Click here to return to Contents Page

CCT 2005
Second International Conference on Clean Coal Technologies for our Future
10-12 May 2005 • Castiadas (Cagliari), Sardinia, Italy • www.cct2005.it

Co-combustion of coal and Sulcis municipal solid waste in a circulating fluidized bed combustor

Carlo Amorino, Giovanni Raggio, Alessandra Madeddu, Giorgio Cau, Thomas Zotter, Thomas Ortner

Co-combustion of Coal and Sulcis Municipal Solid Waste in a Circulating Fluidized Bed Combustor

Carlo Amorino, Giovanni Raggio, Alessandra Madeddu
Sotacarbo SpA

Giorgio Cau
University of Cagliari, Department of Mechanical Engineering

Thomas Zotter, Thomas Ortner
Austrian Energy and Environment AG

Abstract

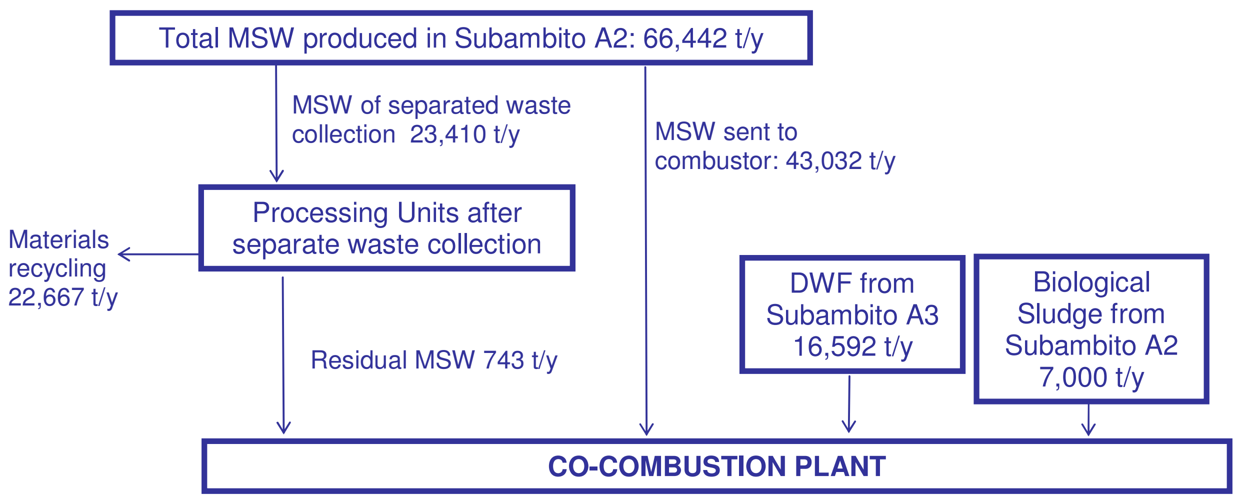
The Provincial Waste Management plan, drawn up by Cagliari's Provincial Authorities envisages for the Sulcis Iglesiente region (Subambito A2) the construction of a waste incinerator for disposing of the 43,775 tonnes of refuse generated each year in the catchment area.
Sotacarbo, Sondel and Austrian Energy and Environment AG have completed a joint project for the design of a waste to-energy facility with a 12 MWe installed electric generating capacity.
The plant is based on the technology developed by Austrian Energy and Environment AG for co-firing Municipal Solid Waste (MSW) and coal in a circulating fluidized bed (CFB).
The project was financed by the European Commission within the Thermie Program and the facility designed in compliance with Italian emission standards and the indications prescribed in the MSW management plans drawn up by the Sardinia Government and the Provincial Authorities of Cagliari.
The proposed plant is intended to contribute effectively to solving the problem of waste disposal in the Sulcis-Iglesiente area, burning coal and producing low CO_2 emissions.

Keywords: MSW, Coal, Incineration, Co-Combustion, CFB.

