M-WTE

Multi-Purpose Reactor Enhanced Waste -To - Energy

Waste to Resources with no Dioxins

INTRODUCTION

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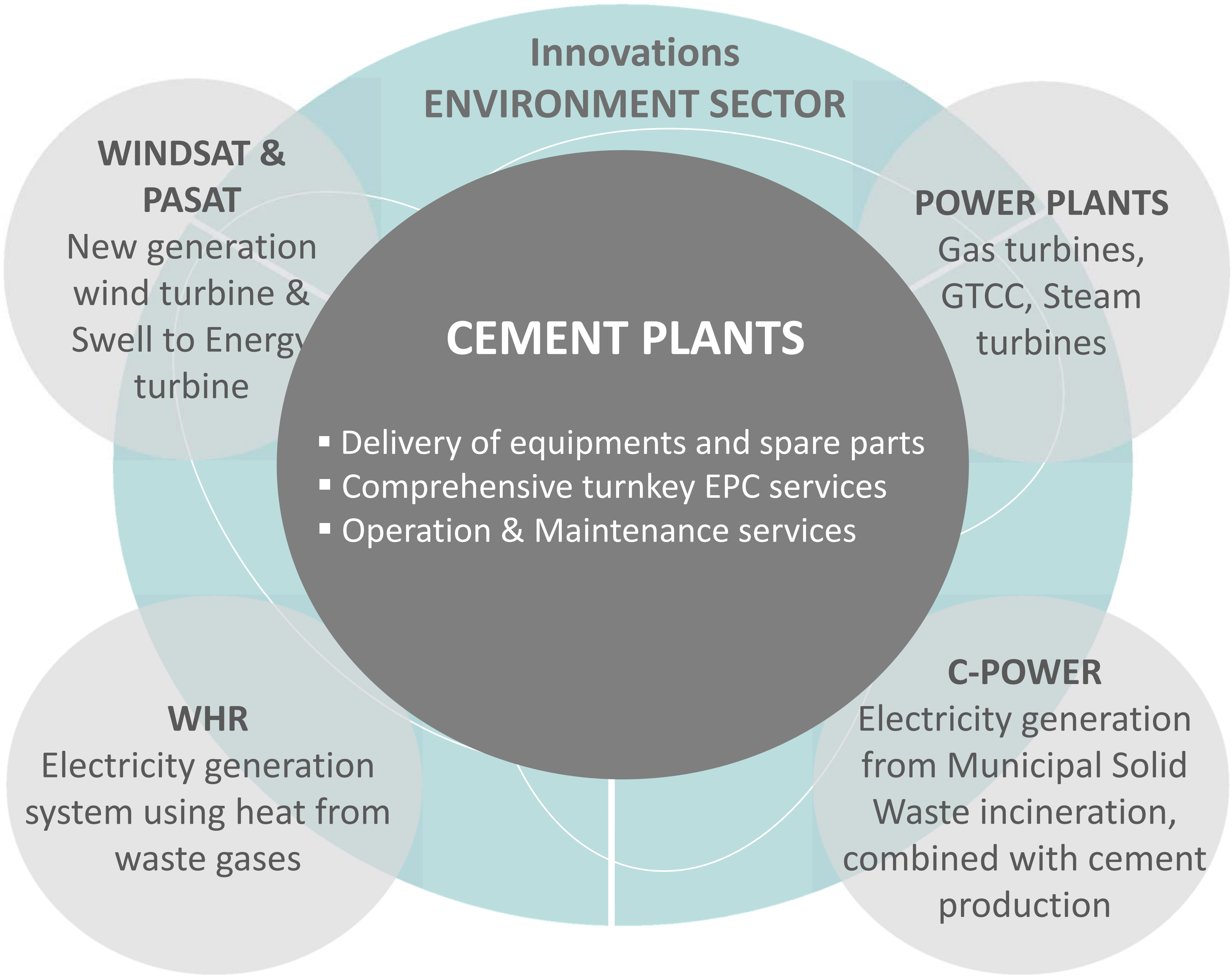
Activities


