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# Demonstration plant of co-combustion of coal and on site pretreated waste in a fluidised bed for electricity production

*C Amorino, A Madeddu, G Raggio, G Cau, T Zotter*

CCT 2002

# Demonstration plant of co-combustion of coal and on site pretreated waste in a fluidised bed for electricity production

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## 1. Introduction

This paper deals with a project for the realization of a Municipal Solid Waste (MSW) incineration plant, located in Sardinia, "Sulcis Iglesiente" area. The plant will allow the production of electrical energy for a net power of around 11 MWe by means of the co-combustion of coal and pre-treated MSW in an atmospheric circulating fluidised bed (CFB) combustor. The project aims to contribute effectively to the solution of "Sulcis Iglesiente" waste disposal problems and at the same time to permit the use of coal with lower CO2 emissions (**Attach. 1).**

The co-combustion plant will be equipped with an ad-hoc system for the treatment of solid, liquid and gaseous residues. It will be integrated with a high efficiency thermal cycle using steam with higher temperature and pressure characteristics compared to the conventional MSW recovery system.

At present the project is in progress, its activities have been financed by the European Community through the Thermie contract N° SF/ 003/ 98. The proposal has been presented by Sotacarbo SpA, coordinator of the project, together with AEE- Austrian Energy& Energietchnik GmbH, owner of the CFB combustion process and by Sondel-Società Nordelettrica SpA, a private producer of electrical energy (**Attach. 2).**

## 2. Legislative setting of the initiative

This project is set in:

- the national legislation on the liberalization of the internal electricity market ("Bersani Decree" D.Lgs. n. 79 of 16th April 1999) and Ministerial Decree of 11th November 1999 on the renewable source.
- the national legislation on the technical characteristics of disposal system and the relative emission limits ( "Ronchi Decree", D.Lgs. n. 22 of 5th February 1997 and DM of 5th February 1998).
- the regional and provincial planning on Municipal Solid Waste management (MSW management Regional and Provincial Plans).

## 3. "Sulcis Iglesiente" waste disposal demand

The project aims to create an incineration plant able to satisfy the "Sulcis Iglesiente" (so called "Subambito A2") MSW disposal demand. This plant will produce electrical energy and it will be designed in accordance with the indications of the MSW management Regional & Provincial Plan. The waste to be treated by the plant are in summary show in following table.

| | |
|---|---|
| Municipal Refuse Total Amount of "Subambito A"" (t/year) | 66.000 |
| Waste from Differential harvest (t/year) | 22.000 |
| MSW from "Subambito A2" (t/year) | 44.000 |
| Dry Waste Fraction from "Subambito A3" (t/year) | 17.000 |
| **Total Waste to be disposed (t/year)** | **61.000** |

I. With regard to the plant capacity, the above mentioned documents forecast that:
   - the quantity of waste produced by the "Subambito A2", as forecast for 2003, shall be about 66,400 t/year, around 44,000 t/year of which are destined for the disposal system;
   - about 17,000 t/year of Dry Waste Fraction (DWF) from the "Subambito A3" ("Medio Campidano" area) will go to the disposal system that is planned in the "Subambito A2". This last quantity, added to the 44,000 t/ year of the previous point, determines an amount of around 61,000 t/year of waste that can be send to the disposal plant;
   - the plant capacity will be more than 61,000 t/year because the Assimilate Municipal Waste will be included, in accordance with the requirements of the MSW management Provincial Plan.

   Therefore the plant has been sized for disposing of about 105,000 t/year of MSW. Such a quantity is higher than the above mentioned one because it takes into account the assimilated municipal waste (20%), a safety range (30%) on the annual waste production (as required by the Regional Plan), the waste production variations during the year and finally the quantity of biological sludge from water treatment plants located in the "Sulcis Iglesiente" area.

II. As far as the integration of the MSW pre-treatment unit in the co-combustion plant is concerned, the Provincial Plan confirms that "this option is a plant management choice in order to minimise the amount of residues to be send to landfill."

III Finally, regarding future plant construction, the Consortium for the "Sulcis Iglesiente" Nucleus of Industrialization (CNISI) (the consortium suitable for regional planning, construction and management of the waste incineration plant), has shown an interest in the co-combustion technology. Therefore CNISI commissioned a feasibility study of the waste incineration plant to the University of Cagliari. This study confirmed the suitability of co-combustion technology for waste disposal in the Sulcis Iglesiente. After this confirmation, CNISI proposed the construction of such plant to the "Provincia di Cagliari". This proposal was included in the Provincial Plan, stating that CNISI's project was of particular interest.

## 4. Development of co-combustion technology

Design activities began with a feasibility study that Sotacarbo carried out with the Departments of Mechanical and Chemical Engineering of Cagliari University.
This study resulted in:

a. **fluid bed combustion technology** as the most suitable for incinerating waste in combination with coal. Such a choice is mainly based on:
   - low environmental impact;
   - higher electrical energy efficiency compared to that of conventional systems. This higher efficiency is due to the intrinsic characteristics of CFB technology, which makes it possible to obtain values of 25-28% compared with 15-18% of the waste burning conventional systems;
   - high plant operational flexibility, allowing compensation for the waste seasonal variations (qualitative and quantitative);
   - the chance to comfortably incinerate municipal solid waste produced from a relatively restricted area. This fact would permit new applications of the technology in Italy and/or in overseas;

b. **the advantage of using Pre-Treated MSW** (MSWPT- in the meaning of the least treatment allowed by legislation) as combustor feed instead of RDF (Refuse Derived Fuel).
   The former offers:
   - lower investment and operating costs;
   - a more effective contribution to the solution of waste disposal. Because of its low treatment efficiency, RDF production generates a significant quantity of residues destined to landfill. As a consequence it does not make much contribution to the reduction of landfill volumes.

On the basis of such evaluations, Sotacarbo, Austrian Energy Energietechnick (AEE) and Sondel - Società Nordelettrica presented a financing proposal to the European Commission in the framework of the Thermie program. The plant design activities started with the contract N° SF/ 003/ 98.

