



The Rob Rockefeller S.C.

**FLAMELESS PRESSURIZED
OXY-COMBUSTION TECHNOLOGY**

A new way of burning at close to zero emissions



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HISTORICAL DEVELOPMENT

- ✓ The Sofinter Group is leader in combustion technology and fully owns a Research Company on combustion operating one of the biggest test rig in Europe
- ✓ Due to the rising environmental concerns on combustion emissions the Sofinter Group decided in 2002 to invest in a spin off, ITEA, dedicated to the development of a whole new way of burning: the flameless combustion
- ✓ In 2004 a new pilot plant with the significant capacity of 5 MWth has been built by Itea at Research Company branch facility
- ✓ Itea, through the testing activity at the plant, has registered important patents on processes and equipment making the flameless combustion technology an industrial product ready to be marketed
- ✓ The development of the technology in the fields of application has been done through the collaboration with industrial partners and the construction/operation of additional test rigs (Singapore and Georgia Tech. University)

In detail:

- ✓ From 2006 to 2011 – Development of Power application in collaboration with Enel
- ✓ In 2008 a larger plant (15 MWth) has been built in Singapore; the long term operational campaigns done in the Singapore plant gave to Itea the operational experience needed to make the flameless combustion technology a product ready to be marketed in a number of industrial applications



HISTORICAL DEVELOPMENT

- ✓ From 2010 to 2013 - Development of toxic waste treatment and Oil & Gas applications in collaboration with ENI
- ✓ From 2013 to 2014 - UPA: Micro Pilot construction for high pressure coal treatment
- ✓ From 2014 to 2016 - Development of "Municipal solid waste" treatment in collaboration with AMIU Puglia
- ✓ From 2016 to 2018 - Feasibility of a large coal pilot in collaboration with SWRI, EPRI, PRA, GE Global Research, JACOBS)
- ✓ From 2016 to 2018 – Development of sewage sludge treatment in collaboration with AQP

