DESIGN and MANAGEMENT of ELECTRICAL POWER ASSETS

Technical Report 0086/2019

Project Pegasus – Pilot of the Municipality of Potenza

WP 3 "Testing"

Technical and economical evaluation

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Reference documents

N°	Document	Title
[1]	TS 072/2017 rev.1	Pilot of Municipality of Potenza - WP 3 "Testing": Measuring equipment for testing campaign
[2]	TR 079/2018	Pilot of Municipality of Potenza - WP 3 "Testing": Methodology for data processing
[3]	TR 082/2018 rev.1	Pilot of Municipality of Potenza - WP 3 "Testing": Technical and economical assessment for period November 2017-May 2018

Index

1 Scope..5

2 Forewords..6

3 Economic benefits related to the installation of the cogenerating system in the Swimming pool 9

4 Economic benefits related to the exchanges of electricity with the local distribution network 10

5 Energy and environmental benefits 13

6 Cost-benefit assessments 14

7 Conclusion...17

Annex 1 - Swimming pool short description 18

Annex 2 - Santa Lucia Escalator short description 20

Annex 3 - CHP schematic view and performances 22

Annex 4 - Example of maintenance plan of CHP system based on natural gas fueled motor... 24

Figure Index

Fig.1 – Pilot sites location in the map of the Municipality of Potenza 6

Fig.2 – Schematic view of CHP system and the condensing boiler with relevant thermal Control Unit and the electrical connection with the public grid and the Swimming pool main switchgear 8

Fig. 3 - Net operating and investing Cash flow 16

Fig. 4 – Debt Service Cover Ratio... 16

Fig. 1.1 in Annex 1 – Swimming pools 16

Fig. 1.2 in Annex 1 – Boilers in thermal power plant 16

Fig. 1.3 in Annex 1–Swimming pool thermal energy consumption [MWh$_t$] in 2018 year 19

Fig. 1.4 in Annex 1 – Swimming pool electricity consumption [MWh] in 2018 year 19

Fig. 2.1 in Annex 2 – Views of Santa Lucia Escalators 21

Fig. 2.2 in Annex 2 – Santa Lucia Escalator electricity consumption [kWh] in 2018 year 21

Fig. 3.1 in Annex 3 – CHP Schematic view 23

Fig. 3.2 in Annex 3 – CHP technical performances.. 23

Table Index

Table 1 – Variation in natural gas and electricity consumption in the Swimming pool due to the partial replacement of the existing boiler with CHP system 9

Table 2 – Economic benefits related to the partial replacement of the existing boiler with a high-efficiency cogenerating system... 10

Table 3 – PUN and PZ values for 2018 year 11

Table 4 – Economic benefit coming from “Scambio sul posto altrove” rules.............. 12

Table 5 - CHP System operation time 12

Table 6 – CAPEX borne by the Municipality.. 14

Table 7 – O&M Costs.. 15

Table 4.1in Annex 4 – Maintenance Plan of a CHP system based on natural gas fueled motor 25

1 Scope

In the frame of the Work Package 'Testing' and after the conclusion of the measurement phase lasted from November 2017 until December 2018 this document performs a complete technical and economic assessment of the pilot developed by the Municipality of Potenza.

In the reference document [3] has been evaluated the achievable benefits on the basis of data collected in the period November 2017-May 2018 according to the methodology for data defined in the reference document [2].

This document makes reference to the acquired data during the whole year 2018 in order to take into account any seasonal effects and the variability over time of the main parameters related to the pilot operation.

After a summary of the main results from the previous reports, this document evaluates the benefits related to the use of an high-efficiency cogenerating system and the exchanges of electricity with the grid.

The energy and environmental benefits related to the pilot development are quantified in terms of primary energy savings and reduced carbon emission.

Finally the financial indicators are evaluated in order to demonstrate the sustainability of the investment related to the pilot.

2 Forewords

The pilot developed by the Municipality of Potenza includes two sites: the Swimming pool located in the Montereale Sport Park (see Annex 1) and the Santa Lucia Escalator (see Annex 2), the longest one installed in the city, both owned by the Municipality.

The thermal energy demand in the Swimming pool related to water and ambient air heating varies during the year from 3 to 5 times the electricity consumption for the operation of recirculation pumps, fan and lighting. The use of a cogenerating system, instead of the existing condensation boiler, in addition to thermal energy makes available electricity exceeding the local demand that can be fed into the local distribution network.

According to the 'Scambio sul posto' regulation[1] the prosumers with a generation capacity from renewable sources up to 200 kW receives a compensation equal to the difference between the value of the electricity fed into the grid and the value of the electricity consumed. This benefit is related to the purpose to foster the use of renewable sources and on the fact that the electricity from distributed generation is used by the surrounding electrical loads in so reducing the transiting electricity on the transmission and distribution networks with consequent lower losses.

Moreover two or more public sites located in Municipalities with a population up to 20,000 inhabitants have the possibility to be assimilated as a single prosumer, provided that at least one of them is equipped with an electrical generation capacity from renewable source. According to this particular rule, named 'Scambio sul posto altrove', the compensation is evaluated taking into consideration the exchanges of electricity with the public network of all the involved sites.

Fig.1 – Pilot sites location in the map of the Municipality of Potenza

[1] Regulation 570/2012/R/efr *by* Italian Regulatory Authority for Energy, Networks and the Environment

Making use in the Swimming pool of an high-efficiency cogeneration according to UE Directive 2004/8/EC (that means a Primary Energy Saving higher than 10%) the CHP system is assimilated to renewables sources. Under the condition the CHP electric power is lower than 200 kW the pilot including the Swimming pool and the Escalator in principle can take advantage of the 'Scambio sul posto altrove' rules. But this regulation cannot be applied for the Municipality of Potenza accounting more than 60.000 inhabitants. It is a specific objective of the pilot the demonstration of the achievable advantages through the 'Scambio sul posto altrove" rules without any unbalance or other negative effects on the involved distribution networks taking into account the small distance between the location of the Swimming pool and Santa Lucia Escalator (less than 500 meters).