## 5. Plant Site

The co-combustion plant will be located in "Sulcis Iglesiente" area, in the south- west of Sardinia (**Attach. 3)**. CNISI selected the area of "Barega" in the territory of "Carbonia", at the boundary with the territories of "Iglesias" and "Gonnesa".
The site is near the closed barite mine of Bario Sarda company, it is in a central part of the "Sulcis Iglesiente" territory and it is linked to the provincial "Villamassargia- S.G. Suergiu" road, by a secondary road which leads to the mine. (**Attach. 4)**

CNISI has already carried out a geological and hydrogeological study in the "Barega" area. The environmental regional department has already declared this site suitable for a MSW landfill construction. These evaluations will be integrated in order to obtain from the "Provincia di Cagliari" the declaration of site suitability for plant construction.

With this declaration, the plant layout will be upgraded and the plant design will be completed. There is a preliminary plant lay-out in **Attach. 5**.

## 6. General description of the plant

The plant will be made up of three main sections: the treatment of the wastes and coal, the co-combustion section (with ashes treatment and flue gas clean up units) and the power generation plant section (**Attach. 6**).

The plant design conditions use three kind of fuels fed to the co-combustion plant:

1. **Municipal Solid Waste (MSW)** ***and assimilates*** for a total amount of 98,500 tons/year, made up of:
    - for around 73% by MSW from the 25 towns of "Sulcis Iglesiente" ("Subambito A2").
    - for around 27% by Dry Waste Fraction (DWF) from the "Subambito A3" ("Medio Campidano" area)
2. ***Biological Sludge*** from the water treatment plants of "Sulcis Iglesiente" area, up to a maximum of around 7,000 t/ year.
3. ***Coal*** *for a maximum rate of around 26,000 tons/year.*

### *6.1 Coal and Refusals treatment section*

The treatment plant is sized to be fed with a maximum rate of about 270 t/ d of waste.
Firstly, the bulky materials are separated from municipal solid waste (MSW). The latter are sent to the primary crusher where the waste bags are torn up (**Attach. 7).** Subsequently the metals and non metal materials are eliminated by magnetic and induction separators. Then the wastes are sent to the mechanical selection where a "trommel" separate the Dry Waste Fraction (DWF) and the Organic Waste Fraction (OWF). While this latter is fed to a drying, bio-stabilisation and refining unit in order to obtain a fuel to be burned in the fluidised bed combustor, the DWF is mixed together with the Dry Waste Fraction from the "Medio Campidano" and sent to an inert separation unit in order to eliminate the remaining metal and inert materials.
After that the DWF mixture is sent to a secondary crusher suitable to obtain the grain size required by the fluidised bed co-combustion process.

The pre-treatment section is equipped with a waste packing unit where the DWF is manufactured as compressed bales enveloped by a polythene film. This unit concords with the regional planning requirements on incineration plant availability. It includes a bale storage section that in normal operational conditions will be used for compensating differences in the waste rates between the pre-treatment and co-combustion sections; while in the case of the combustor (off-line) programmed maintenance, it is used for storing the waste bales until restarting.

The pre-treatment section also receives the biological sludge from water treatment plants operating in the "Sulcis Iglesiente" area. The sludge is dried in a suitable unit and then sent to the combustor. At the moment we are in the process of selecting commercial drying equipments.

In this section there is also a coal storage and treatment unit (Sulcis and/or commercial). The coal, with grain size of 40- 50 mm, is first weighed and then transported by truck to covered storage, from here it moves by belt conveyor to hammer mill where the grain size is reduced to around 12 mm. Then, the ground coal is stored in two silos from which it is sent (by bucket elevator) to the combustor feeding system.

The main data on the treatment section mass balance are summarised in the following table, allowing a comparison between the MSW quantities projected in the Provincial Plan and those considered in the pre-treatment plant design.

**Waste Pretreatment Section Data**

| **Input** | | **Provincial Plan** | **Design** |
|---|---|---|---|
| MSW from Subambito A2 | t/year | 43.800 | 71.540 |
| DWF from Subambito A3 | t/year | 17.177 | 27.010 |
| Sludge | t/year | 7.000 | 7.000 |
| ***Total Input*** | **t/year** | **67.977** | ***105.550*** |
| **Output** | | | |
| PT-MSW (Pretreated MSW) | t/year | 37.800 | 60.871 |
| DOWF (Dry Organic Waste Fraction) | t/year | 7.112 | 11.616 |
| Dry sludge to combustion | t/year | 2.772 | 2.772 |
| ***Recoverd Fuel*** | ***t/year*** | ***47.684*** | ***75.259*** |
| Waste water & uncombustible materials | t/year | 20.293 | 30.291 |
| ***Total Output*** | ***t/year*** | ***67.977*** | ***105.550*** |

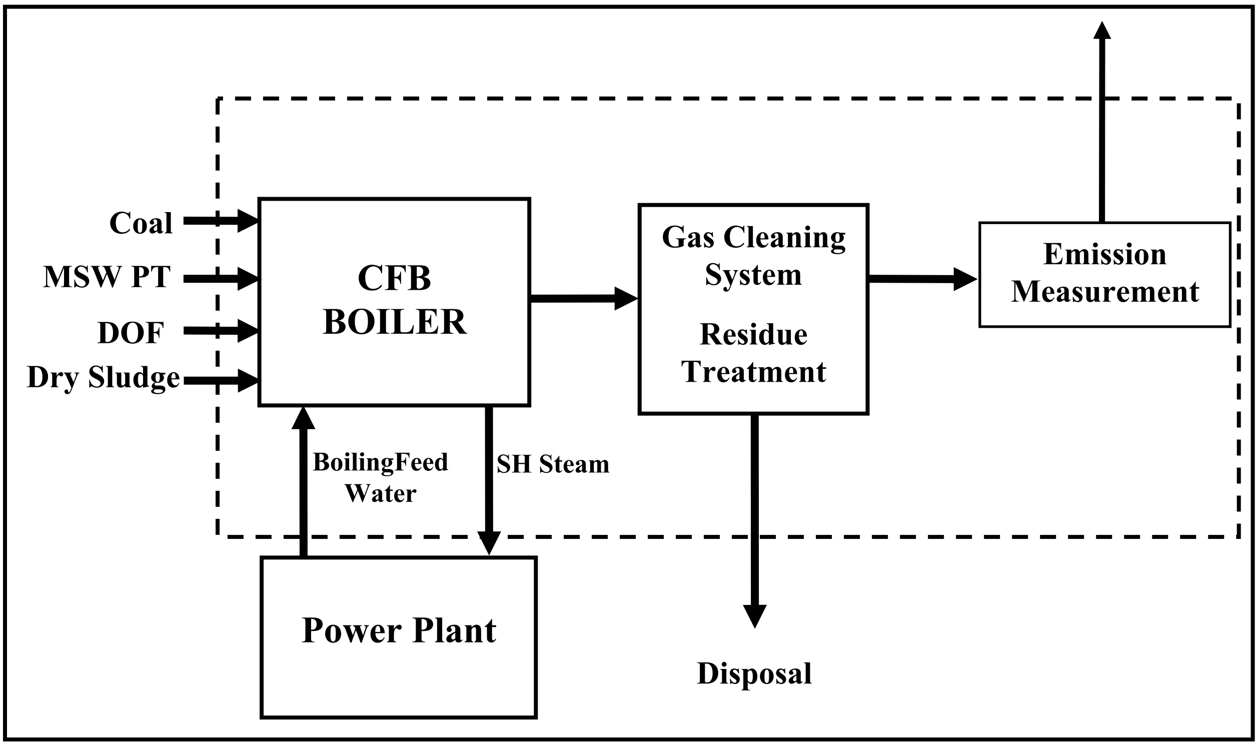
The expected total waste recovery is between 65 and 70%.