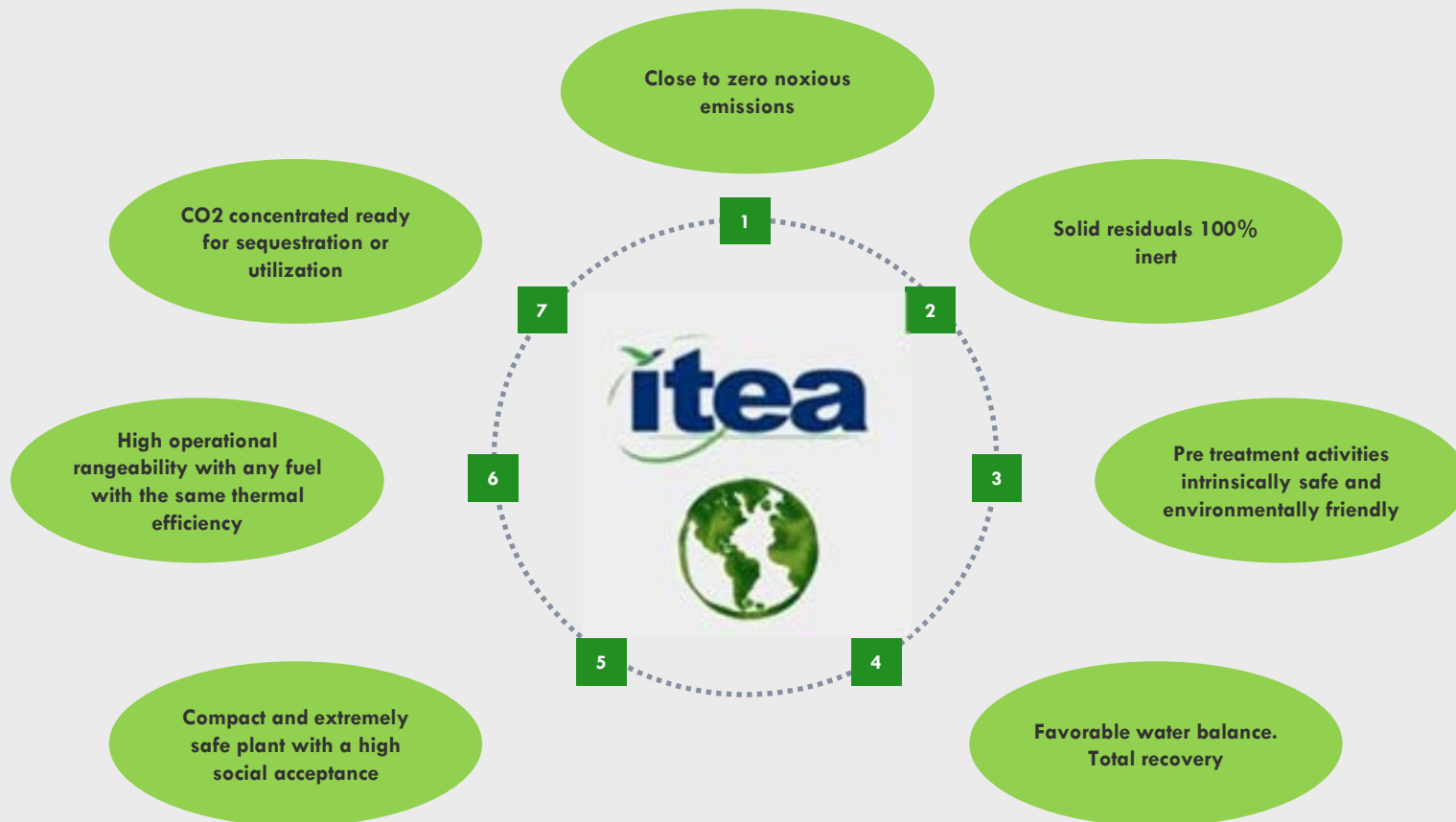


POWER AT ZERO EMISSIONS



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Eco friendly, cost effective, advantages



KEY SUCCESS FACTOR OF ISOTHERM PWR

- ✓ The lowest emissions rank that known combustion technologies can guarantee
- ✓ The ashes are reduced to totally inert vitrified slags
- ✓ 96% of introduced heat (LHV) is recovered
- ✓ High range ability of the combustion process (from 10% to 100%), at constant performance; response to power demand cycling
- ✓ Extended acceptance of water content in the fuel
- ✓ Ease in commercial CO₂ recovery for different utilizations (Industry, Eor, sequestration)
- ✓ Capacity to burn simultaneously different kinds of waste and fuels
- ✓ Compact relatively small plant highly automated
- ✓ Competitive capex



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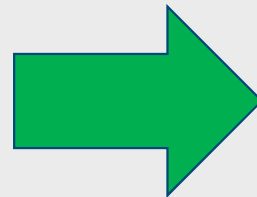


TRADITIONAL COMBUSTION

- ✓ Chaotic not completely controlled reaction
- ✓ Formation of dangerous products during combustion



- ✓ Dirty fumes to be cleaned in expensive and complex fumes treatment lines
- ✓ Dangerous not completely combusted ashes with increasing problematic disposal
- ✓ Limited range ability (The plants reduces the performances when reduces capacity)
- ✓ The change of fuel, when possible, requires strong plant's modification and in some case derating of the capacity
- ✓ The fumes cannot be used due to the low CO₂ concentration
- ✓ Big dimensions for a specific capacity of the plant



ITEA'S APPROACH

- ✓ High and uniform temperature
- ✓ Total absence of dangerous products during combustion

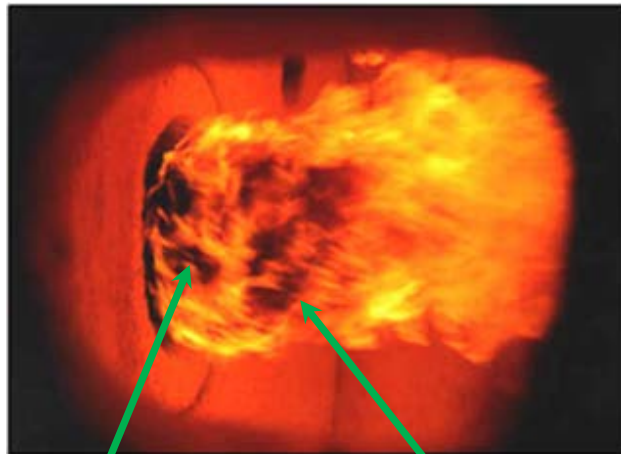


- ✓ Simple fumes treatment
- ✓ Incombustible ashes reduced to vitrified inert slugs
- ✓ High plant range ability (10 => 100%)
- ✓ High CO₂ concentration in outlet fumes
- ✓ Flexible fuel



TRADITIONAL COMBUSTION

“chaotic”
non locally controllable

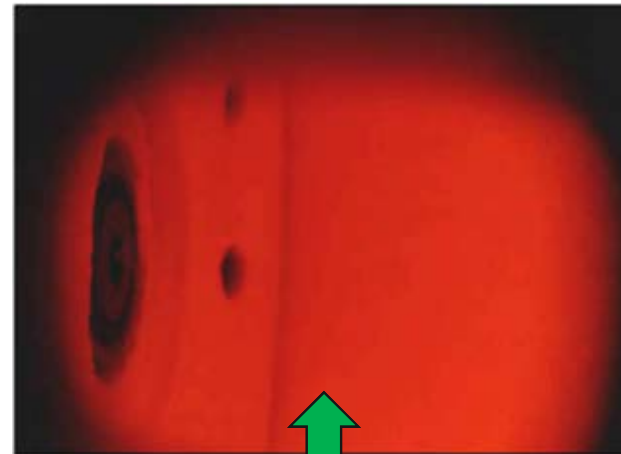


Cool Zone

Flame Front:
Peak Temperatures

«FLAMELESS COMBUSTION»