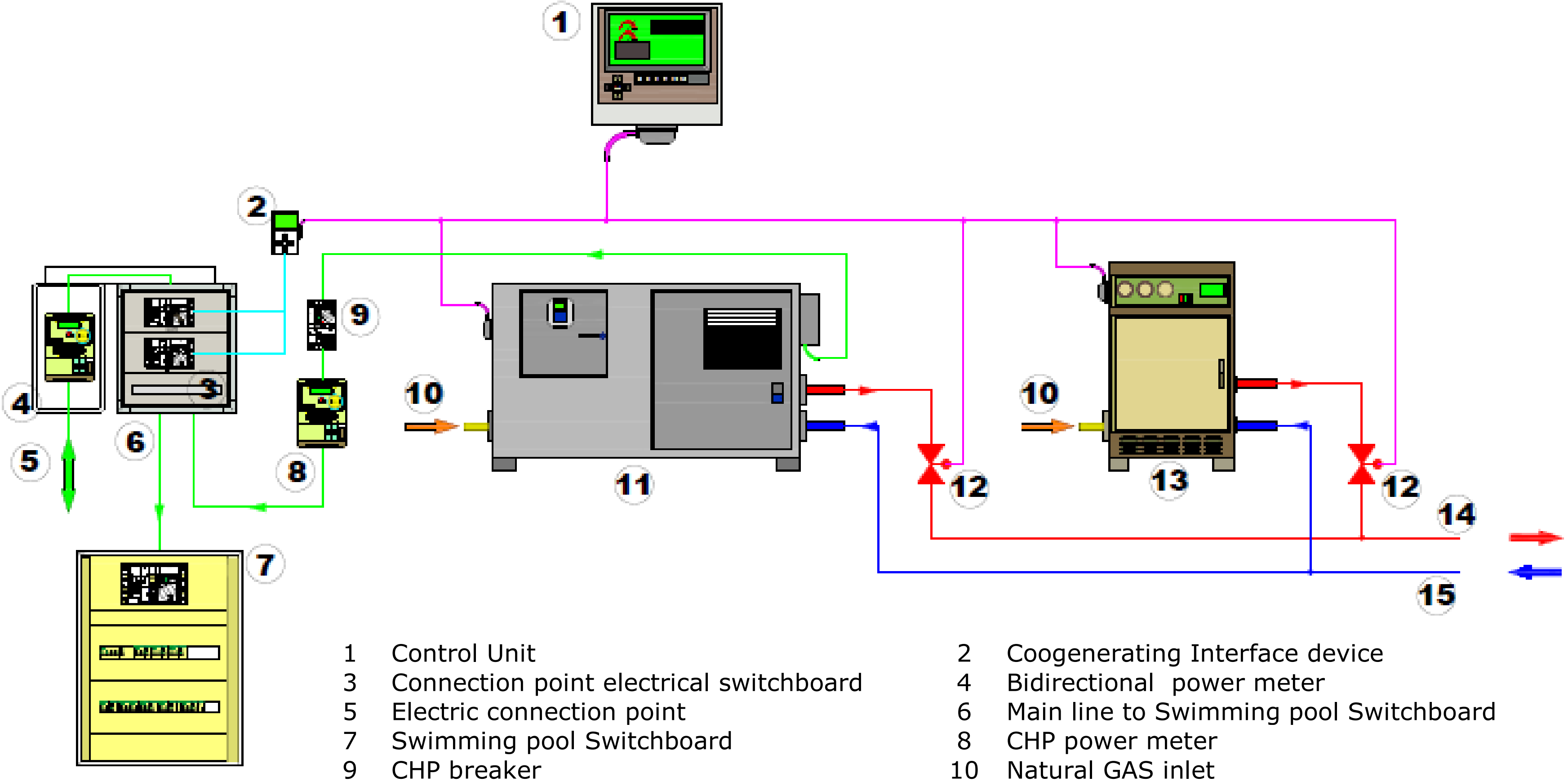
In the previous report (see reference document [1]) has been described the measuring equipment for the testing campaign aimed to acquire the electricity and thermal energy consumption of the pilot while the reference document [2] defined the methodology applied for the technical and economical assessment addressed to identify the optimal configuration of the pilot.
On the basis of data acquired in the period November 2017 – May 2018 a previous report (see reference document [3]) defined in 120 kW of heating capacity and 65 kW of electric power the most performing size of the CHP system in terms of return on the related investment. Based on these ratings the selected CHP consists of a gas fueled engine, with heat exchanger for heat recovery from exhaust gas, and an electric generator. A schematic view of the cogenerating system is shown in Annex 3 together with the CHP technical performances in terms of generated heat and electricity towards the inlet flow of natural gas.

In order to assure the high efficiency of the cogenerating system it has been considered an operating rating from 30% up to 100% of the maximum gas natural inlet flow. A Control Unit devoted to:

- to integrate the thermal power from CHP operating at 100% of its maximum power with thermal generation by the boiler,
- to replace the CHP when the required thermal power is less than 30% of its maximum delivered power.

As shown in Figure 2 this Control Unit interfaces the control systems of the Swimming pool Heating System managing CHP, boiler and the relative operating equipment (pumps, valves, etc.).

Taking into account the acquire data from 1/1/2018 up to 31/12/2018 this report evaluates the energy and environmental benefits related to the use of such CHP system in partial replacement of the existing boilers, as well as the economic benefits related to the 'Scambio sul posto altrove' rules and the related financial assessment.



1	Control Unit	2	Coogenerating Interface device
3	Connection point electrical switchboard	4	Bidirectional power meter
5	Electric connection point	6	Main line to Swimming pool Switchboard
7	Swimming pool Switchboard	8	CHP power meter
9	CHP breaker	10	Natural GAS inlet
11	CHP	12	Hot water regulation valve
13	Boiler	14	Hot water outcoming
15	Cold water incoming		

Fig.2 – Schematic view of CHP system and the condensing boiler with relevant thermal Control Unit and the electrical connection with the public grid and the Swimming pool main switchgear

3 Economic benefits related to the installation of the cogenerating system in the Swimming pool

The replacement in the Swimming pool of the existing boiler with a cogenerating system leads to a larger natural gas consumption but at the same time to a reduction of the electricity withdrawn from the public grid as shown by Table 1 listing these variations for the different months of 2018 year.