Innovations
ENVIRONMENT SECTOR
WINDSAT & PASAT
New generation wind turbine & Swell to Energy turbine
POWER PLANTS
Gas turbines, GTCC, Steam turbines
CEMENT PLANTS
▪ Delivery of equipments and spare parts
▪ Comprehensive turnkey EPC services
▪ Operation & Maintenance services
WHR
Electricity generation system using heat from waste gases
C-POWER
Electricity generation from Municipal Solid Waste incineration, combined with cement production

STRENGTHS

- **COST EFFECTIVENESS:** SATAREM provides clients with a fully integrated offer, the best turnkey services at the most effective cost.
- **FLEXIBILITY:** SATAREM delivers equipments and services in accordance with clients' schedules and SATAREM's high specifications, including European standards and norms.
- **DESIGN:** We design in house all processes and master engineering for each project, like C-Power WTE technology that is patented.
- **SUPPLIERS:** We develop long term relationships with our core equipment' manufacturers.
- **QUALITY:** At each step of the process, SATAREM controls the quality of the equipment delivered by its suppliers in order to ensure their compliance with all relevant standard(s)
- **MARKETING:** Very efficient commercial network

Our values: price and flexibility

Waste Management Options

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Unmanaged Dumping: EHS Unacceptable

Environmental Hazards :
- Land pollution by stockpiled garbage
  - Toxic heavy metals
  - Organic pollutants
  - Non biodegradables
- Ground water pollution by leachate (garbage juice)
- Air pollution by VOC
  - Landfill gas methane (potent Green House Gas =21x CO_2)
  - Other fugitive gas: dioxins & furan, POP, hydrogen sulphite, ammonia

Safety Hazards:
- Spontenous burning of garbage pile, major source of dioxin emission
- Landfill gas explosions - safety risk to scavengers & personnel on site

Health Hazards :
- Land, water and air pollutants
- Breeding ground for vectors & diseases
- Odor and toxic air emissions problem

Sanitary Landfills: Not Highly Sustainable

Leach Prevention : Difficult to Manage

Leachate Treatment: Another Challenge

Occupy Large Land Area

Landfill Gas – Maximum 70% Collection

Waste Incinerators: A Compromised Solution

Municipal Waste-to-Energy Facility Shanghai China

Advantages：

- Weight & volume reduction
- Energy recovery & reuse
- Occupy less space than landfills

Sludge Incinerator East London UK

Hazardous Waste Incinerator Limay France

Disadvantages：

- Dioxin re-formation in flue gas
- Toxic fly ash to manage
- High Capex and Opex
- Not flexible in throughput
- Dedicated for specific waste types