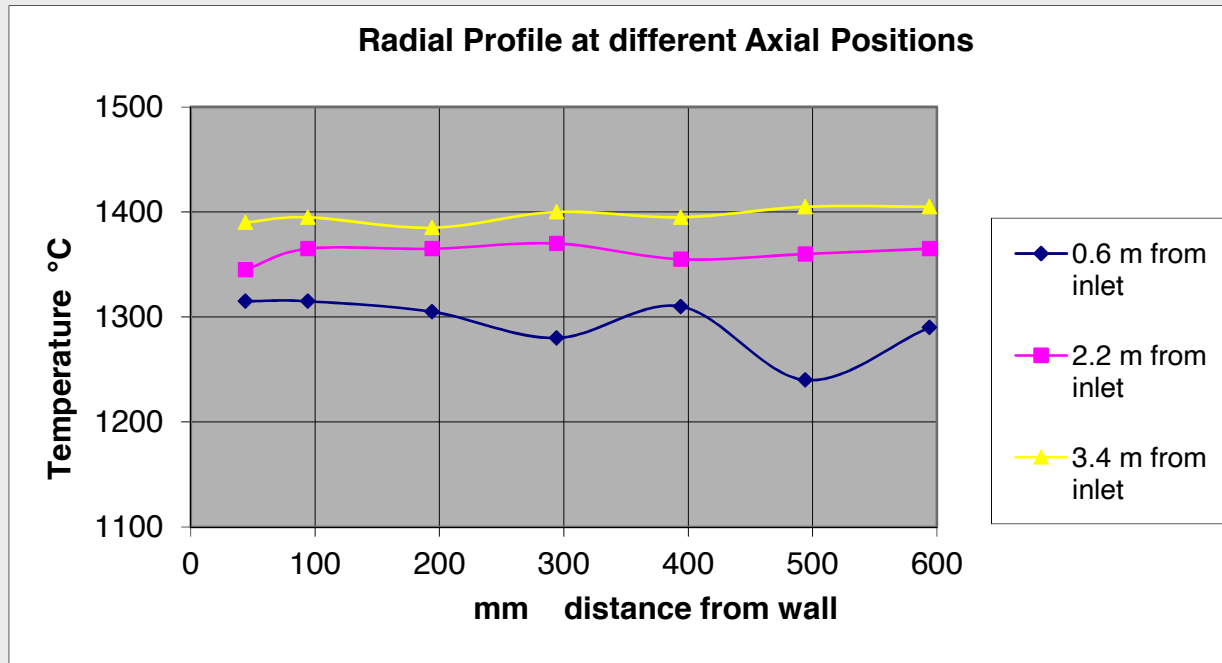
MILD, flameless, «volume combustion»
volume expanded - controllable



High Uniform Temperature

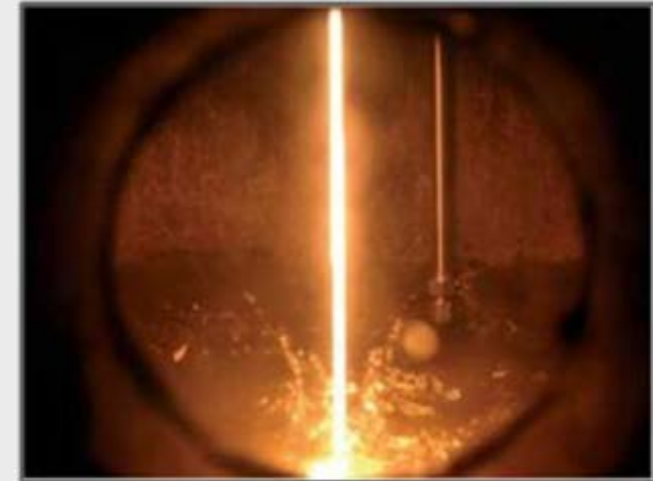


High, uniform Temperature



Ashes quantitative melting and coalescence is unique to Isotherm process.

- ✓ Quantitative Melting
- ✓ Liquid phase triggers slag coalescence
- ✓ Molten slag drained at combustor bottom

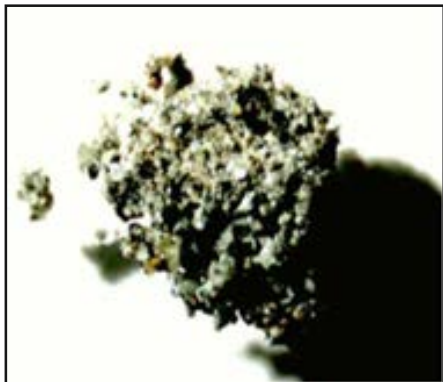


- ✓ Molten slag quenched in a water bath
- ✓ Vitreous Granular
- ✓ Zero Residual Carbon
- ✓ Impervious to Heavy Metal Leaching
- ✓ Fully inert