It has to be noted that an high-efficiency cogenerating is favored through incentives and tax benefits. According to Italian rules a cogeneration is considered high-efficiency when:

$$\frac{\frac{E_e}{0,525}+\frac{E_t}{0,9}}{scm * 9,59} > 0,75$$

being:

- E_e the electricity generated by CHP system[kWh],
- E_t the thermal energy generated by CHP system [kWh],
- **scm** the natural gas consumption (standard cubic meters) by the CHP system,
- **9,59** the net heating value of natural gas [kWh/smc],
- **0,525** the national average efficiency of natural gas electric conversion,
- **0,9** the national average efficiency of natural gas thermal conversion.

Table 1 – Variation in natural gas and electricity consumption in the Swimming pool due to the partial replacement of the existing boiler with CHP system

Month	Increased consumption of natural gas [scm]	Avoided electricity from the public grid [kWh]			
		F1	F2	F3	Total
January	6.303	13.937	9.305	15.573	38.815
February	5.692	12.598	9.670	13.085	35.353
March	6.294	14.165	10.997	14.437	39.599
April	6.097	11.278	9.075	16.833	37.186
May	6.260	14.251	10.523	16.086	40.860
June	5.713	15.337	7.051	15.397	37.785
July	5.429	13.841	6.300	14.637	34.778
August	1.320	2.706	1.244	2.520	6.470
September	5.124	9.401	4.553	9.739	23.693
October	6.196	15.781	7.908	14.019	37.708
November	6.099	15.223	7.525	14.343	37.091
December	6.301	13.983	6.769	17.113	37.865
2018 year	**66.802**	**152.501**	**90.920**	**164.282**	**407.703**

The results of the above table have been obtained adopting the following CHP operation criteria:

- CHP operation is driven by heat demand and then the electricity generation is directly related to the request of thermal power in the Swimming pool
- CHP operation is in the range from 30% up to 100% of its maximum natural gas inlet flow.

Under the condition a gas fueled cogenerating system is high-efficiency it benefits of:

- a reduced excise tax on the consumed natural gas, equal to 0,175373 €/scm ;
- the achievement of "energy efficiency certificates" (TEE) in quantity equal to:

$$0,00012 * \left(\frac{E_e}{0,525} + \frac{E_t}{0,9} - scm * 9,59\right).$$

Since for the whole year 2018:

$$E_e = 498\ MWh\ ; \qquad E_t = 928\ MWh \quad ; \qquad scm = 165.544$$

the annual number of the achieved "energy efficiency certificates" amounts to **47,3**, with a corresponding value of **13258** € on the basis of the price defined by ARERA for the period June 2017-May 2019.[2]

The following Table 2 lists the economic benefits due to the partial substitution of the existing boiler with an high-efficiency cogenerating system, taking into account in addition to the fiscal benefits and energy incentives also of the avoided purchase of the electricity evaluated with the following average rate during the year:

- electricity consumed in the time band F1: 224,7972 €/ MWh,
- electricity consumed in the time band F2: 219,0632 €/ MWh,
- electricity consumed in the time band F3: 196,7274 €/ MWh.

Table 2 – Economic benefits related to the partial replacement of the existing boiler with a high-efficiency cogenerating system

Cost for increased consumption of natural gas [€]	Fiscal benefit on the natural gas consumed by CHP [€]	Energy efficiency certificates [€]	Avoided purchase of electricity [€]	Total Economic benefits [€]
52.129	**19.225**	**13.258**	**86.404**	**66.758**

4 Economic benefits related to the exchanges of electricity with the local distribution network

The "Scambio sul posto altrove" rules, as per Annex 2 of the reference document [2], define a reimbursement equal to the minimum of the following two terms:

[2] see Determina ARERA DMRT/EFC/4/2018 dated 22/06/2018.

- the electricity monthly fed into the public grid multiplied by the average price PZ of the electricity sales contracts stipulated during the month in the South area of the national territory,
- the electricity monthly drawn from the network multiplied by the national average monthly price of electricity PUN resulting from the Italian electricity exchange market.

The considered values of PUN and PZ for 2018 year are below listed in Table 3.

Moreover a further credit, equal to 0.01 €/kWh applied on the minimum between the electricity withdrawn from the network and that fed into the network, is acknowledged. This credit is related to the reduction of the losses in the transmission and distribution networks due to the considerably shorter distribution chain of the electricity locally generated.

The rules above summarized are very effective as adequately demonstrated in Annex 2 of the reference document [2]. The reimbursement credited to the prosumer grows when increasing the quantity of electricity fed into the network, as long as it remains less than or equal to that withdrawn from the network. If the energy withdrawn is lower than that fed into the network, the reimbursement decreases until annulled for zero withdrawals but this is the case of a producer. Similarly the reimbursement is null for zero immission of electricity on the network, as this is the case of a consumer.

Table 3 – PUN and PZ values for 2018 year

Months	PUN [€/MWh]			PZ [€/MWh]
	F1	F2	F3	
January	55,96	53,98	41,81	47,47
February	65,60	61,48	47,88	54,93
March	63,68	63,09	47,88	52,60
April	53,88	56,15	43,67	50,35
May	59,09	60,50	45,61	54,75
June	62,40	60,00	52,09	59,39
July	66,65	66,50	57,75	62,07
August	69,93	71,57	64,03	66,08
September	82,82	79,89	69,84	70,68
October	80,72	79,02	65,54	68,05
November	76,52	69,72	57,75	63,36
December	74,65	69,64	57,98	62,49

For the pilot of the Municipality of Potenza only the Swimming pool can fed electricity into the network while the electricity is withdrawn from both the Swimming pool and the Escalator.

The exchanges of electricity with the public network and the corresponding economic benefits according to the "Scambio sul posto altrove" are listed in Table 4 for the 2018 year.

Table 4 – Economic benefit coming from "Scambio sul posto altrove" rules

Month	Electricity fed into the network by the CHP system [kWh]	Electricity withdrawn from the network [kWh]		"Scambio sul posto altrove" benefit [€]
		by Swimming pool	by Escalator	
January	9.530	359	40.723	548
February	8.314	277	36.055	540
March	8.681	588	37.856	543
April	9.600	324	31.500	579
May	6.815	610	39.353	441
June	2.846	1.764	36.048	197
July	1.409	4.710	35.356	102
August	2.184	6.941	35.470	166
September	12.167	2.301	37.254	982
October	9.357	730	37.632	730
November	9.694	118	36.839	711
December	10.481	66	38.568	760
Total	**91.078**	**18.787**	**442.654**	**6.299**

While the electricity withdrawals by the Escalator are poorly influenced by seasonal factors, in the case of the Swimming pool the reduced thermal demand during the summer months leads to a lower generation and therefore greater withdrawals from the network in order to cope the local electric demand.
The CHP monthly operating time, namely the equivalent hours at full power, for the different months is reported in the following Table 5.