Cement Plant as a Waste Management Option

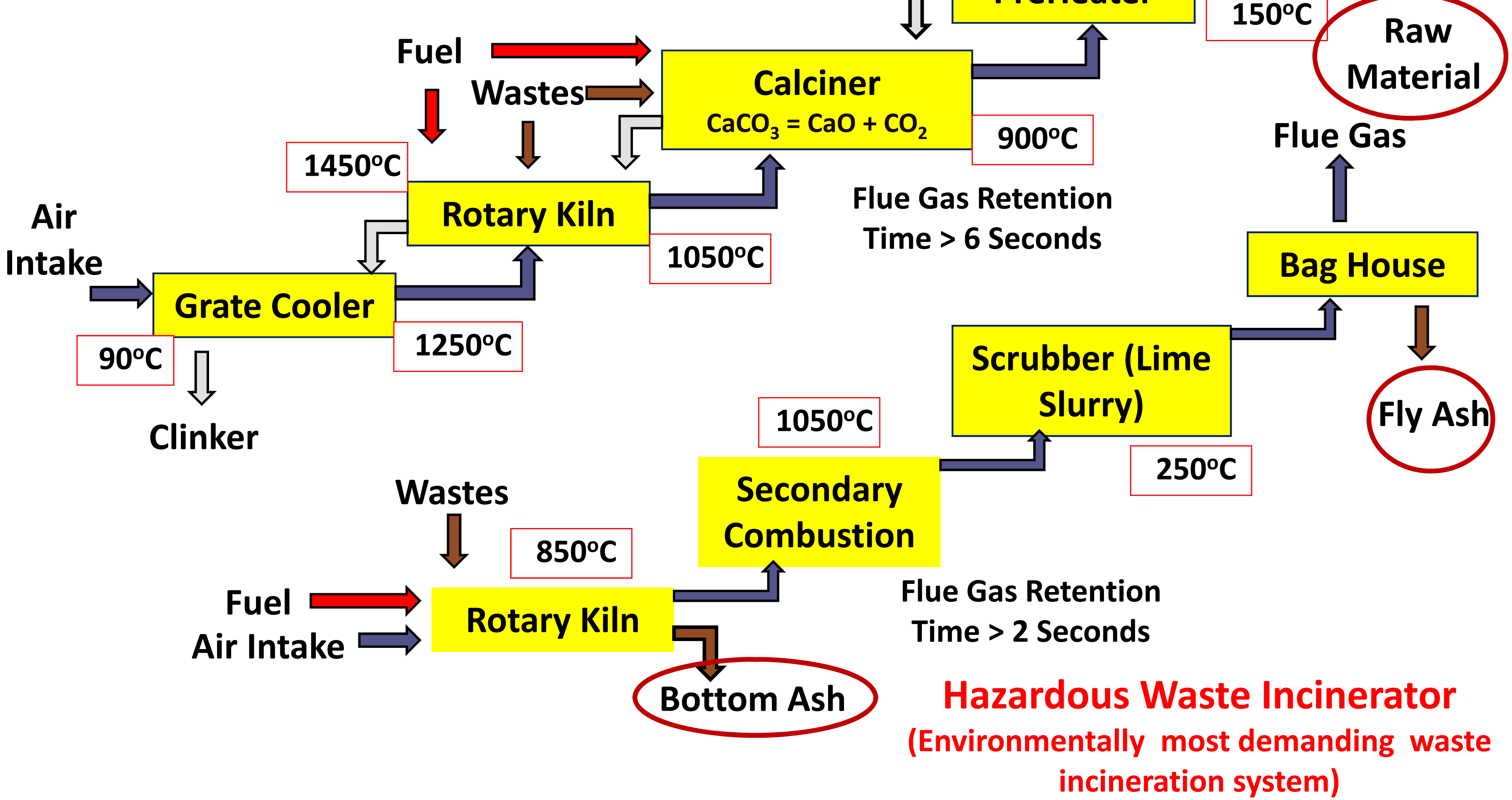
Use of cement kilns for hazardous waste destruction and waste derived fuels are becoming common global practice due to distinctive economical and environmental advantages

- Lower capital and operation costs
  - No need to build and operate dedicated facility
  - No ashes to manage
- Lower environmental risks
  - Alkaline process environment neutralizes acids gases
  - Toxic heavy metal ions stabilized in cement matrix
  - Minimized dioxin & furan formation
- Higher sustainabilities
  - Waste reused as fuel and raw material
  - Reduce limestone raw material usage
  - Reduce fossil fuel usage
  - Net reduction of CO_2 emission
  - UN approved CDM methodologies

Cement Plant: Advantages over Incinerators

Cement Processing Plant : Comparative Advantages

- Higher Reaction Temperature
- Longer Retention Time
- Excessive Lime for Acid Gas Scrubbing
- Silicate Cement Matrix for Heavy Metal Capturing
- In Process Energy & Material Re-utilization



Cement Plant for Waste : Minimal Dioxin Formation

Use of waste-derived fuels at preheater/precalciner and dioxins in emission

Plant	Year	Type of alternative fuel	PCDD/PCDF emissions in ng I-TEQ/Nm^3
1	2002	Animal meal, plastics and textile	0.0025
2	2002	Animal meal and impregnated saw dust	0.0033
3	2002	Coal, plastic and tyres	0.0021 & 0.0041
4	2002	Tyres	0.002 & 0.006
5	2002	Petcoke, plastic and waste oil	0.001
6	2002	Petcoke, sunflower shells and waste oil	0.012
7	2002	Tyre chips	0.004 & 0.021
8	2002	Solvents	0.07
9	2002	Impregnated saw dust and solvents	0.00003 & 0.00145
10	2002	Solvents	0.00029 & 0.00057
11	2002	Sludge	<0.011
12	2002	Car waste and sludge	0.0036 & 0.07 & 0.0032