1. Introduction

The Waste Management Plan for the Province of Cagliari [1] estimates total Municipal Solid Waste (MSW) production in the Sulcis Iglesiente Area (Subambito A2) at 66,442 t/y.
As shown in Figure 1, 35% of this waste, amounting to some 23,410 t/y is processed after separate waste collection for materials recycling (paper, glass, metals, plastics materials and organic materials). The remaining stream of around 43,032 t/y passes to the incineration plant along with the approximately 743 t/y of residual MSW from processing the separated materials.
The Provincial Plan envisages an additional 16,592 t/y of Dry Waste Fraction (DWF), retrieved from Subambito A3 to be delivered to the plant.
Based on the indications contained in the Regional Waste Management Plan [2] the plant should be able to burn the biological sludge coming from domestic wastewater treatment plants of the Sulcis Iglesiente area, amounting to about 7,000 t/y.

Figure 1. Amount of waste to be supplied to the waste-to-energy facility according to the Regional & Provincial MSW management Plans [1] [2]



Sotacarbo together with the Departments of Mechanical and Chemical Engineering at Cagliari University, conducted a feasibility study for the design and operation of a plant for the co-combustion of MSW and coal with electricity generation.

The feasibility study resulted in:

- ⇒ the choice of the fluidized bed combustion technology as the most suitable for co-incinerating the MSW produced in the Sulcis-Iglesiente region with coal.
- ⇒ identification of an optimum capacity of 12 MWe for the required scale economies so to ensure proper management of the facility.

The design of the waste-to-energy plant was funded by the European Commission within the Thermie Program (contract N° SF/003/98).

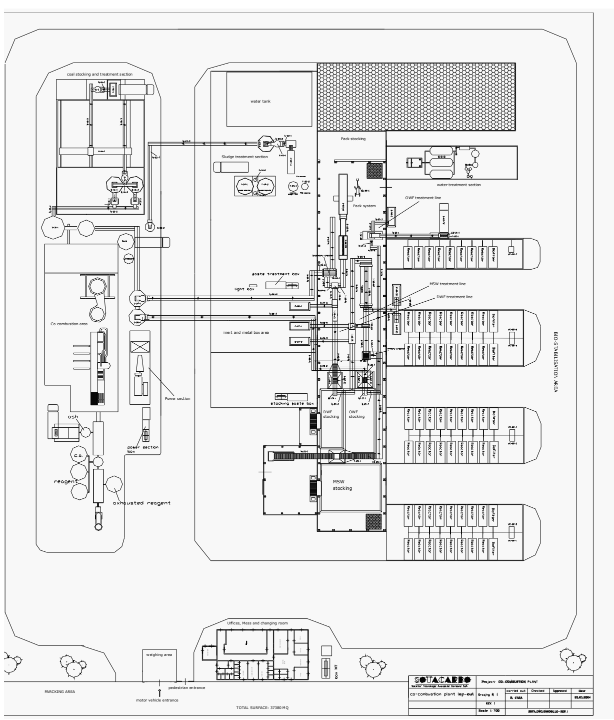
The proposal was presented by:

- ⇒ Sotacarbo SpA;company of the Sardinian Government and Enea engaged in the development of advanced technologies for coal use;
- ⇒ AEE- Austrian Energy & Environment AG; proprietor of the co-combustion technology;
- ⇒ Sondel-Società Nordelettrica SpA; company of the Falck Group.

The proposed 12 MWe plant is based on co-combustion technology of coal and waste in a CFB combustor which is able to dispose of the waste produced in the Sulcis Iglesiente area in compliance with the MSW management plans of the Sardinian Government and Provincial Authorities of Cagliari.

Total investments for construction of the plant, whose design was completed in June 2004, is estimated to be of the order of 50 €/Mln, including the initial period of demonstration operation.