Table 5 - CHP System operation time

Month	Equivalent hours of full power operation
January	744
February	672
March	743
April	720
May	734
June	725
July	557
August	133
September	552
October	724
November	720
December	744
Total 2018 year	**7.768**

5 Energy and environmental benefits

No less significant than the economic benefits are the energy and environmental ones related to the pilot developed by the Municipality of Potenza. In fact, are these types of benefits that have induced the regulation concerning the high-efficiency cogeneration as well as the "Scambio sul posto altrove" rules with the related economic benefits referred in the previous chapters.

The use of cogenerating systems allows primary energy savings and consequent reduction of CO_2 and other pollutants (particulate matter, NO_X, SO_X) produced by the natural gas combustion process. These achievable benefits must be referred to the context in which the intervention takes place, usually that of the belonging country.

For the Italian electricity system the following reference data may be considered:

- 52,5 % the average electricity generation efficiency,
- 90% the average thermal energy generation efficiency,
- 330 gr CO2/kWh of consumed electricity (measured at user meters),
- 1,95 kg CO2/smc burnt of natural gas.

The Primary Energy Saving related to the cogenerating system may be defined as:

$$\boldsymbol{PES = 1 - \frac{1}{\frac{Ee/(scm * 9,59)}{0,525} + \frac{Et/(scm * 9,59)}{0,9}}}$$

being:

- **E_t** the thermal energy generated by CHP system [kWh],
- **E_e** the electricity generated by CHP system[kWh],
- **scm** the natural gas consumption (standard cubic meters) by the CHP system,
- **9,59** the net heating value of natural gas [kWht/smc],
- **0,525** the national average efficiency of natural gas thermal conversion,
- **0,9** the national average efficiency of natural gas electric conversion.

Based on data reported at § 3 :

$$\boldsymbol{E_e = 498\ MWh\ ; \quad E_t = 928\ MWh\ ; \quad scm = 165.544}$$

the value of PES for the whole year 2018 amounts to 19,81% corresponding to a natural gas saving of **32794 scm/year.**

Taking into consideration the avoided losses in the transmission and distribution networks due to the shorter distribution chain of the electricity generated in the Swimming pool and assuming an overall value of losses equal to 10%, a further energy saving of **49,8 MWh/year** can be accounted.

The corresponding avoided CO_2 emissions can be evaluated as:

32794 x 1,95 + 49800 x 0,33 = **80382 kg/year**

that is equivalent to the quantity of CO_2 adsorbed by 6 hectares of a coniferous forest in a temperate climate.

6 Cost-benefit assessments

The cost-benefit analysis related to the installation in the Swimming pool of a cogenerating system operating under the rules of the "Scambio sul posto altrove" is performed in the following on the basis of the data resulting from the previous Chapters and under appropriate assumption.

As per Chapter 6 in the reference document [3], the evaluation is performed assuming that the requested investment is carried out by the Municipality of Potenza, the owner of the Swimming pool and Santa Lucia Escalator.

6.1 Capital Expenditures

The useful life of the more critical parts of the identified CHP is around 60.000 operating hours at full power. After this operational limit the system requires a strong reconditioning consisting in the replacement of the natural gas fueled motor and an extraordinary maintenance of the remaining parts (heat exchangers, generator, electrical panels, etc.) in order to assure the CHP operation for additional 60,000 hours at full power in conditions of full functionality and reliability.
Being the CHP operating time at full power equal to 7768 h/year (see Table 5) it is reasonable to consider for the system a total life of 16 years with a reconditioning intervention at the end of eighth year.
Taking into account the capital costs evaluated at Chapter 6 of the reference document [3], the total investment borne by the Municipality are listed in Table 6.

Table 6 – CAPEX borne by the Municipality

	At the beginning	After 8 years
CHP system [€]	97.500	39.000
CHP installation [€]	10.000	5.000
Thermal Control Unit [€] (1)	10.000	-
Bidirectional meter and procedural costs [€] (2)	5.000	-
Detailed project, construction, acceptance tests and commissioning [€] (3)	35.000	-
VAT [€]	34.650	9.680
Total capital costs [€]	**192.150**	**53.680**

(1) this electronic device controls the thermal energy dispatching :
- giving priority to the CHP system compared to boiler,
- assuring a natural gas inlet flow of CHP not lower than 30% of its maximum value.

(2) the bidirectional meter accounts the electricity fed into and withdrawn from the public network while the procedural cost concerns the eligibility to the "Scambio sul posto" rules.

(3) all the engineering services carried out for Swimming pool plant modifications, equipment procurement and installation, final acceptance tests and commissioning.

It has to be noted in the above table that all the capital costs are burdened by VAT tax as the Municipality cannot recover it.
It is assumed that the Municipality has to stipulate a loan covering all the involved capital costs with 3% of interest rate.

6.2 Operating Expenditures

The additional operating and maintenance costs due to CHP installation in the Swimming pool have been estimated as 0,02 €/kWh$_e$ of generated electricity over the full operating life of the system. Taking into account a typical maintenance schedule of a CHP system based on natural gas fuel motor shown in Annex 4, the considered O&M costs over the 8 years of system useful life are listed in the following Table 7.

Table 7 – O&M Costs

Year	**O&M Costs [€]** (VAT included)
1	8.906
2	9.272
3	9.943
4	10.858
5	12.078
6	13.603
7	15.372
8	17.568

6.3 Financial Indicators

Taking into account:

- the economic benefits:
    - related to the use of the cogenerating system instead of the condensing boiler (see Table 2),
    - deriving from the "Scambio sul posto altrove" rules (see Table 3),

  which overall amount to 73.057 Euro year;
- the capital and operating expenditures of the previous paragraph 6.1 and 6.2, respectively;

the following financial indicators have been obtained:

- the pay-back period is equal to 3,26 year,
- the Net Present Value, discounted at 3,5%, after 16 years is equal to 0,48 MEuro (see Figure 3),
- the Internal Return Rate amounts to 24,7%.