### *6.2 Co-Combustion Section*

In this section the pre-treated municipal solid waste (MSWPT), the dry organic fraction (DOF) and the biological sludge are fed to the co-combustion process together with the coal.

The Co-combustion section is made up of the following main components: CFB boiler, ashes treatment plant and flue gas cleanup unit (see the following scheme). The thermal

energy developed in the combustion process is utilised for producing superheated steam to be sent to a turbine for electrical energy production.
The flue gas from the combustion process is cleaned and analysed before being sent to the stack. The solid residues (ashes) from the combustion and gas cleaning process are sent to an inertisation unit before to be sent to landfill.




**Arrangement of Co-Combustion Section**

The main data on the co-combustion section mass balance can be seen in the table below.

| **Input** | | **Design** |
|---|---|---|
| PTMSW to combustion | t/year | 60.871 |
| DOWF | t/year | 11.616 |
| Dry sludge to combustion | t/year | 2.772 |
| Coal | t/year | 17.706 |
| Sorbent | t/year | 881 |
| Additives (gas cleaning) | t/year | 2100 |
| Air | t/year | 641.630 |
| **Total** | **t/year** | **737.575** |
| **Output** | | |
| Bottom ash | t/year | 5.615 |
| Fly ash (+ spent additives) | t/year | 10.522 |
| Flue Gas | t/year | 721.439 |
| **Total** | **t/year** | **737.575** |
| %waste/%coal | %/% | 69%/31% |

### *6.2.1 CFB Boiler*

The combustor will be designed to burn a total variable amount of pre-treated refusals from a minimum of 48,000 t/year to a maximum of around 75,000 t/year. The amount of coal will vary from 31% to 53% (these values are expressed in terms of heating value) in order to have a power production of about 45 MWt.
The combustor will be of an atmospheric circulating fluidised bed (CFB) type supplied by Babcock Borsing Power-Austrian Energy. This combustor is suitable for burning the above mentioned fuels mixtures. The mechanical features and performances of the plant will match the national legislation requirements on environmental protection.
The combustor will be adequately equipped for monitoring combustion operating conditions, gas circulating flows and gas emissions.
Ashes will be stored in a proper silo for their inertization before sending to landfill (**Attach. 8**)

The fuel feeding system will be equipped with instrumentation for the continuous recording of all feeding flows and for their sampling.
Coal and pre-treated waste will be mixed in the combustion chamber, where a sorbent (limestone) will be injected for the sulphur abatement. Sorbent amount depends on the fuel composition. The fuel component proportions in the feeding mix will vary with the waste composition, their seasonal availability and the coal type to be used.

The CFB Boiler is equipped with a heat recovery system for generating superheated steam to be sent to the power section. The steam generator will be able to maintain the same steam characteristics in a load range from 100% to 50% of the maximum continuous load.

The main technical data of the co-combustion plant are summarised in the following table.

| | | |
|---|---|---|
| Fluid bed temperature | °C | 870 - 880 |
| Feed water temperature | °C | 180 |
| Live steam temperature | °C | 450 |
| Superheated steam pressure | bar | 60 |

### *6.3. Power Production section.*

The superheated steam from the CFB Boiler is fed into a turbine connected with an electrical generator for producing electrical energy corresponding to a gross power of about 12.5 MWe
The steam fed to the turbine will have a temperature of 450 °C and a pressure of 60 bars and the electricity produced will be sent to the national electricity.
The main technical data concerning the power section are summarised in the following table.

| | | |
|---|---|---|
| **Pressure of thermal cycle** | **60** | **bar** |
| **Temperature of thermal cycle** | **450** | **°C** |
| **Gross Power** | **12,5** | **MWe** |
| **Net Power** | **≈11** | **MWe** |
| **Net electrical Efficiency** | **25- 28** | **%** |

# 7. Environmental issues

## *7.1 Gas emissions*

The plant will respect the emission limits of Italian legislation on environment for this plant category. A gas cleaning system will allow the reduction of acid gas, heavy metal and dust concentrations in the flue gas.

In particular acid gases will be removed by using a dry system based on sodium bicarbonate process, heavy metals and dioxins are removed by active carbons and dusts by filters.

The gas cleaning plant includes a storage system for chemicals and active carbons, a reactor where sodium bicarbonate and active carbons react with acid gas and a bag filter for removing dust entrainment from flue gas.

Expected environmental data for gas emissions are shown in the following table. They result under the limits of the current national legislation (Ministerial Decree 503/ 97).

| Emissions | | Expected | **Law Limit** |
|---|---|---|---|
| **Dusts** | **[mg/Nm$^3$]** | **6** | **10** |
| **HCl** | **[mg/Nm$^3$]** | **19** | **20** |
| **SO2** | **[mg/Nm$^3$]** | **87** | **100** |
| **HF** | **[mg/Nm$^3$]** | **< 1** | **1** |
| **NOx** | **[mg/Nm$^3$]** | **100-150** | **200** |
| **Sb,As,Pb,Cr,Co,Cu,Mn,Ni,V,Sn** | **[mg/Nm$^3$]** | **<0,5** | **0.5** |
| **Hg(gas+part)** | **[mg/Nm$^3$]** | **< 0,01** | **0.05** |
| **Cd+Tl(gas+part)** | **[mg/Nm$^3$]** | **<0,05** | **0.05** |

**(Ref. Condition: 11% O2, dry)**

## *7.2 Liquid waste*

The liquid emissions will be reduced to practically negligible values and will in any case concur with the Italian legal requirements on environmental protection.