Figure 2. Plant Lay Out



2. Plant sizing

The total amount of MSW to be delivered to the plant has been calculated using:

- ⇒ the 2003 - 2009 projections developed by Cagliari Provincial Authorities, for the Sulcis-Iglesiente region reported in the ‘Provincial Waste Management Plan for the Province of Cagliari’ (PP) [1]

⇒ the “Regional Waste Management Plan” (RP), drawn up by the Sardinian Regional Government in September 1998 [2].

Following these guidelines [1] [2], the plant has been designed taking into account :

⇒ the residual waste from Subambito A2 (Sulcis Iglesiente), after separate collection and materials recovery (43,775 t/y anno)

⇒ the DWF from the Subambito A3 (“Medio Campidano” area) amounting to 16,592 t/year;

⇒ 7,000 t/y of biological sludge produced by waste water treatment facilities in the Sulcis Iglesiente area;

⇒ the municipal-like solid waste estimated to account for 20% of total waste generated;

⇒ the maximum design capacity allows for a safety margin of 30%, on an annual basis, of the total throughput of waste.

⇒ An additional safety margin of 10% has been allowed for in design calculations.

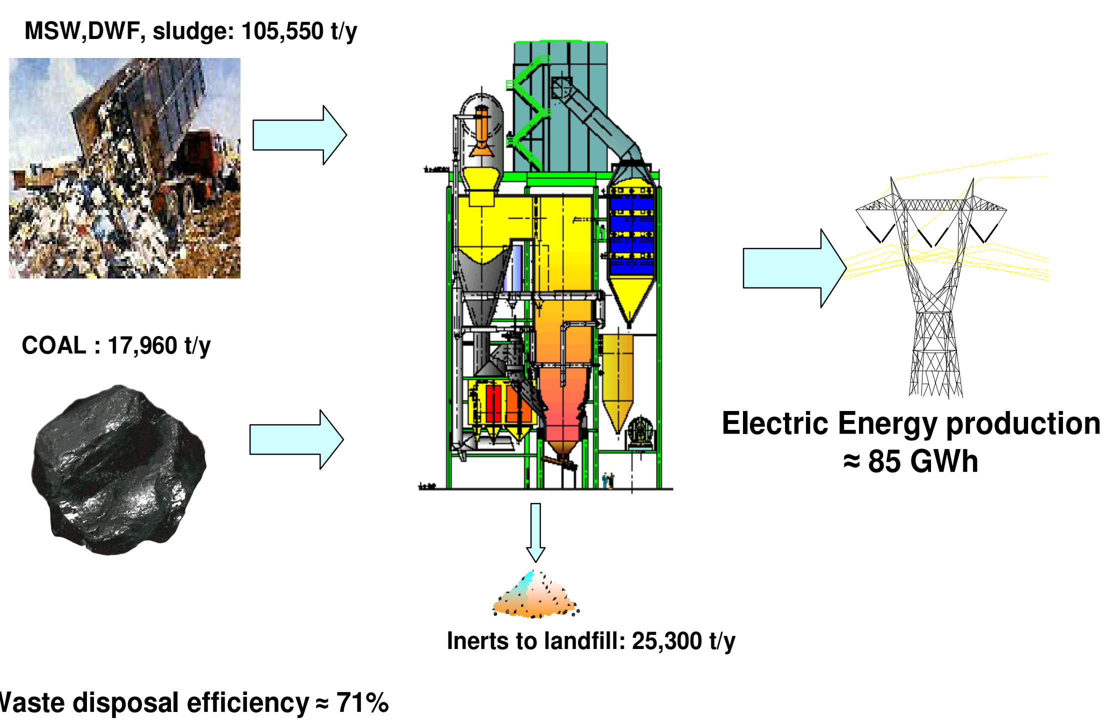
Based on the above tonnages, the plant has been sized to handle the following quantities each day :

⇒ MSW from subambito A2: 196 t/d;

⇒ DWF from subambito A3: 74 t/d;

⇒ Biological sludge from subambito A2: 19 t/d.