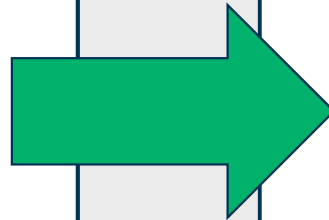
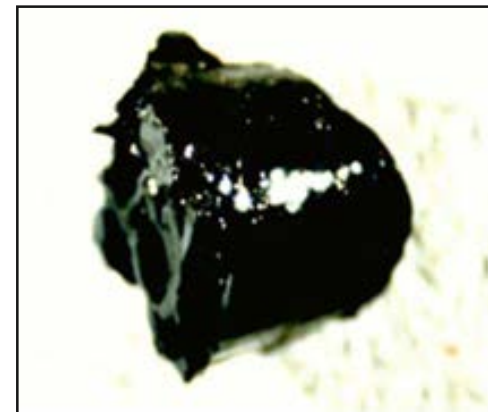
HEAVY ASHES

TRADITIONAL COMBUSTION



VITREOUS ASHES

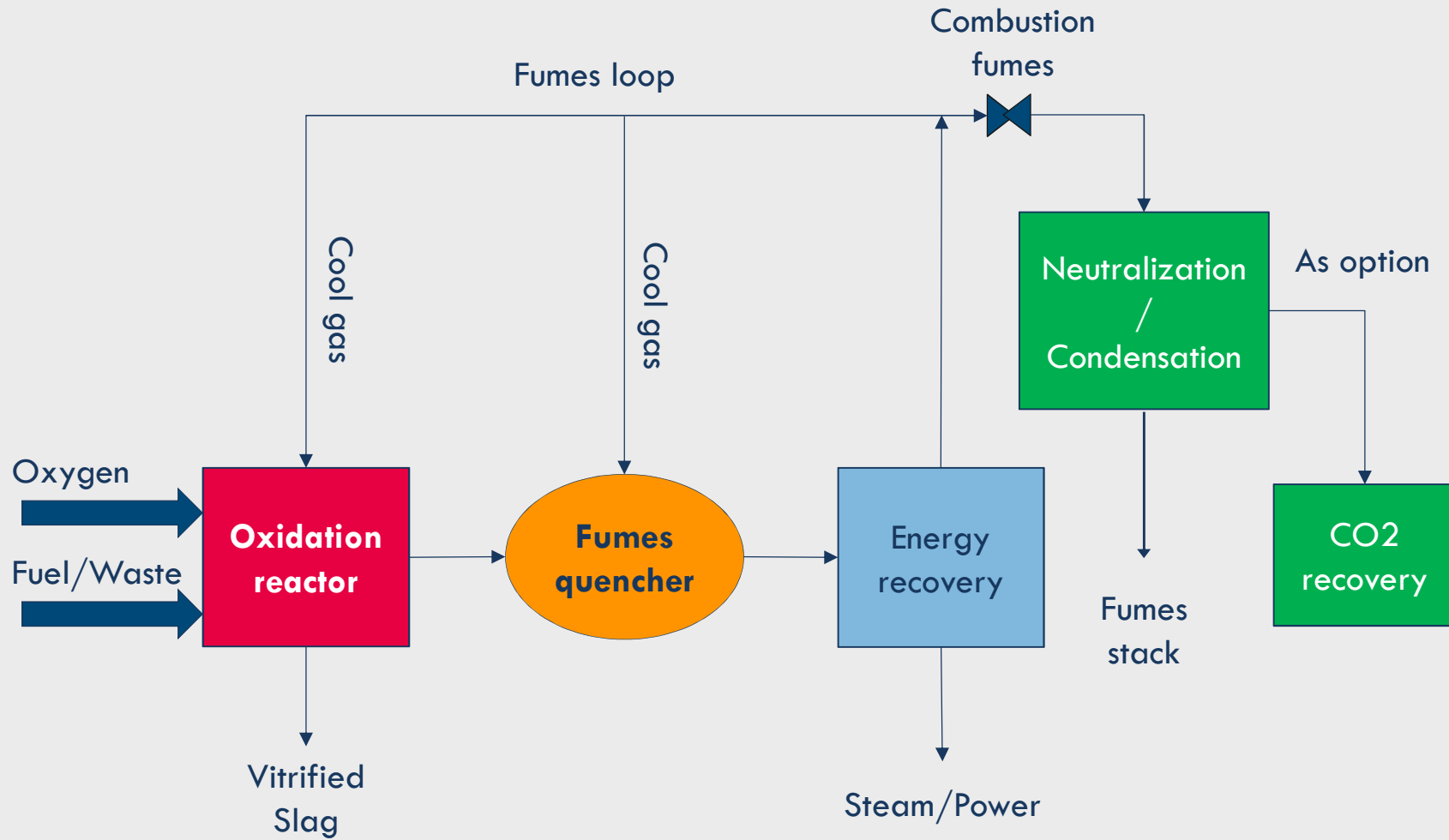
ITEA PROCESS



Flue Gas Emissions		
Noxious Gas:	EU 2010/75	Isotherm PWR® at stack
CO	50 mg/m ³ , peak value 200	< 1 mg/m ³ (1)
NOx	200 mg/m ³ , peak value 400	< 100 mg/m ³ (1)
SOx	50 mg/m ³ , peak value 200	< 10 mg/m ³
TOC	10 mg/m ³ , peak value 20	<0.05 mg/m ³ (1)
HCl	10 mg/m ³ , peak value 60	< 0.1 mg/m ³
PAH	0,1 mg/m ³	<0.0001mg/m ³ (1)
Dust (total)	10 mg/m ³ , peak value 30	< 1 mg/m ³