Source: Results of LaFarge Study as presented by Karstensen in 2006

Cement Plant for Waste : Limitations

Limitations of cement kilns as a waste management facility:

- Large quantities of waste not acceptable to cement process
  - Takes only refuse derived fuel with high calorific value, or hazardous waste in limited quantities
- Fluctuations in waste quality affects cement quality
  - Chlorine and alkali concentration needs careful control
  - Cannot take mixed municipal solid waste or mixed industrial waste with unknown composition especially when calorific value are not homogenized
- Air emission quality affected by cement raw material content
  - During waste destruction dioxin reformation is prevented thru removal of pre-cursors (chlorine ions, aromatic persistant organics compounds) in the cement kiln and calciner.
  - Nevertheless the counter-current cement process dictates that volatile pollutants (e.g. volatile heavy metals or organics) naturally present in cement raw material would not be destroyed at lower temperatures of the pre-heater and would escape to the atmosphere with the flue gas.
  - This will interfere waste incineration flue gas quality and prevent proper monitoring of emission quality.

M-WTE : WTE Inspired by the Cement Process

M-WTE (Multipurpose Reactor enhanced Waste-to-Energy) is:

- A Waste-to Energy process enhanced by cement processing technology
  - Adoption of cement calcination process in Multi-Purpose Reactor (MPR)
  - One step secondary combustion and high temperature acid gas scrubbing of flue gas
- An environmentally superior option to conventional WTE process
  - Prevention of dioxins reformation instead of management of dioxins upon re-formation
  - Dioxin free incineration fly ash combined with MPR reagent could be re-used as cement raw material or construction material, thus avoiding need for secure landfilling
- A process overcoming the limitations of both the cement plant and the dedicated incinerator as waste management facilities
  - Versatile – one facility for destruction of all waste types: MSW, sludge and hazardous waste
  - Variable waste quality and high quantity waste throughput – not possible with cement kiln waste destruction program
- A new combination of proven technologies
  - Use of cement thermal process for waste destruction and dioxin prevention
  - Use of primary incinerator + secondary combustion chamber for enhanced organics destruction

M-WTE : Economic Advantages

- Lower Capital Costs
  - One single facility for destruction of various waste types – MSW, sludge & hazardous waste
  - MPR: a secondary combustion chamber with acid gas scrubbing function eliminating the independent acid gas scrubber
  - No need for active carbon injection unit as no need for dioxin removal
  - Simplified incineration unit and overall process design eliminating unnecessary civil work and structural components
- Lower Operating Costs
  - No toxic fly ash to manage, no stabilization & secure landfill costs
  - No carbon injection unit operation costs
  - Designed for low cost maintenance and high availability
- Upside Income Potentials
  - Re-use of combined ash (bottom ash + MPR reagent + fly ash) as construction material to brick making or cement processing raw material
  - Enhanced energy conversion efficiency from waste calorific value to electricity through elevated heat exchange temperature at super-heater
  - When working in parallel with cement plant synergies on energy and material recovery will result in enhanced cement production, zero solid residue and maximum economic advantages (i.e. C-POWER system)

M-WTE: A Versatile Waste Management Option

Management Method	Co-mingled Municipal Garbage	Sewage & Industrial Sludge	General Industrial Waste	Hazardous Waste	Challenges & Issues
Sanitary Landfill					Occupy Large Land Area, Green House Gas & Ground Water Pollution Risks
Secure Landfill					
Aerobic Digestion					Bio-Degradables Only, Final Disposal of Solids, Toxic Heavy Metals
Anaerobic Process					
Recovery and Recycling					Limited to Selected Recyclables, Secondary Pollution Risks
Conventional Waste Incinerator*	Waste-to-Energy Plant	Dedicated Incinerator	Waste–to-Energy Plant	Dedicated Incinerator	Costly to Build & Operate; Bottom & Fly Ash to Manage, Dioxin
Cement Plant Based Waste Management					Limited Waste Types & Quantities
MPR Enhanced Waste-to-Energy	Universal Design for Multiple Waste Types Simplified Process : Lower CAPEX & OPEX				New Combination of Proven Technologies with Limited Track Record