Water deriving from different sections of plant (civil sewers from offices, percolation liquids from the MSW storage, sludge treatment unit, organic waste fraction bio-stabilization and water from floor washing ) is sent to a purification plant where the pollutants (BOD, P and N) are abated by means of physical-chemical and biological treatments.

The objective of this treatment is to get a good quality industrial water to be recycled to the plant (floor washing, fireproof system, green area irrigation). Therefore the liquid waste might be practically reduced to zero.

## *7.3 Solid by-products*

The solid by-products will be mainly made up of the MSW fraction from the treatment plant (metals and inert materials) and the ashes from the co-combustion plant (heavy and fly ashes). While inert materials from the pretreatmet plant can be directly sent to landfill or possibly recycled, ashes have to be inertised using a suitable process, before being sent to landfill.

## 8. Investment Costs

A preliminary evaluation of the plant cost, including the treatment sections, the co-combustor, the power production unit, electric energy transfer system and the Balance of Plant (BOP) is about €35 million.

A preliminary distribution of investment costs between the main plant components is shown in the following table.

| | |
|---|---|
| Pre-treatment Plant Section | 30 % |
| Co-combustion Section | 39 % |
| Power Plant section | 13 % |
| B.O.P. | 18 % |
| Total | 100 % |

## 9. Status of the project

At the present the fuel treatment section design is being finished and the design of the co-combustion section, power production plant and Balance Plant is in progress.
The job program predicts that the plant design activities could be concluded in the first half of 2003. Subsequently the environmental impact study and the plant general design upgrading could be completed in the first semester of 2004.

## 10. Conclusions

The activities carried out so far have allowed to highlight **the most interesting aspects of CFB co-combustion technology**:

- High operational and managerial flexibility, due to the "energy flywheel" function of coal. The calorific input of the feed mix can be kept constant, compensating for qualitative and quantitative variations in the waste. This factor causes greater operational flexibility.
- High combustion efficiency due to the features of the circulating fluidized bed.
- Low CO2 specific emissions in consideration of the limited influence on the green house effect due to use of MSW pre-treated; its contribution would be considered void for the quota of carbon present in the biodegradable wastes.
- Low dioxin and furan emissions due to the contemporary action of the temperature control of the fluidized bed technology and of the coal, which works as a thermal regulator.
- Diversification of the fuel mix.

In conclusion the more important items of the **co-combustion project** could summarise as follw.
The plant:

1. will allow the satisfaction of the disposal demand of MSW produced by the Sulcis Iglesiente area ("Subambito A2"), according to potentiality indications of Regional Plan and Provincial Plan of MSW management;
2. will be equipped with a MWS treatment section;
3. will answer to the national legislation requirements on MSW disposal with energy recovery;

4. will be in accordance with the Regional Plan of MSW management, concerning the incineration plant location in the “Sulcis Iglesiente” area;
5. will be in accordance with the Provincial Plan of MSW management with regard to the choice of co-combustion technology for refuse disposal in the “Subambito A2”;
6. will accepts seasonal variations in the quantity and characteristics of the waste (for the “energy flywheel” function of coal;
7. will use the Circulating Fluidised Bed (CFB) combustion, a tested technology that satisfies the technological reliability request of the Regional Plan;
8. will guarantee the operational reliability and flexibility required by the Regional Plan. Particularly it will guarantee waste disposal also when the combustor is off line for maintenance and it will have a high flexibility for quantitative and qualitative variations of refusals;
9. will send the electrical energy produced to the national electricity net according to the national legislation on the renewable source electricity market (for the biodegradable part of refuse).
10. will take advantage of the green certificates for an eight years period, for the energy fraction derived from the renewable source.