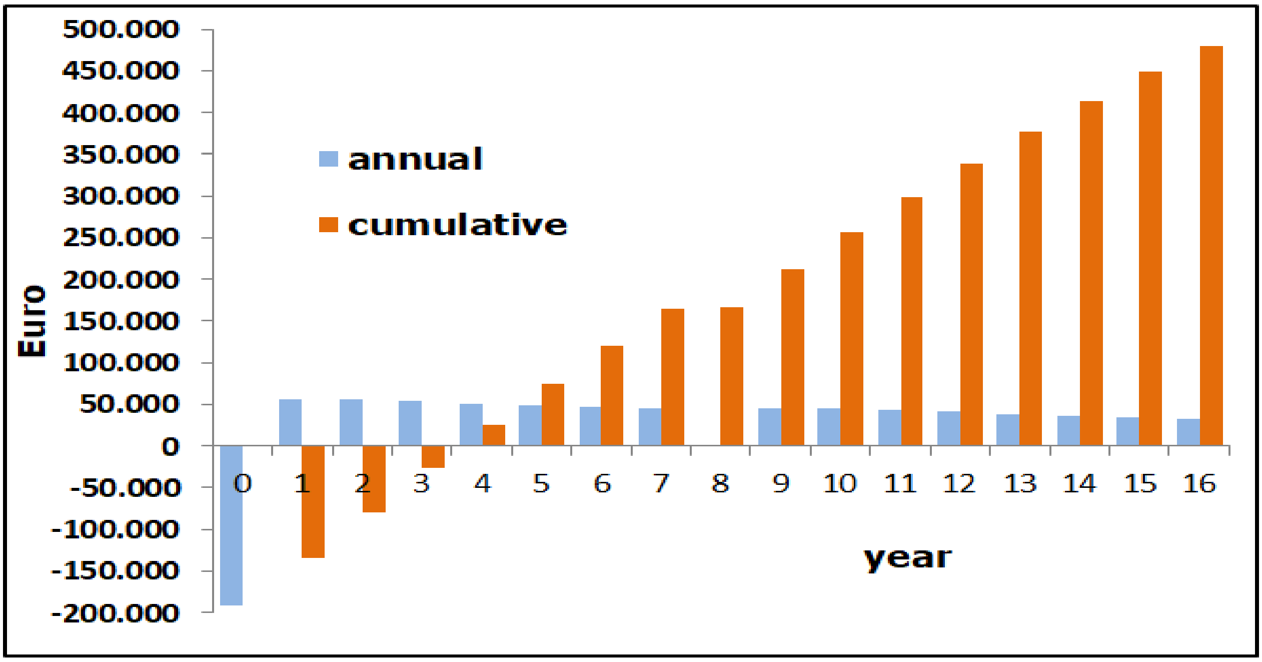


Fig. 3 - Net operating and investing Cash flow

Additionally to these positive values of the financial performances it has been evaluated the Debt Service Coverage Ratio (DSCR) providing the measure of how much the project is bankable. Figure 4 shows the trend of DSCR calculated as the ratio between the Net Operating and Investing Cash Flow and the interest and the repayment of loan during the first 8 years.
The reduction of Net Operating and Investing Cash Flow over the years is due to the increase of the O & M costs, while in the eighth year there is an additional investment related to the reconditioning of the cogenerating system in order to extend its useful life to more 8 years. In any case the DSCR value always remains greater than 2, demonstrating an excellent capacity of debt repayment.

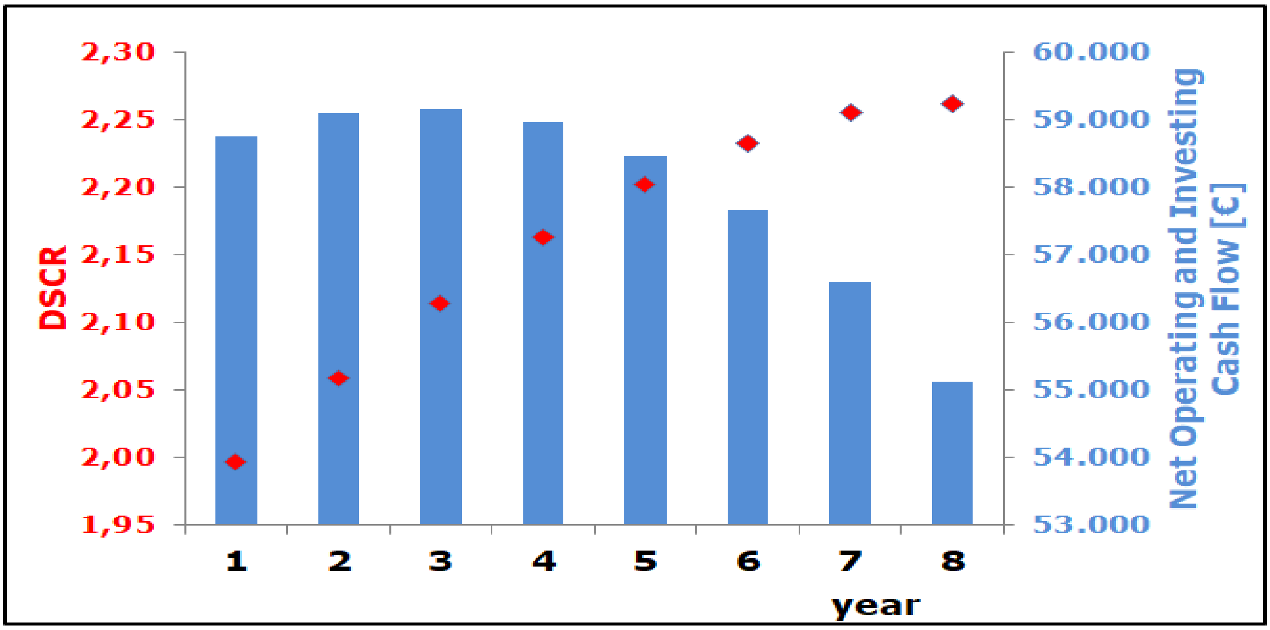


Fig. 4 – Debt Service Cover Ratio

6.4 Sensitivity analysis

The analysis has been conducted by changing (increasing/decreasing) the most significant adopted parameters, one by one while the remaining being unchanged.
The following results have been obtained:

- in the event of the cogenerating system out-of-service for a whole winter month of each year , NPV would be reduced to 393.316 € (instead of NPV = 480.663 € when the cogenerating system is full operating);
- NPV amounts 463.930 € with 5% interest rate on the load stipulated by the Municipality;
- NPV amounts 333.769 € when the discount rate grows up to 7%.