Figure 3. Plant Mass Balance and Energy Production (Design Data)



3.Integration strategy

The main sections of the co-combustion plant consist of:

⇒ fuel treatment units;
⇒ CFB co-combustion section;
⇒ flue gas treatment unit.

The strategy adopted for integrating the different plant sections is based on the assumption that a municipal waste disposal service will be provided also during the scheduled shut-down of the boiler calculated as 21 days /year.

To guarantee uninterrupted disposal of the waste delivered to the plant, it has been designed to operate 8760 hours annually.

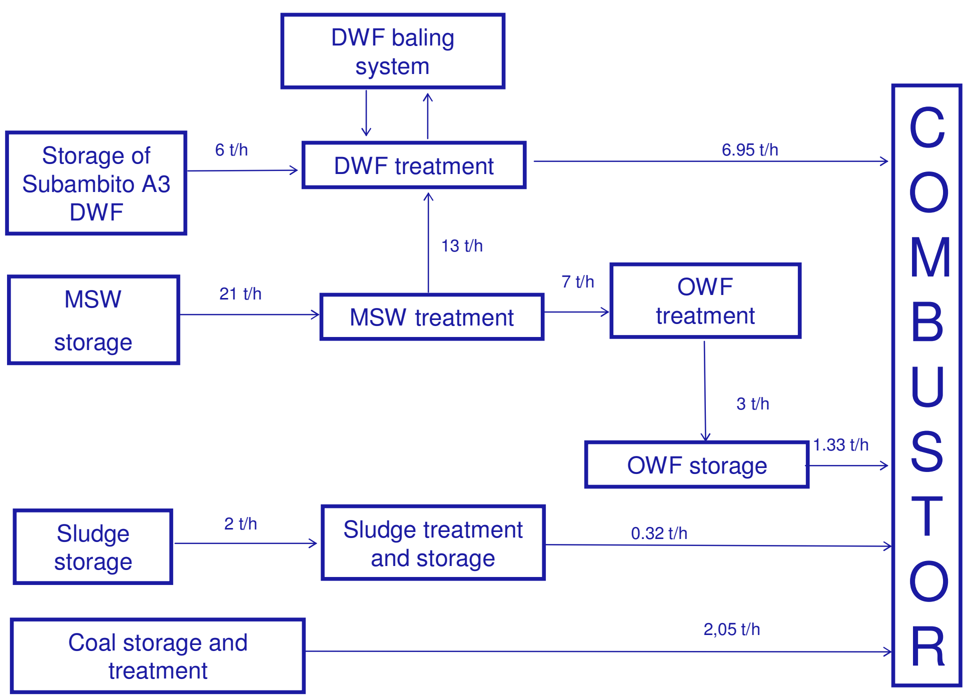
During shutdown for boiler maintenance, the dry fraction leaving the treatment line is sent to the temporary storage section. When operation is resumed it is retrieved and disposed of gradually in the boiler, along with the stabilized organic fraction.

3.1 Fuel Treatment Units

This treatment section comprises:

⇒ MSW treatment unit;
⇒ Biological Sludge treatment unit;
⇒ Coal treatment unit.

Figure 4. Block Diagram of the Treatment Units.



The aim of the MSW treatment unit is to mechanically separate the DWF from the organic waste fraction (OWF) contained in the mixed MSW.
The MSW is sent to a primary crusher where the waste bags are opened leaving the waste more or less intact. Afterwards a magnetic separator eliminates the ferrous metals contained in the stream.
The DWF is separated from the OWF by means of a "trommel" screen.
While OWF is sent to a drying, bio-stabilisation and refining unit in order to obtain a fuel for burning in the fluidized bed combustor, the DWF is sent to the DWF treatment unit along with the DWF from the "Medio Campidano".
The remaining metals and inert materials contained in the DWF stream are removed using an inert separator. The DWF then passes to a secondary crusher where it undergoes reduction to the size required by the fluidized bed co-combustion process.
The unit is also equipped with a waste packing unit where the DWF is compacted into bales and encapsulated in a polythene film. This unit fulfils regional programming requirements regarding incineration plant availability. It includes a bale storage section that in normal operating conditions will be used for compensating differences in waste feed rates between the pre-treatment and co-combustion sections, while during (off-line) scheduled combustor maintenance, it is used for storing the bales until such time as operation is resumed.