PM 2.5	Not yet regulated (Industrial avg. 1.000 – 5.000 µg/m³)	<10 µg/m³
Dioxin, Furans	0,1 ng/m ³	<0.0001 ng/m ³ (1)
Heavy metals	0,5 mg/m ³	< 0.1 mg/m ³
SOOT / Organic Carbon	Not yet regulated	Zero (1)

(1) Performances already attained at combustor outlet







Gioia del Colle
5MWth Plant

Operating
pressure: 4 Bar

Main use:
Multifuel

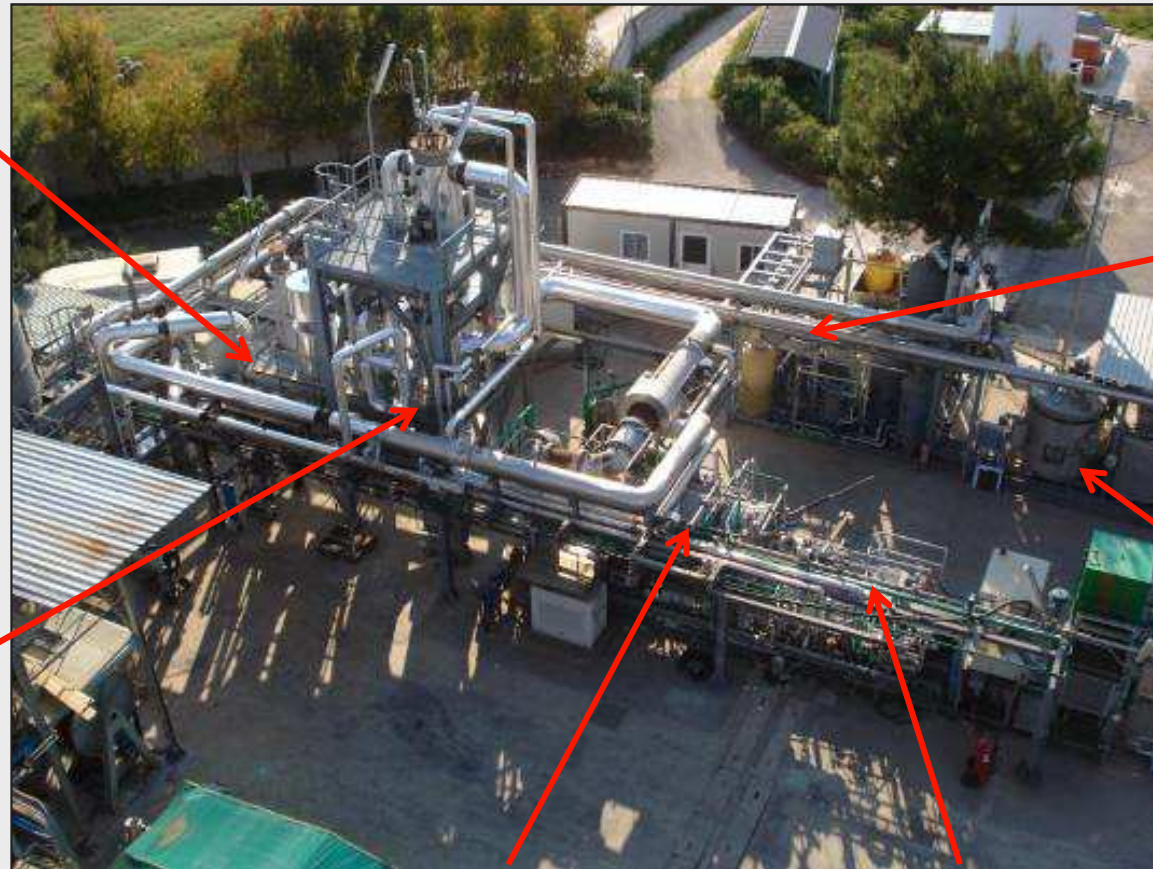


Singapore 15MWth Plant / Main use: Liquid toxic waste
Not in operation



Georgia Tech University 100kWth Plant
Operating pressure: 30 Bar
Main use: Coal testing
Not in operation