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# CO-COMBUSTION

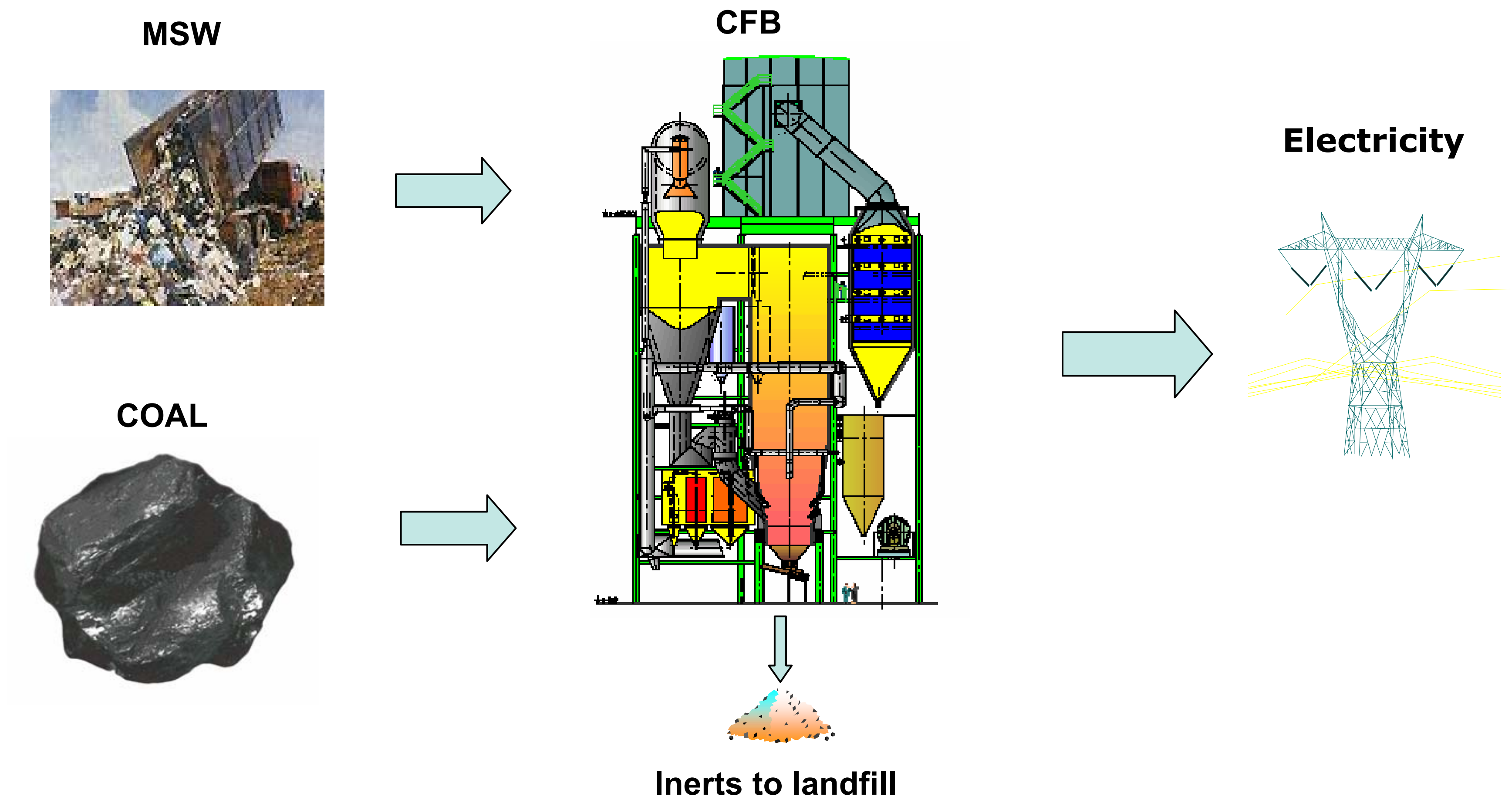


Fig. 1

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# Demonstration plant of co-combustion of coal and on site pre-treated waste in a fluidised bed for electricity production

## THERMIE PROJECT N° 003/98



Fig. 2

# PLANT LOCATION

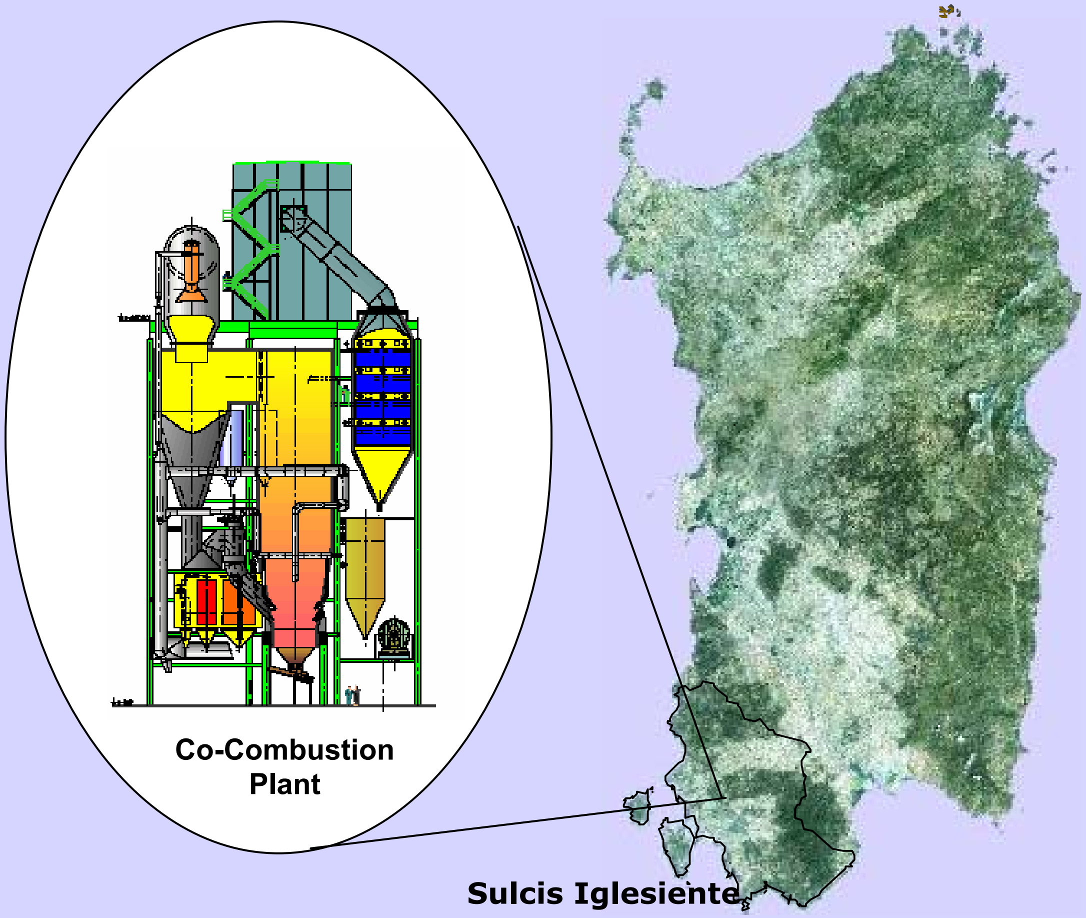
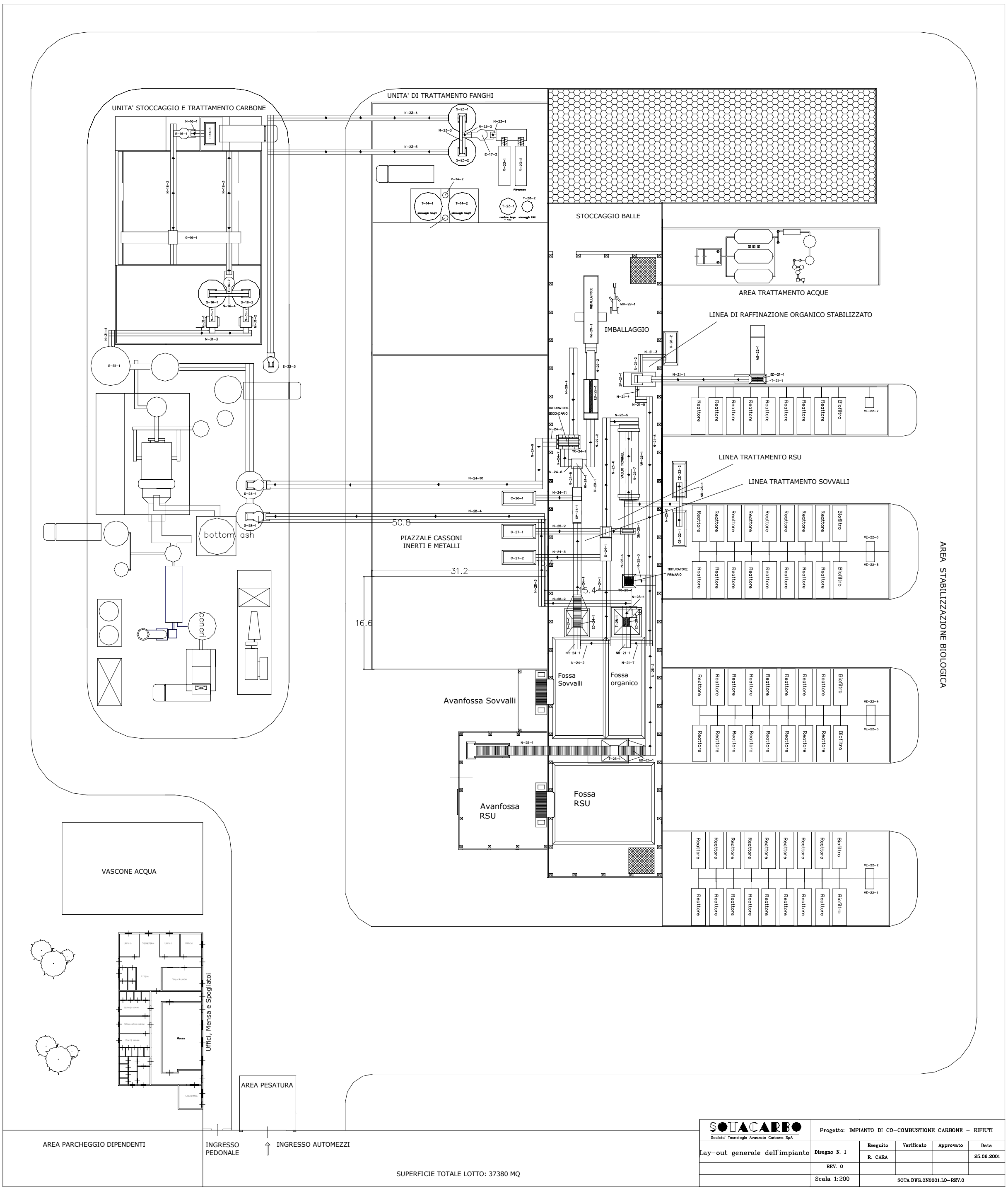