The plant also receives the biological sludge from water treatment plants operating in the Sulcis Iglesiente Area. The sludge is dewatered by means of a filter press which reduces the water content from 80% to less than 60% by weight. It then passes along a conveying line into the combustor.

Before passing into the combustor, the coal is crushed in order to obtain the grain size required by the fluidized bed co-combustion process (grain size of 6 mm for the 90% wt; top size about 10 mm).

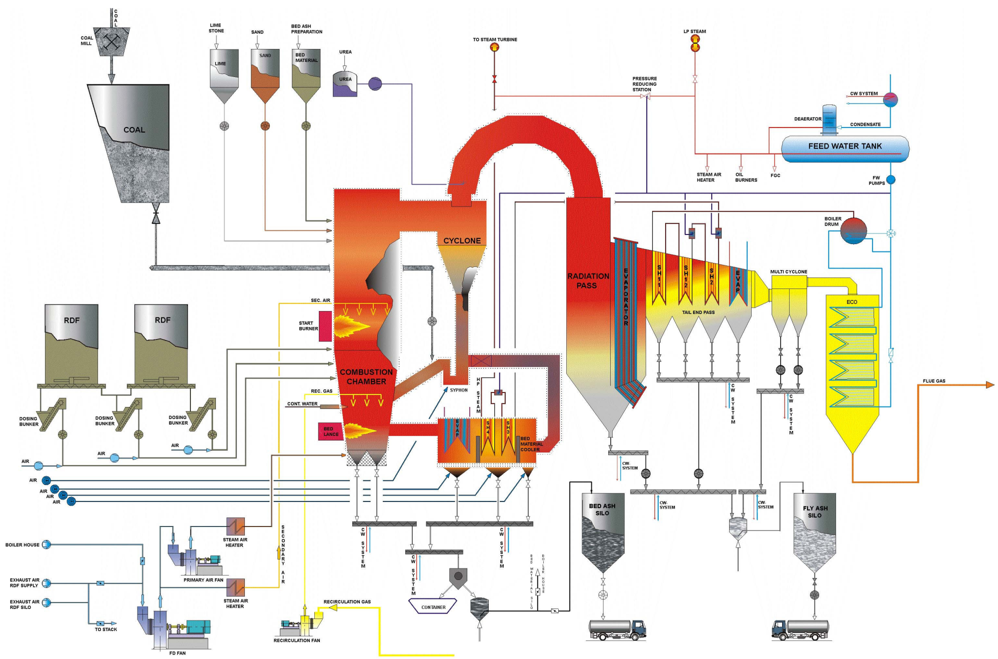
Table 1. Mass Balance of Waste Treatment Units

Input		Design data
MSW delivered to plant	t/year	71,540
DWF delivered to plant	t/year	27,010
Sludge delivered to plant	t/year	7,000
Total	t/year	105,550
Output		
OWF to combustion	t/year	11,616
PTMSW to combustion	t/year	60,871
Dry sludge	t/year	2,772
Wastewater	t/year	15,948
Not fuel materials and other waste	t/year	12,175
Ferrous metals to recovery	t/year	1,769
Non ferrous metals to recovery	t/year	400
Total	t/year	105,550

3.2 Co-combustion section

The atmospheric circulating fluidized bed is based on Austrian Energy & Environment technology, The combustor is designed to produce 52 t/h of superheated steam at 60 bar and 450 °C.
The flow-sheet of the co-combustion unit is shown in the following figure.