Blower

**Small
Compact
Simple
(few unit operation)**

**Fully automated
Easy to operate**

Boiler

120 ft X 60 ft

**Fumes: Water
Condensation**

**Fumes
Neutralization**

Reactor

Feeding set

Flameless Pressurized Oxy-combustion

5 MWth Pilot Unit - Aerial View
in operation since 2004



- ✓ **PCT/IB2004/001220:** METHOD AND PLANT FOR THE TREATMENT OF MATERIALS IN PARTICULAR WASTE MATERIALS AND REFUSE
- ✓ **PCT/IB2005/001290:** HIGH-EFFICIENCY COMBUSTORS WITH REDUCED ENVIRONMENTAL IMPACT AND PROCESSES FOR POWER GENERATION DERIVABLE THEREFROM
- ✓ **PCT/EP2007/011193:** PROCESS FOR THE PURIFICATION OF COMBUSTION FUMES
- ✓ **PCT/EP2008/010054:** COMBUSTION PROCESS
- ✓ **PCT/EP2008/010095:** COMBUSTION PROCESS
- ✓ **PCT/EP2008/010096:** COMBUSTION PROCESS
- ✓ **PCT/EP2010/060558:** STEAM GENERATOR
- ✓ **PCT/EP2013/065390** COMBUSTION PROCESS FOR FUEL CONTAINING VANADIUM COMPOUNDS
- ✓ **PCT/EP2013/065393** COMBUSTION PROCESS FOR FUEL CONTAINING VANADIUM COMPOUNDS
- ✓ **PCT/EP2014/077543** PRESSURIZED OXYCOMBUSTION PROCESS



The technology, due to its flexibility, has many potential applications.

Itea, thanks also to the support of its industrial partners, focused its research and development efforts on four areas:

- ✓ Municipal Solid Waste to material recovery and energy production
- ✓ Industrial waste treatment and landfill remediation
- ✓ Oil and gas recovery enhancing processes
- ✓ Coal power plant ready for Carbon Sequestration or E.O.R.

Some of the institutions that work with us or study our technology...





- ✓ The application is already at the commercial stage
- ✓ New improvements are being tested to extend the range of treatable wastes and improve the economics
- ✓ The market size for the application is 15 MWth unit

Competitive Advantages

The technology is capable of treating effectively and permanently a vast range of wastes containing both organic and inorganic contaminants.

In the case of toxic landfills remediation, due to the high environmental compliance and its compact size, the plant can operate on site. This means avoiding the costly and risky transportation of toxic wastes.



- ✓ Capable of treating with the highest environmental compliance any not recyclable fraction of municipal wastes, currently landfilled or incinerated in traditional incinerators
- ✓ The application is already at the commercial stage for the 15MWth plant
- ✓ The “first in kind” 15MWth plant has been authorized; detailed engineering on going
- ✓ Market requirement sizes for the application are as follows:
 - 15 MWt module for Italian/european market
 - 50 MWt module for large third world cities

Competitive Advantages

- ✓ *Very low integral emission level*
- ✓ *High overall net energy recovery efficiency*
- ✓ *High flexibility in inlet waste acceptance*
- ✓ *CO2 recovery option (no stack)*
- ✓ *Ashes recovered as No leaching material*



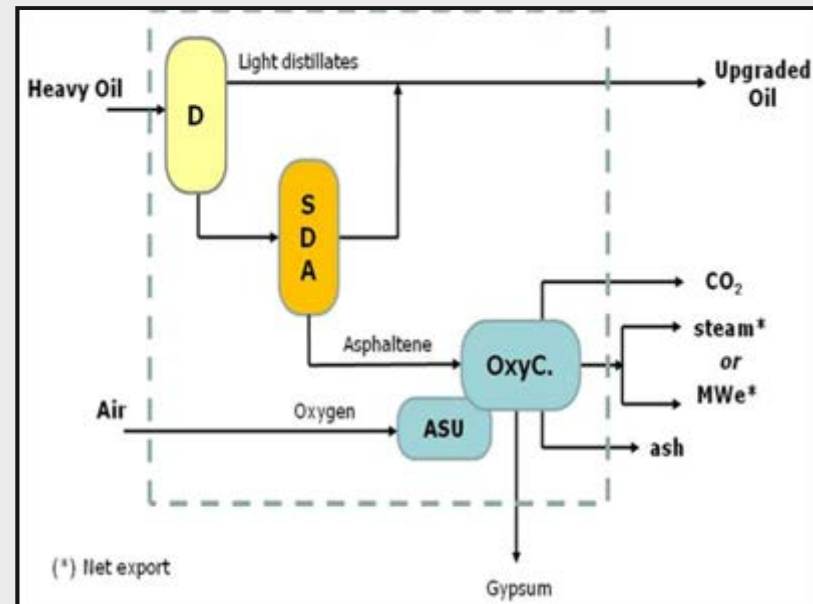
The “Oil and Gas” field includes a variety of industrial specific “business cases” i.e.:

OIL HEAVY FRACTIONS TREATMENT:

Asphaltene isotherm combustion, power-steam and concentrated CO₂ EOR grade production

Application Strengths

- ✓ Full package transforming API gravity 8.4 into DAO API 17.9
- ✓ Compact SDA + Isotherm at well site
- ✓ From 50 MWth skid Isotherm Unit to large 500 MWth unit
- ✓ High efficiency
- ✓ Co-production of power-steam and CO₂ for EOR at well site



The “Oil and Gas” field includes a variety of industrial specific “business cases” i.e.:
LOW LHV NATURAL GAS (HIGH CO₂ CONTENT)

- ✓ NG straight from well
- ✓ High efficiency Joule-Bryton and Rankine cycle
- ✓ Synergy with GOX (Oxygen cryo-fractioning)
- ✓ Liquified CO₂ for sequestration

Application Strengths

- ✓ Very low LHV : > 50% CO₂ , 10% N₂, non operable with TGCC
- ✓ High net (overall) efficiency: 34%
- ✓ Medium capacity: 150 MWth
- ✓ CAPEX : 3.000 €/kW 30% lower than competitors (reference competitor: membrane +TGCC)



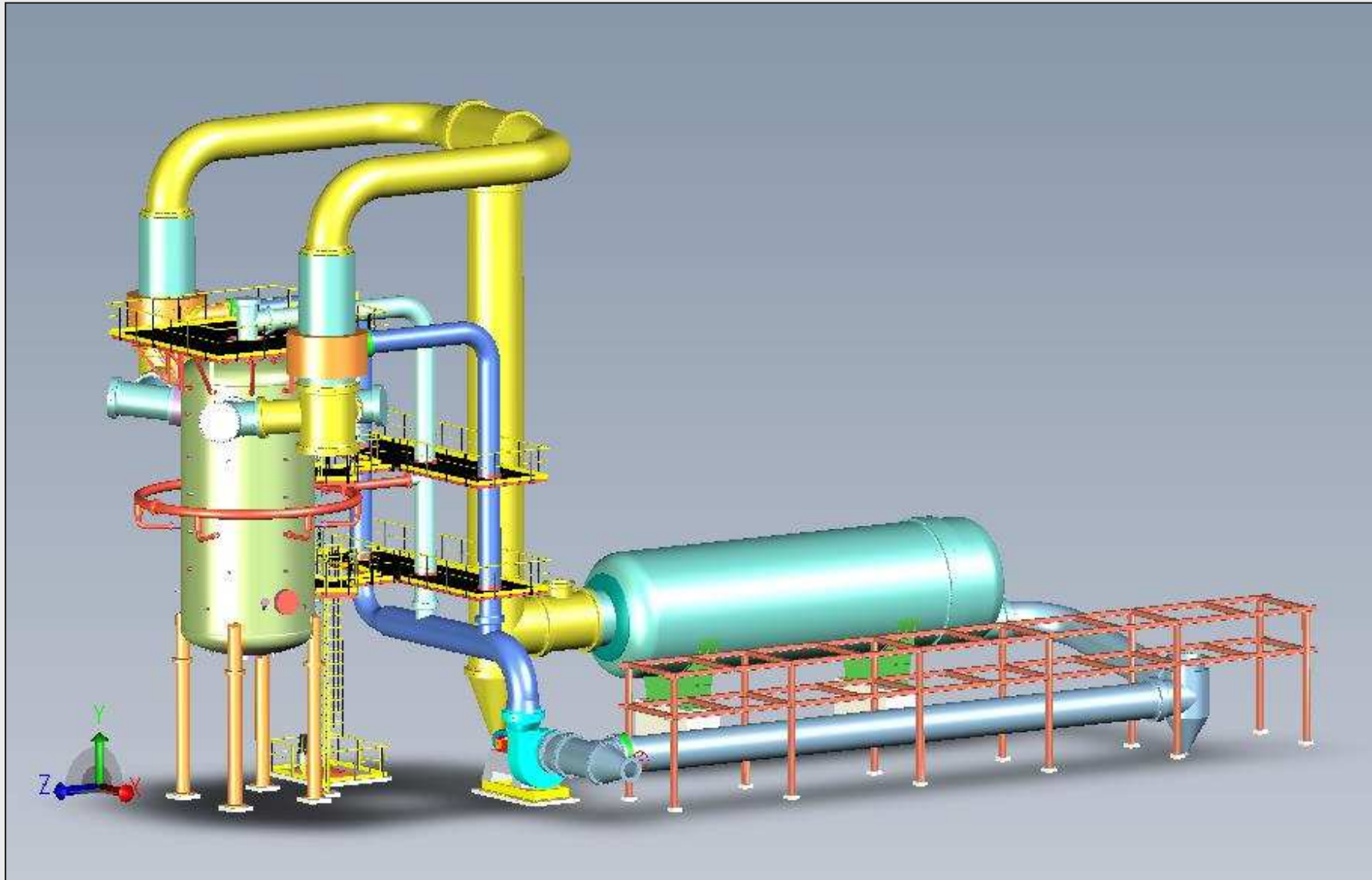
R&D and Engineering activity

- ✓ Wet grinding, pumpable slurry
- ✓ Full extension to “any” Low ranking coal
- ✓ 50 MWth pilot (intermediate development step, towards industrial units)
- ✓ 350 MWe FEED engineering study
- ✓ Three projects ongoing with US partners