Fig. 3

# PLANT LOCATION


Fig. 4




# Fig. 5 Preliminary Plant lay Out

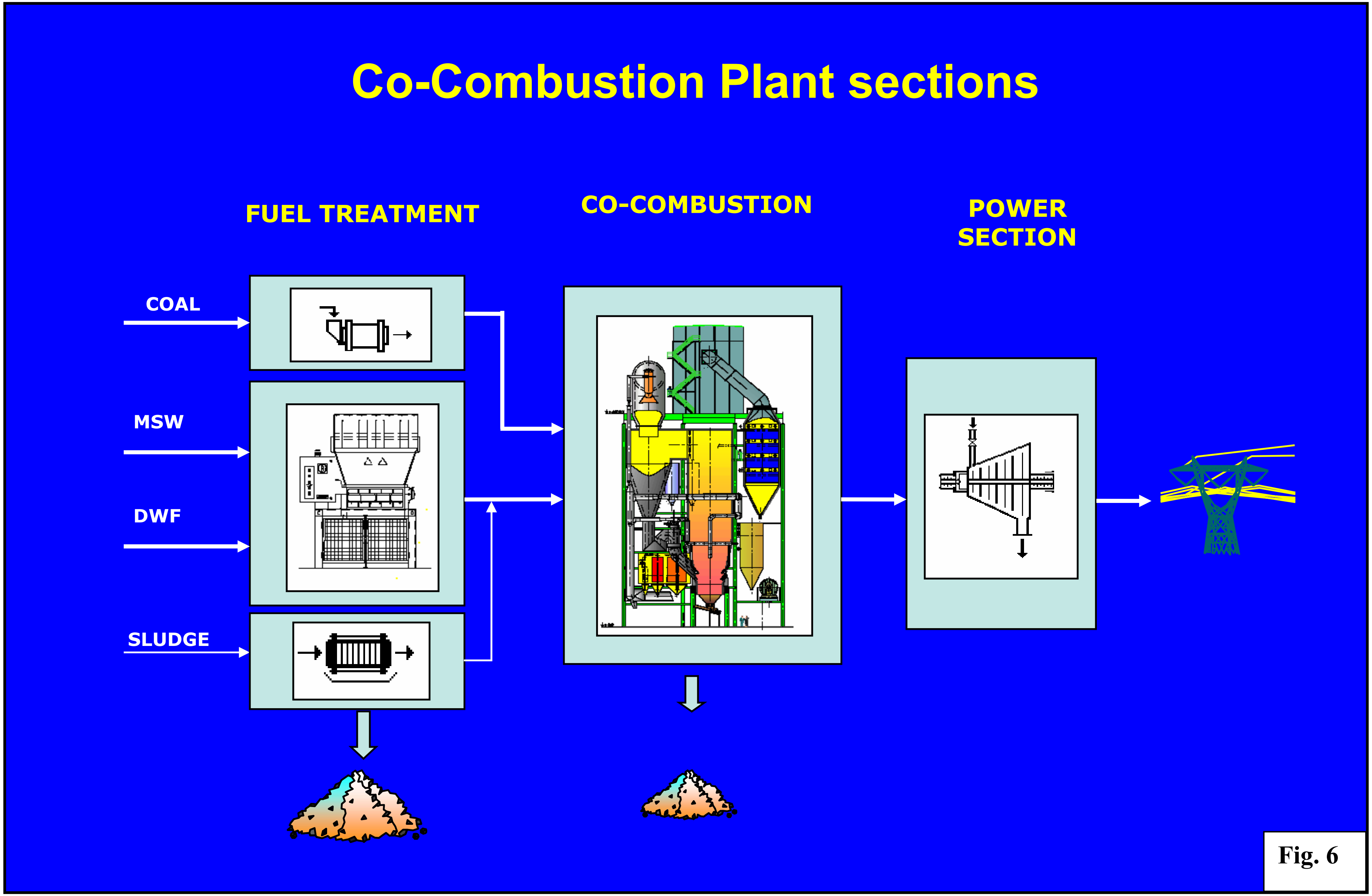

Co-Combustion Plant sections
FUEL TREATMENT
CO-COMBUSTION
POWER SECTION
COAL
MSW
DWF
SLUDGE