Figure 5. Flow-sheet of the co-combustion unit.



DWF and OWF are fed into the combustion chamber by pneumatic injection, coal and sludge are fed separately to the combustor via the recirculation piping of the bed material, downstream from the siphon, thereby assuring optimum distribution of the fuels within the fluidized bed.

The bed is composed primarily of quartz sand,fluidization is assured by injection of both primary combustion air, through the AE nozzle bottom, and secondary combustion air through the riser.
The distribution of the combustion air within the combustion chamber creates staged combustion conditions producing temperatures of between 870 and 880 °C at the outlet.
The strongly expanded fluidized bed and the resulting intensive internal circulation of the bed material in the combustion chamber proper assure a good tie-in even of the light fuel particles in the fluidized bed, sufficiently long residence times and thus satisfactory burn-out in the combustion chamber as well.
Both the low operating temperature and the distribution of the combustion air prevent the formation of thermal NOx in the boiler.
The limestone is fed into the combustor chamber by means of a pneumatic injection system to neutralize the SO_2 (from the fuel) in the flue gas.

The bed material entrained by the flue gas at the riser outlet is separated in a cyclone and recirculated via the siphon to the bottom of the combustion chamber.

The flue gases then pass into the post-combustion chamber. EC regulation 2000/76/EC establishes for flue gases a minimum residence time of two seconds at temperatures of at least 850°C after the last air input is assured.

The downstream heat recovery steam generator has been designed as a natural circulation boiler.
The superheated steam from the CFB Boiler is fed into a turbine connected to an electricity generator producing a gross output of about 12 MWe.

The main performance of the co-combustion unit is summarized in the following table.

Table 2. Austrian Energy and Environment AG Co-Combustion Unit, Process Data

Process Data	**Unit**	**Value**
Thermal output	MW	42.8
Fuel		
MSWPT	t/h	6.95
OWF	t/h	1.33
Sludge	t/h	0.32
Coal	t/h	2.05
Combustor air		
Primary air	Nm^3/h	25,100
Secondary air	Nm^3/h	37,700
Excess air	%	40
Flue gas		
Flue gas dry	Nm^3/h	60,700
Combustion chamber outlet	°C	>850
Steam		
Live steam flow	t/h	52.3
Live steam temperature	°C	450
Live steam pressure	bar	60

3.3 Flue gas treatment unit

The flue gas treatment unit is based on the NEUTREC® process.
The process uses dry sodium bicarbonate and activated carbon for neutralazing SO_2 and HCl and adsorbing the heavy metals contained in the flue gas leaving the co-combustion unit.
Dry scrubbing offers the following advantages:

- ⇒ greater energy efficency;
- ⇒ ease of plant management;
- ⇒ no water consumption.

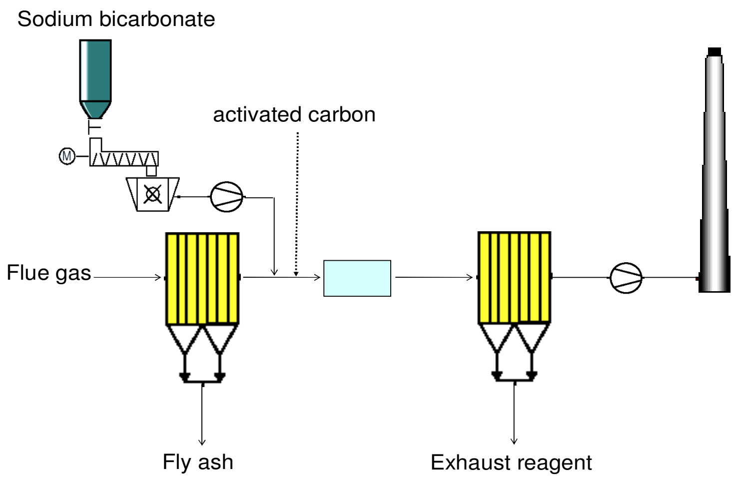
The flue gas exiting the co-combustion unit passes through a bag filter for fly ash capture. The dedusted flue gas is then conveyed to the reactor where the pollutants are removed. The flue gas then passes into a second bag filter for spent reagent and activated carbon removal.

