated energies utilized by CES

CES utilizes CCHP system (assimilated to renewable energy by Italian Regulation under specific condition), solar panels (SP), and photovoltaic system (PHS).

- CCHP system is made up of one “Microturbine AE-T100” of Ansaldo (MT) fed by methane (CH_4), one “Power generator” (PG) and one “Heating recovery steam generator” (HRSG). As regard MT, data coming from technical specification [2] show that MT by 333 kWh_t (thermal energy input coming from combustion of CH_4) produces 167 kW_t (thermal power output of HRSG) and 100 kW_e (electrical power output of PG). In first part of paper, people calculate the yearly average operational time of work of CCHP system in 5,100 h/year (instead of 8,760 h/year) to take in account operational times wasted for normal and extraordinary maintenance services.

  By means of previous data, people calculate the yearly supplying coming from CCHP system:

✓ Output of thermal energy: 167 $kW_t \cdot$ 5,100 h/year =
= 851,700 kW_th/year (1)

✓ Output of electrical energy: 100 $kW_e \cdot$ 5,100 h/year =
= 510,000 kW_eh/year (2)

In function of yearly average operational time and thermal input, people calculate the yearly energy consumption:

✓ Input of thermal energy: 333 $kW_t \cdot$ 5,100 h/year $\cdot$ 0.0036 GJ/kWh =
= 1,698,300 kWh_t/year $\cdot$ 0.0036 GJ/kWh = 6,113.88 GJ/year (3)

- Thermal energy production by SP, as showed in first part of paper, takes to an yearly average of 38,800 kW_th/year, that is:
  38,800 $kW_th \cdot$ 0.0036 GJ/kW_th = 139.68 GJ/year (4)
- Electrical energy production by PHS, as showed in first part of paper, takes to an yearly average of 11,730 kW_eh/year, that is:
  11,730 kW_eh/year $\cdot$ 0.0036 GJ/kWeh = 42.23 GJ/year (5)

By means of all previously reported, CES supplies:

- ✓ Total thermal energy : (1) + (4) = 890,500 kW_th/year (6)
- ✓ Total electrical energy: (2) + (5) = 521,730 kW_eh/year (7)

Analysis about polluting substances discharged into atmosphere by operational CES

People limited analysis to NO_x, CO, PM_{10} and considered pollution produced by CES coming only from combustion of CH_4 fueling MT since SP and PHS do not produce polluting matters. By technical handbook [3] people obtained specific polluting emission in the case of gas turbines fed by methane. The average for each specific polluting substance are:

NO_x = 0.048 kg/GJ CO = 0.0048 kg/GJ PM_{10} = 0,0002 kg/GJ (8)

By (3) and by (8) people obtained total yearly amount of emissions caused by CES.

$$\left.\begin{aligned} NO_x &= 0.048 \text{ kg/GJ} \cdot 6{,}113.88 \text{ GJ/year} = 293.47 \text{ kg/year} \\ CO &= 0.0048 \text{ kg/GJ} \cdot 6{,}113.88 \text{ GJ/year} = 29.35 \text{ kg/year} \\ PM_{10} &= 0.0002 \text{ kg/GJ} \cdot 6{,}113.88 \text{ GJ/year} = 1.23 \text{ kg/year} \end{aligned}\right\} \quad (9)$$

Theoretical values of pollutant substances in case of energy productions by means of conventional methods and systems

- Thermal energy

  Production of thermal energy commonly happens by "industrial boiler" (IB). Total thermal efficiency of IB depends on many causes: efficacy of combustion, kind of fuel utilized, losses of heat in external blanket of IB, amount of heat contained in smokes discharged in atmosphere by smokestack, sales model of IB, etc. etc.

  People elaborated incidence of previous factors analyzing technical data [4] showed in the book of production of IB coming from an important European factory. The evaluation by data processing allows appreciating in about 80% the average of total thermal efficiency of IB. For room reason the copious hypothesis at the basis of previous value are not here reported. Choosing 80% as total thermal efficiency to supply by fuel to IB, people obtain the corresponding thermal energy by combustion of fuel in IB to obtain the same amount of thermal energy produced by CES as follows:

  890,500 kWh_t/year / 0.80 = 1,113,125 kWh_t/year = 4,007.25 GJ/year (10)

  Usually fuel to supply IB may be gaseous fuel, heavy fuel or gasoil. Technical handbooks [5] show pollutant specific emissions in function of kind of fuel as shown in tab.3.