Application Strengths

- ✓ Applicable to low ranking coals (high water content, low melting ash, lignite)
- ✓ High net (overall) efficiency
- ✓ “Ready for” CCS concept at competitive economic conditions
- ✓ “Suitable for” CCS retrofitting” in existing coal power units





48 Mwt coal application 3D firing-boiler pressurized loop





SUMMARY

Some concepts on Itea's technology and industrial applications Milan 15.9.2020 1 - ITEA and its technology

Itea is a company pertaining to the Sofinter – AC Boilers group; the group is a world player in boiler production sector. The two main brands of the group are Ansaldo Caldaie and Macchi: AC Boilers (ex Ansaldo Caldaie) builds big boilers to be installed in power stations; Macchi builds boilers to be installed in refineries/petrochemical complexes and large industrial compounds.

The technology used for the boilers of both companies is the traditional way to burn ordinary fuels (gas, oil, coal, biomasses, municipal waste, etc..) i.e. air combustion at atmospheric pressure.

Itea has developed a very peculiar new technology "Flameless pressurized oxy-combustion" that is a technological breakthrough and presents a wide range of advantages.

Considering only the environmental aspects, this technology solves, at the source, the three main environmental concerns of traditional combustion, i.e.:

- a)** In traditional combustion, the fumes exiting the boiler contain pollutants that should be reduced through a purification process that includes many different purification units, whose number, in the years, has increased in accordance with restrictions in fumes quality due to the increasing focus on environmental aspects.
- b)** The produced ashes in traditional combustion are porous and contain some percent of not reacted carbon; they release polluting components and the focus on environmental aspects is causing increasing costs for their disposal/use.
- c)** The fumes purification train described in point a) has not effect on CO₂; the fumes, poured in the atmosphere, contain CO₂, that is not a pollutant, but it is one of the main responsible of climate change. To collect CO₂ from the fumes of the traditional combustion is very costly.



The “Flameless pressurized oxy-combustion” wipes out the three concerns:

- a)** The fumes exiting the reactor (before any purification treatment) are already very pure and made substantially of water vapour and CO₂; the contaminants are, in many cases, some order of magnitude below current regulations.
- b)** The ashes are vitrified and do not contain not reacted carbon; they do not release pollutants and the industry can easily use them.
- c)** Being the fumes constituted essentially of water vapour and CO₂, the separation of CO₂ from the fumes is very easy, producing liquid CO₂ available for industrial usages, EOR (enhanced oil recovery) or CCS (sequestration).

2 – Main industrial applications

The technology is therefore a new combustion way, environmental safe, that allows:

- More efficient solutions in the current industrial applications of traditional combustion
- New solutions in industrial sectors where the traditional way cannot be used Presently, the market is showing deep interest on the following industrial sectors:

- o Treatment of sludge coming from municipal sewage treatment plants

The R&D project concluded in spring 2019, and in summer, regional public authorities have declared this application as the most advanced technology in the sector;

- o Treatment of mixture of not- recyclable plastic waste. The first phase of the project has been completed; Itea is discussing with Corepla (the public authority responsible for plastic waste collection and treatment) and Saipem the contents of the second phase.



- Municipal solid waste treatment; in this sector the technology has been qualified as “emerging technology” in the European BAT (best available technology); the first industrial plant, that foresees also the production of liquid CO₂ from the fumes, has been authorized in south of Italy. There are some other commercial initiative practically identical to the authorized project;

- Treatment of waste gas (at present often burned in stacks in industrial plants) to produce steam/power and liquid CO₂ for chemical and industrial usages; on this application Itea is licensing Saipem and concluded – fall 2019 - , jointly with Saipem, the FEED of a 90 MWt gas project;

- Power production from fossil fuels, with CO₂ recovery for industrial usages, EOR (enhanced oil recovery) and CCS (carbon capture and sequestration in the Unites States. Itea is currently involved, as technology provider to a group of USA companies, on four projects, heavily financed by DOE (US department of energy).

- Treatment of contaminated material in petrochemical exhausted landfill; the technology appears the most economical solution to remediated exhausted petrochemical landfills; a deep studies and experimental campaigns have been made on toxic landfilled material with ENI/Syndial

- In the last years , the development of technology application to two additional industrial sectors started with two specific R&D projects:

- o Treatment of sludge coming from municipal sewage treatment plants

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