The use of the dual filter system enables at the fly ash and spent reagent to be handled separately. By so doing:

⇒ the fly ash can be landfilled after inertization;

⇒ the spent reagent can be recovered and regenerated by the supplier.

Figure 6. Flow sheet of flue gas treatment.



The NEUTREC®process is widely used in flue gas scrubbing, especially flue gas generated by waste incineration and the treatment assures compliance with the atmospheric emission limits prescribed by 2000/76/CE shown in the following table.

Table 4. Legislative Limits

Emissions		**Legal Limit - Daily average**
Dust	[mg/Nm^3]	10
HCl	[mg/Nm^3]	10
NOx	[mg/Nm^3]	200
HF	[mg/Nm^3]	1
SO2	[mg/Nm^3]	50
		Legal Limit – average values measured during sampling period minimum 30 minutes and maximum 8 hours
Sb,As,Pb,Cr,Co,Cu,Mn,Ni,V	[mg/Nm^3]	0.5
Hg(gas+part)	[mg/Nm^3]	0.05
Cd+Tl(gas+part)	[mg/Nm^3]	0.05
		Legal Limit - average values measured during a sampling period minimum 6 hours and maximum 8 hours
Dioxin/Furan	[$ngTE/Nm^3$]	0.1

In standard conditions : O2 = 11% v/v, T = 273 °K, P = 101,3 kPa; dry gas

4. Capital costs

The investment costs for constructing the WTE facility are estimated to be in the the order of 50 €/Mln.
The following table gives a percentage breakdown of investment costs.

Table 5. Breakdown of investment costs (%).

Cost type	Percentage
Design and studies	4%
Site acquisition and construction work	7%
Treatment units	23%
Co-combustion unit	35%
Power plant system	19%
B.O.P.	4%
Other costs	8%
Total	**100%**

5. Conclusions

The waste-to-energy facility described here, which has been designed for the co-combustion of MSW and coal, offers an attractive solution to the problem of MSW disposal in the Sulcis Iglesiente, fulfilling the prescriptions established by the Sardinian Government and the Provincial Authority of Cagliari.
In particular the waste plant, which has been sized to meet MSW waste disposal requirements in the Sulcis Iglesiente region (optimum Subambito A2), in line with the indications set forth in the Regional and Provincial Waste Management Plans of the various disposal options envisaged in the plans, combines waste disposal with energy recovery.

The use of a circulating fluidized bed combustor, a widely tested technology, will enable the co-combustion of waste and coal, using the latter as thermal flywheel and to accommodate seasonal variations in waste generation and composition.
In this way the facility will be able to meet the operating reliability and flexibility criteria set forth in the regional waste management plans. It will also be able to guarantee interrupted disposal of waste during shutdown for boiler maintenance and will provide high operating flexibility, being to accommodate variations in the quantity and composition of waste.
Lastly, the plant will deliver the on-site electricity generated to the national power grid in accordance with the prescriptions of the regulations concerning the supply of electricity generated from renewable sources.

References

[1] Provincia di Cagliari - Piano provinciale di gestione dei rifiuti, Stralcio funzionale e tematico gestione rifiuti urbani, Giugno 2001,
[2] Regione Autonoma della Sardegna - Piano Regionale di Gestione dei rifiuti Urbani, documento preliminare luglio 1998,
[3] M, Ekemann, Scott Smouse, J, Winslow, Massood Ramezan, Stanley Harding –Cofiring of coal and waste- IEA Coal Research, IEACR/90, 1996.