Pollutants	Gaseous Fuel g/GJ	Heavy Fuel g/GJ	Gasoil g/GJ	Average g/GJ
CO	39	15.1	16.2	23.44
NO_x	89	142	65	98.67
PM_{10}	0.89	25.2	3.2	9.76

Tab.3

By (10) and the average of tab.3 people calculated theoretical values of pollutant emission in case of thermal energy produced by means of conventional methods and system.

$$\left.\begin{aligned} NO_x &= 98.67 \text{ kg/GJ} \cdot 4{,}007.25 \text{ GJ/year} = 395{,}395 \text{ kg/year} \\ CO &= 23.44 \text{ kg/GJ} \cdot 4{,}007.25 \text{ GJ/year} = 93{,}930 \text{ kg/year} \\ PM_{10} &= 9.76 \text{ kg/GJ} \cdot 4{,}007.25 \text{ GJ/year} = 39{,}110.76 \text{ kg/year} \end{aligned}\right\} \quad (11)$$

- Electrical energy

The supplying of electrical energy not self-produced commonly derives from network connection with public national electricity grid. Electricity production coming from grid happens by means of energy conversion from thermal to electrical energy in generating station. People calculate here after polluting emissions without considering precautionary losses caused by transport of electricity from generating station to point of user because impossible to calculate in general form. People limit himself to evaluate polluting emissions considering only the efficiency of generating station.

Generating station shows different values of efficiency in function of kind of fuel supply as showed in tab.4.

Fuel supply		Efficiency	Average
Oil	=	0.45	0.43
Coal	=	0.40	
Methane	=	0.44	

Tab.4

Taking in consideration average efficiency and electrical energy produced by CES (7), generating station must produces

$$521{,}730\ kW_eh/year\ /\ 0.43 = 1{,}213{,}326\ kW_eh/year = 4{,}368\ GJ/year \quad (12)$$

By (12) and values of tab.3, people calculate theoretical values of pollutant substances in the case of electrical energy production by means of conventional methods and systems as here after reported:

$$\left.\begin{array}{l} NO_x = 98.67\ kg/GJ \cdot 4.368\ GJ/year = 430{,}990.56\ kg/year \\ CO = 23.44\ kg/GJ \cdot 4.368\ GJ/year = 102{,}385.92\ kg/year \\ PM_{10} = 9.76\ kg/GJ \cdot 4.368\ GJ/year = 42{,}631.68\ kg/year \end{array}\right\} \quad (13)$$

Environmental balance

Result showed in (9), (11) and (13) allow calculating environmental balance. People underline that positive values (+) mean amount of pollutants really discharged into atmosphere (9) by CES and negative values (–) are theoretical amount of pollutants saved to be discharged in atmosphere of an hypothetical supplying by means of conventional methods and systems (11) (13):

$$\left.\begin{array}{l} NO_x = (293.47 - 395{,}395 - 43{,}990.56)\ kg/year = -\ 826{,}092\ kg/year \\ CO = (29.35 - 93{,}930 - 102{,}385.92)\ kg/year = -\ 196{,}286.57\ kg/year \\ PM_{10} = (1.23 - 39{,}110.67 - 42{,}631.68)\ kg/year = -\ 81{,}470.45\ kg/year \end{array}\right\} \quad 14)$$

Conclusion

Results showed in (14) prove that thermodynamic design of CES realized on the basis of criteria stated by II Law of Thermodynamic and with use of renewable or assimilated energy sources is the right way to respect environment by decreasing impact of pollutant substances as like about 826 $tons_{NOx}$/year, about 196 $tons_{CO}$/year and about 81.47 $tons_{PM10/}$year. Authors have to underline that planning choices have general effectiveness as regard the application of criteria of II Law of Thermodynamic whereas practical consequence of CCHP technique is convincing for this specific or comparable cases that maintain similar values of ratio between electrical and thermal energies required by user. It means that correct design of CES and interrelated thermodynamics architecture of plants must take in account a lot of input data [1] as like:

- Weather-climate and geographical position of locality of construction
- Types of activities that will carried out in built volumes
- Total amount of energies that yearly have to be supplied
- The possibility to exploit other renewable sources as locally present
- Etc. etc.

However, with reference exclusively to environmental purpose every kind of Complex Energy System that follow criteria of II Law of Thermodynamic and applications of CCHP technique certainly will take to significant advantages for environment.

Nomenclature:

TP	:	Technological Polo
CES	:	Complex Energy System
t (subscript)	:	Thermal “hot” energy
f (subscript)	:	Thermal “cold” energy
e (subscript)	:	Electrical energy
CCHP	:	Combined Cooling Heating and Power
MT	:	Micro turbine
PG	:	Power Generator
HRSG	:	Heating Recovery Steam Generator
PI	:	Photovoltaic installation
SP	:	Solar panels
PHS	:	Photovoltaic system

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