7 Conclusion

The data acquired over the whole year 2018 on the pilot developed by the Municipality of Potenza makes evident the following energy and environmental benefits:

- a saving of about 38.000 smc/year of natural gas corresponding to a reduction of 364 MWh/year in primary energy consumption;
- a consequent avoided CO_2 emission of 80 t/year.

The achievable economic benefits according to Italian regulation "Scambio sul posto" have been estimated in 73 k€/year.
The evaluated financial indicators:

- payback period equal to 3,26 years,
- Net Present Value discounted at 3,5 % equal to 0,48 M€ against a Capital Expenditure amounting 245,8 M€,
- Internal Return Rate equal to 24,7%,

make evident the financial sustainability of the pilot that can be replicated in similar situations characterized by a large thermal requirement in respect of the electricity consumption.

Annex 1

Swimming pool short description

The Swimming pool of Montereale Sport Park consist of a main building housing two pools (Figure 1.1) and a secondary structure where are placed the dressing rooms and offices. In the underlying areas of the main building are located gyms, with related dressing rooms, and technical facilities including the thermal power plant (Figure 1.2).

Fig. 1.1 – Swimming pools

Fig. 1.2–Boilers in power plant

The ambient temperature, pool water and sanitary water heating is performed by a thermal power plant consisting of three boilers, two with 637 kWt and one with 1284 kWt rated power. The heating of the water is carried out through plate exchangers. Two tanks with a capacity of 3000 liters hot water are installed.
The monthly requirement for natural gas during 2018 year is shown in the below chart.

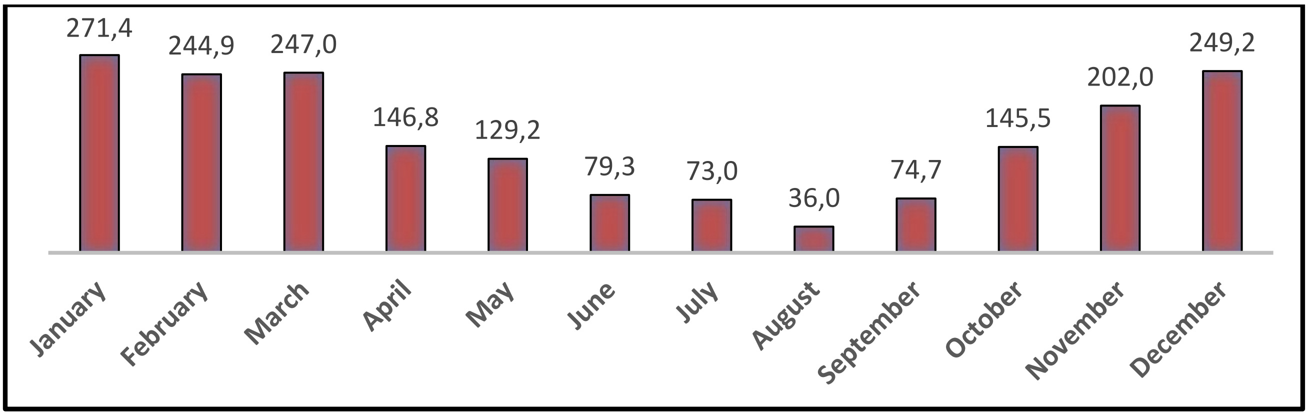


Fig. 1.3–Swimming pool thermal energy consumption [MWh_t] in 2018 year

The pool is powered at 400V with electricity consumption during the year 2018 of 423 MWh.

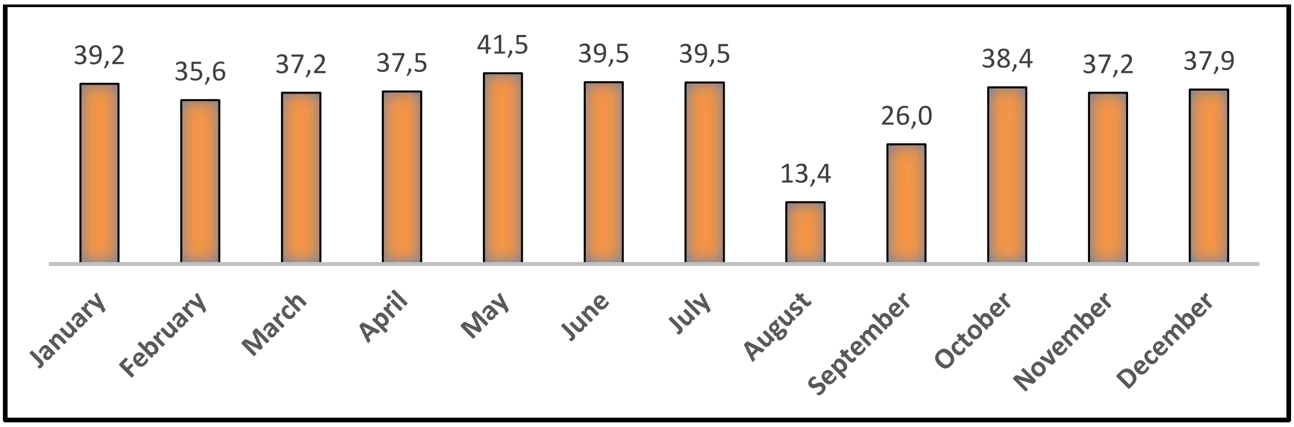


Fig. 1.4–Swimming pool electricity consumption [MWh] in 2018 year

Annex 2

Santa Lucia Escalator short description

The Santa Lucia Escalator shown in the below Figures 2.1 and 2.2 is supplied at 20 kV from the medium voltage Public Grid through the MV/LV substation which is located at Viale dell'Unicef. The Substation mainly includes:

- the medium voltage switchboard supplying the transformers;
- three 500 kVA, 20kV/400 V transformers: two for the normal operation and one as reserve;
- the general low voltage switchboard that makes the parallel connection of the transformers and from which depart the main supply lines of the overall electric system.