Fig. 6

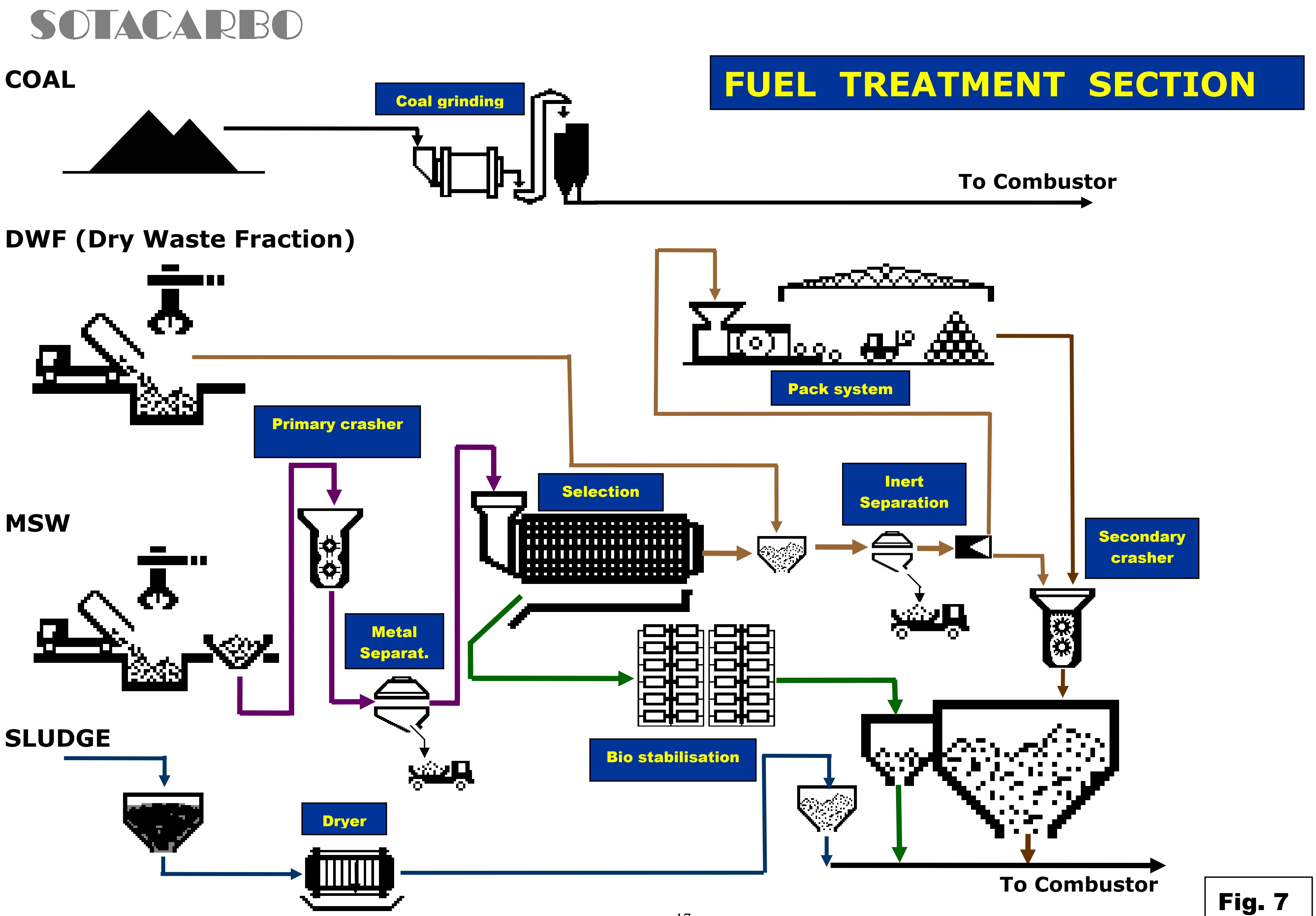
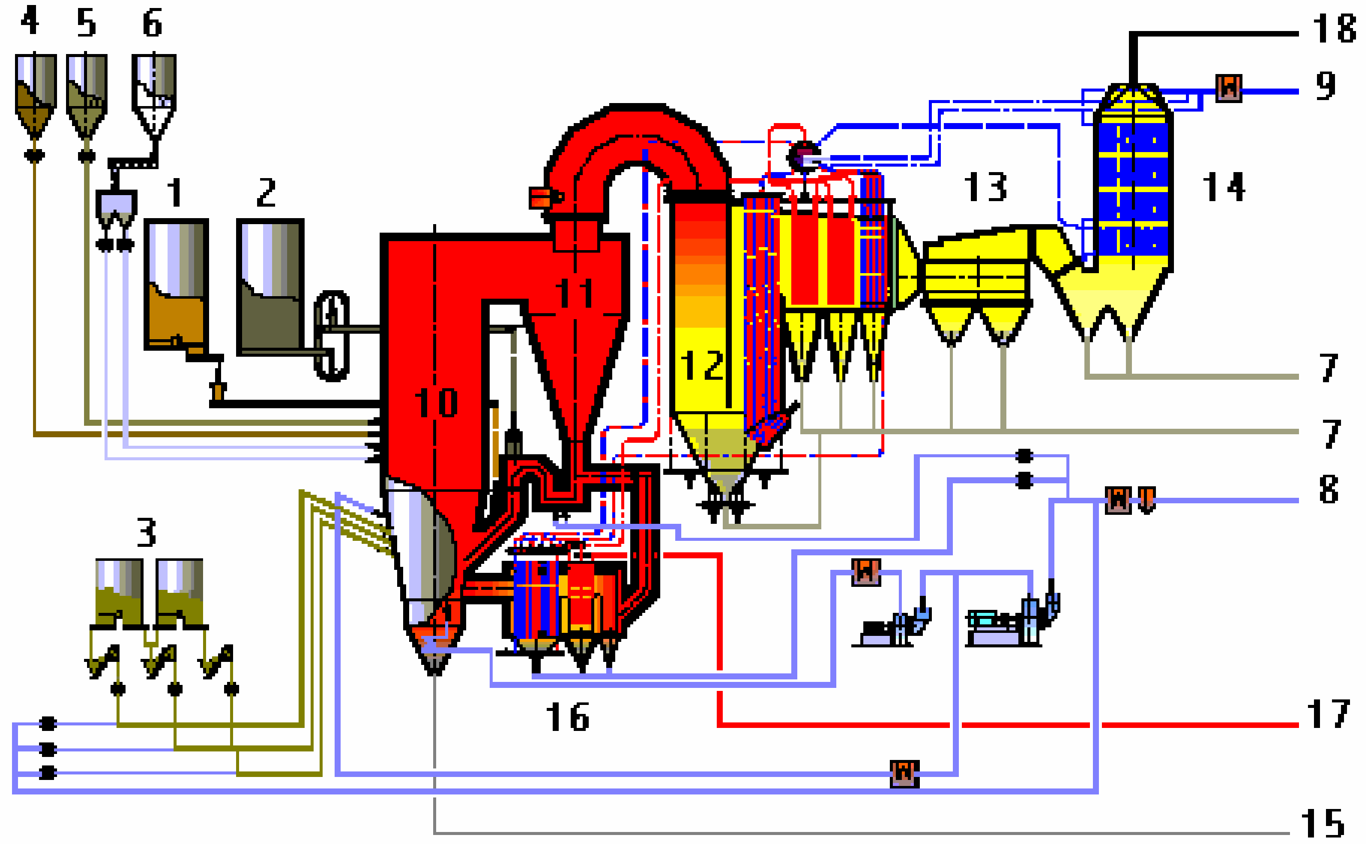