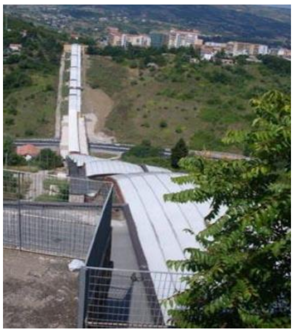



Fig. 2.1 – Views of Santa Lucia Escalators

The general low voltage switchboard is arranged in 4 sections connected through a common bus-bars that makes the parallel connection of the transformers and from which departs the main supply lines. The mainly loads are:

- 8 drive motors, 11 kW each, installed in four of the eight ramps connecting Viale dell'Unicef to Via Mazzini;
- 6 drive motors, 11 kW each, installed in three of the five ramps connecting Viale dell'Unicef to Monte Cocuzzo;
- one 9 kW drive motor of the elevator connecting Monte Cocuzzo to Viale dell'Unicef;
- 4 drive motors, 5,7 kW each one, installed in four elevators connecting the escalator to Via Mazzini;
- auxiliary services for the whole plant (lighting, low voltage supplies, etc.).

The monthly electricity consumption in the year 2018 is shown in the below chart.

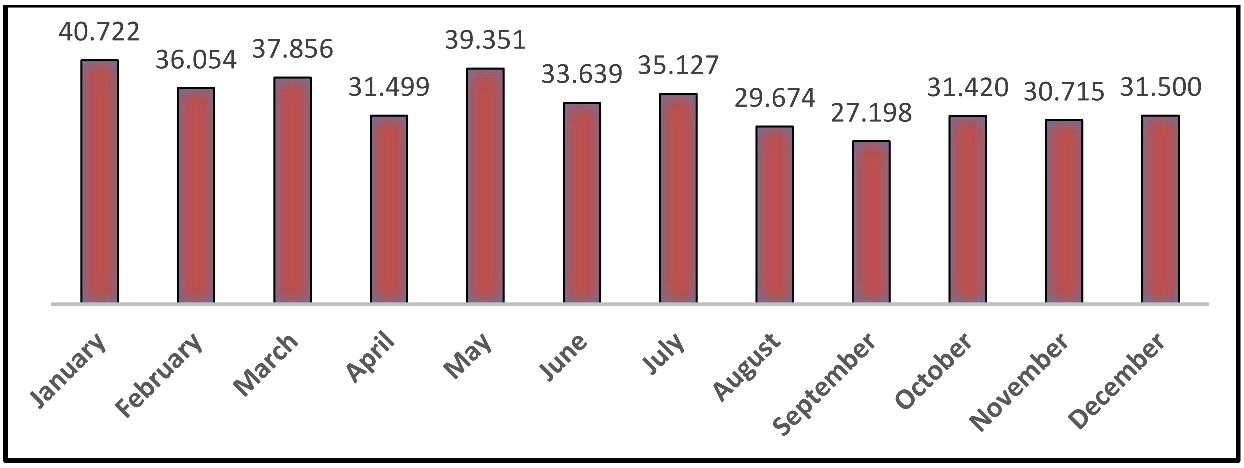


Fig. 2.2 – Santa Lucia Escalator electricity consumption [kWh] in 2018 year

Annex 3

CHP schematic view and performances

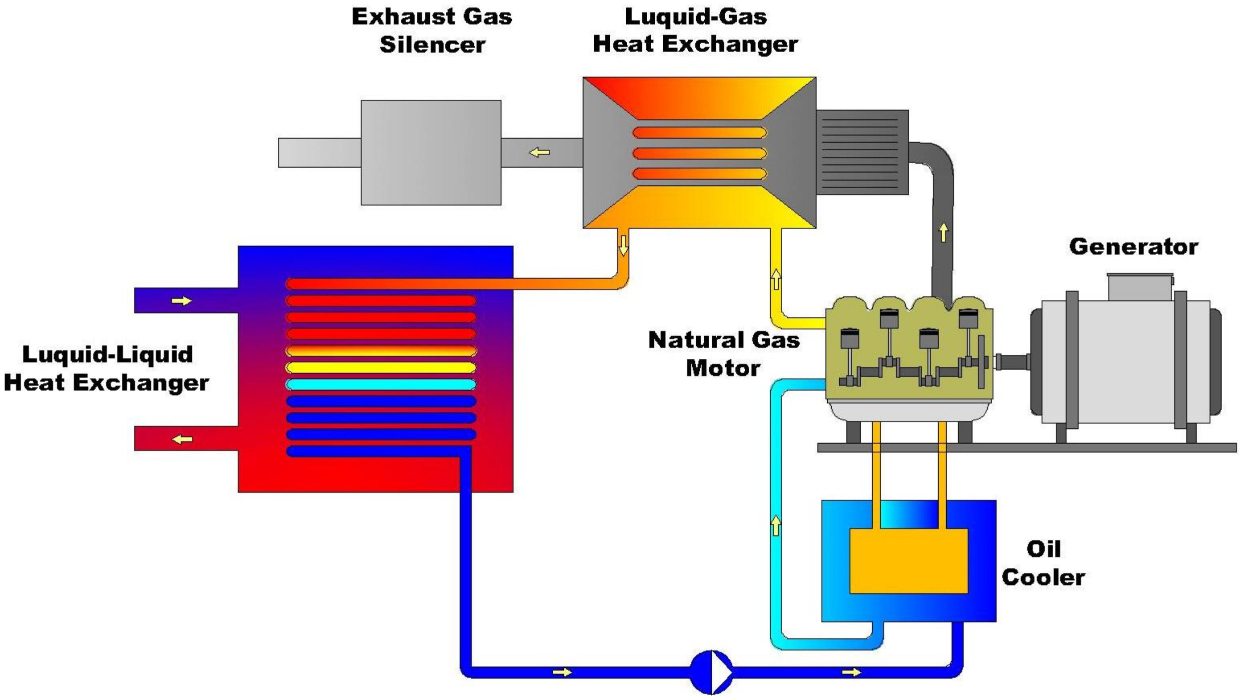


Fig. 3.1 – CHP Schematic view

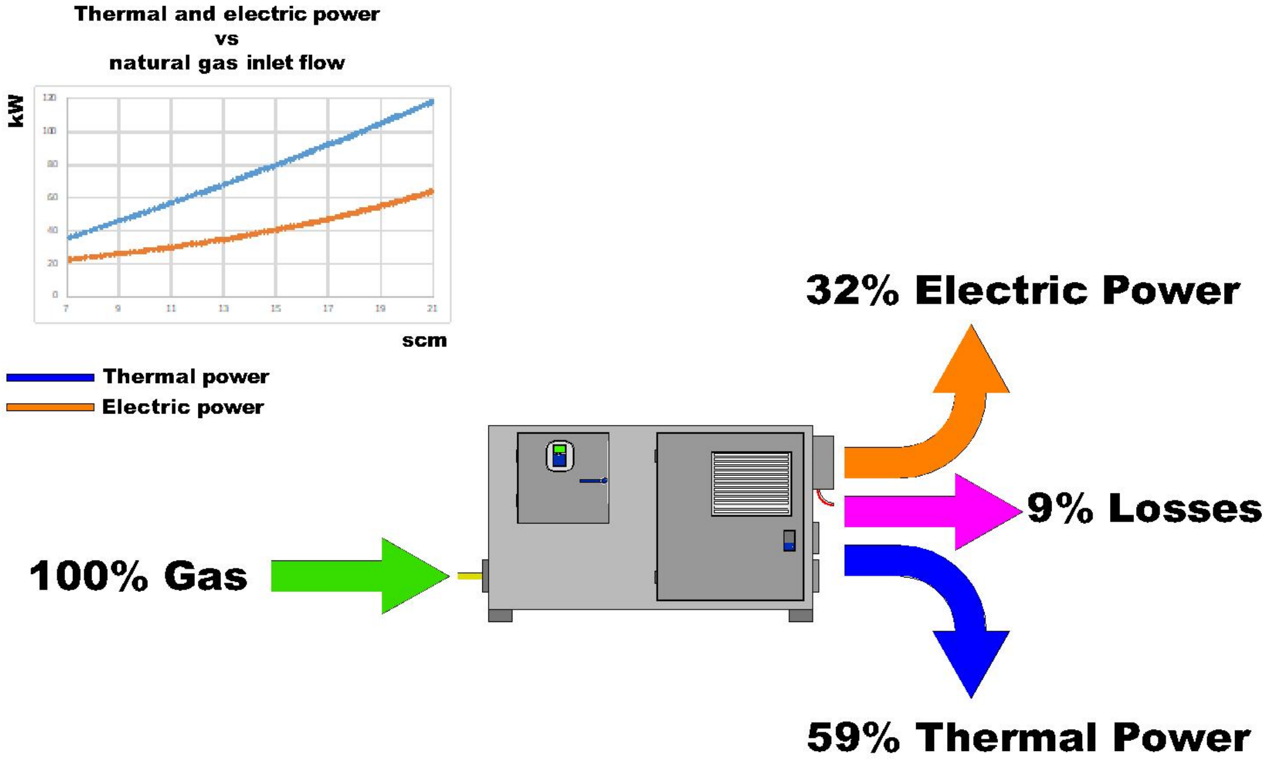


Fig. 3.2 – CHP technical performances

Annex 4

Example of maintenance plan of CHP system based on natural gas fueled motor

Table 4.1 – Maintenance Plan of a CHP system based on natural gas fueled motor

Operazioni	Ore funzionamento					
	100 h	1000 h	3000 h	6000 h	30000 h	60000 h
Controllo visivo (Utente)	x	x	x	x	x	x
Prova di funzionamento (Utente)	x	x	x	x	x	x
Verifica livello olio (Utente)	x	x	x	x	x	x
Controllo tenuta circuiti (Utente)	x	x	x	x	x	x
Verifica rumorosità e assenza vibrazioni motore (Utente)	x	x	x	x	x	x
Controllo visivo esterno Unità e relativo quadro elettrico (Utente)	x	x	x	x	x	x
Verifica ed eventuale registrazione gioco valvole			x	x	x	x
Sostituzione candele			x	x	x	x
Verifica valvola sfiato carter motore			x	x	x	x