SOTACARBO
COAL
Coal grinding
FUEL TREATMENT SECTION
To Combustor
DWF (Dry Waste Fraction)
Pack system
Primary crasher
Selection
Inert
Separation
Secondary
crasher
MSW
Metal
Separat.
Bio stabilisation
SLUDGE
Dryer
To Combustor

Fig. 7

# CFB BOILER (*)




(*) by courtesy of Babcock Borsing Power - Austrian Energy

1. MSWPT tank 2. Coal Storage 3. Dry Organic Fraction 4. Sand Storage 5. Limestone
6. Additives 7. Fly Ashes 8. Air 9. B.F.Water 10. F.B. Combustor
1. Cyclone & Loop Seal 12. Heat Recovery Boiler 13. Multy Cyclone 14. Economiser 15. Bottom Ashes
6. External FB Heater 17.SH Steam 18. Flue gas



**FIG. 8**

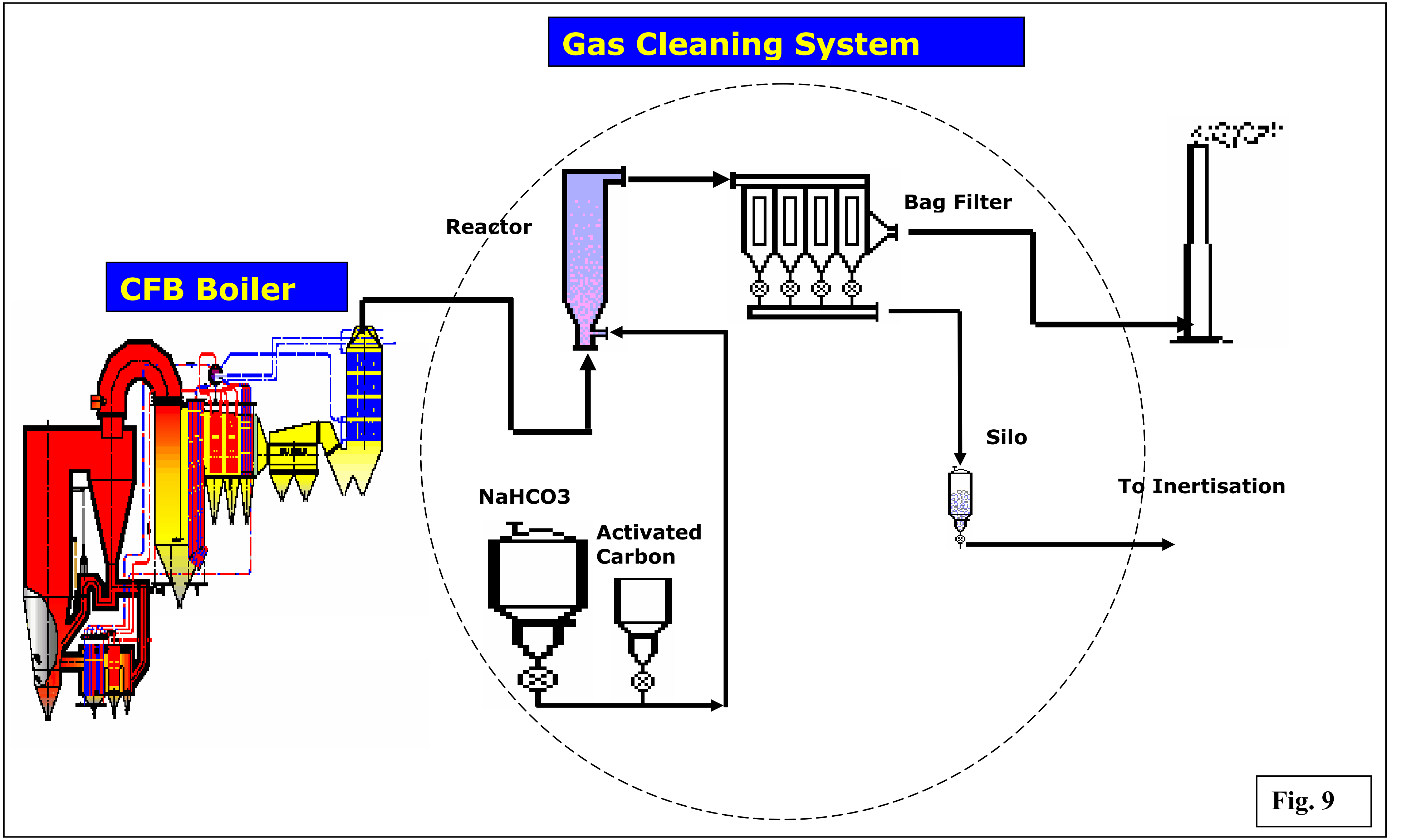

Gas Cleaning System
CFB Boiler
Reactor
Bag Filter
Silo
To Inertisation
NaHCO3
Activated
Carbon

Fig. 9