Sostituzione olio e filtro motore			x	x	x	x
Controllo e registrazione parametri di funzionamento			x	x	x	x
Verifica fasatura accensione			x	x	x	x
Pulizia/sostituzione filtro aria			x	x	x	x
Controllo pacco batterie			x	x	x	x
Verifica e impostazione regolatore giri motore			x	x	x	x
Controllo regolazione, protezioni, sequenza di arresto			x	x	x	x
Verifica condotto scarico fumi (tenuta, contropressione)			x	x	x	x
Controllo cavo accensione ed evt. sostituzione			x	x	x	x
Verifica e pulizia collettore scarico fumi e scambiatore				x	x	x
Controllo e evt. sostituzione scambiatori (acqua, olio)			x	x	x	x
Verifica e evt. sostituzione bobine accensione				x	x	x
Controllo e evt. sostituzione teste cilindri					x	x
Pulizia camere di combustione, verifica canne cilindri					x	x
Controllo e evt. sotituzione tubi e fascette acqua					x	x
Verifica e pulizia rampa gas			x	x	x	x
Controllo e evt. sostituzione pignone e corona motorino avviamento					x	x
Controllo supporti motore			x	x	x	x
Pulizia e ripristino sigillatura scambiatore olio					x	x
Verifica supporti bilanceri, evt. sostituzione bilanceri			x	x	x	x
Misura emissioni nei fumi						x
Controllo sensore giri, accensione, regolatore elettronico						x
Smontaggio, verifica e evt. sostituzione pistoni						x
Verifica e evt. sostituzione canne cilindri						x
Controllo e evt. sostituzione cuscinetti biella						x
Verifica, pulizia e evt. sostituzione pompa acqua						x
Controllo, pulizia e evt. sostituzione valvola pressione olio						x
Verifica tenuta guarnizioni e allineamento albero a gomiti			x	x	x	x
Sostituzione cuscinetti di banco						x
Controllo, pulizia e evt. sostituzione albero a camme e aste						x
Sostituzione pompa olio						x
Sostituzione silent block motore				x		x
Revisione generale motore e generatore						x
Verifica e pulizia quadro di distribuzione			x	x	x	x

Source: Paradigma Italia srl (http://www.paradigmaitalia.it/impianti-di-cocogenerazione)