Applicable Applicable Under Specific Conditions Not Applicable

* Requires various types of incinerator systems & design to manage different types of wastes

M-WTE Process Development History

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M-WTE: Development Background

Hong Kong Chemical Waste Treatment Center

- Where M-WTE was first conceptualized in the late 90's

M-WTE: Development Background

- Satarem and its associates are highly experienced in
  - Technical modifications and innovative designs of cement plants
  - Design, construction and operation of waste treatment facilities
  - Waste substitution of fuels and raw materials in cement
  - Waste heat to power process
- Based on above M-WTE was developed after 5 years of intensive process research
- Pilot scheme designed and constructed by Satarem
  - Conducted at Green Island Cement, Hong Kong, in year 2005
  - Destruction of 40 tpd municipal garbage over 6 months
  - Monitoring: HK Environmental Protection Department
  - Assessment: HK University of Science & Technology
  - Air emission result meets (and beats) EU stipulations

Satarem Incineration & Waste-to-Energy Design

Various Applications

- Municipal solid waste
- Hazardous industrial waste
- Medical waste
- Sewage and industrial sludge
- Special waste

Versatile Design

- Stationary bed incinerators
- Fluidize bed incinerators
- Rotary kiln incinerators
- Mechanical grate incinerators

Superior Environmental Performance

- Incorporation of MPR® technology for front-of-pipe removal of chlorine and persistent organic pollutants
- “Near Zero” dioxins – beats EU Specifications

M-WTE: 50 tpd Pilot Facility

Hong Kong Pilot Plant Results

Air Pollutant	EU Emission Standards (mg/m^3)	Actual Emission Data (mg/m^3)
Dioxins (in TEQ ng/m^3) *	0.1 ng/m^3	0.015 ng/m^3
Total organic carbon (TOC)	10	2
Hydrogen chloride (HCl)	10	2
Hydrogen fluoride (HF)	1	0.02
Sulphur dioxide (SO_2)	50	18
Nitrogen oxides (NOx)	200	50
Carbon monoxide (CO)	50	45
Particulates Matter (PM)	10	4
Heavy Metals (Group 1) :Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V	0.5	0.2
Heavy Metals (Group 2) : Cd & Th	0.05	0.003
Heavy Metals (Group 3) : Be, Se	No regulatory limit	0.025
Mercury (Hg)	0.05	0.003

* All emission levels, including results of multiple (14 samples over 6 months) dioxin sampling, complies with and were well below EU standards

M-WTE
Configured to Prevent
Dioxin Formation

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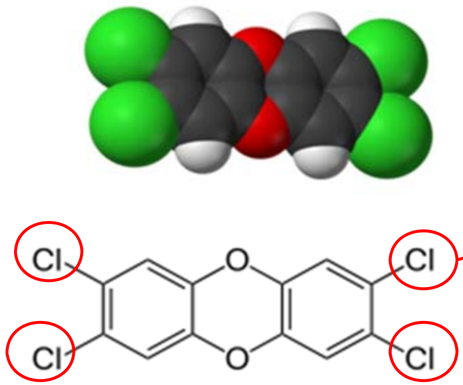
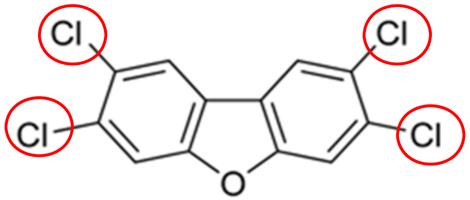
Dioxins & Furans: Components & Formation



2,3,7,8-TetraChloro-Diphenyl Dioxin (TCDD)



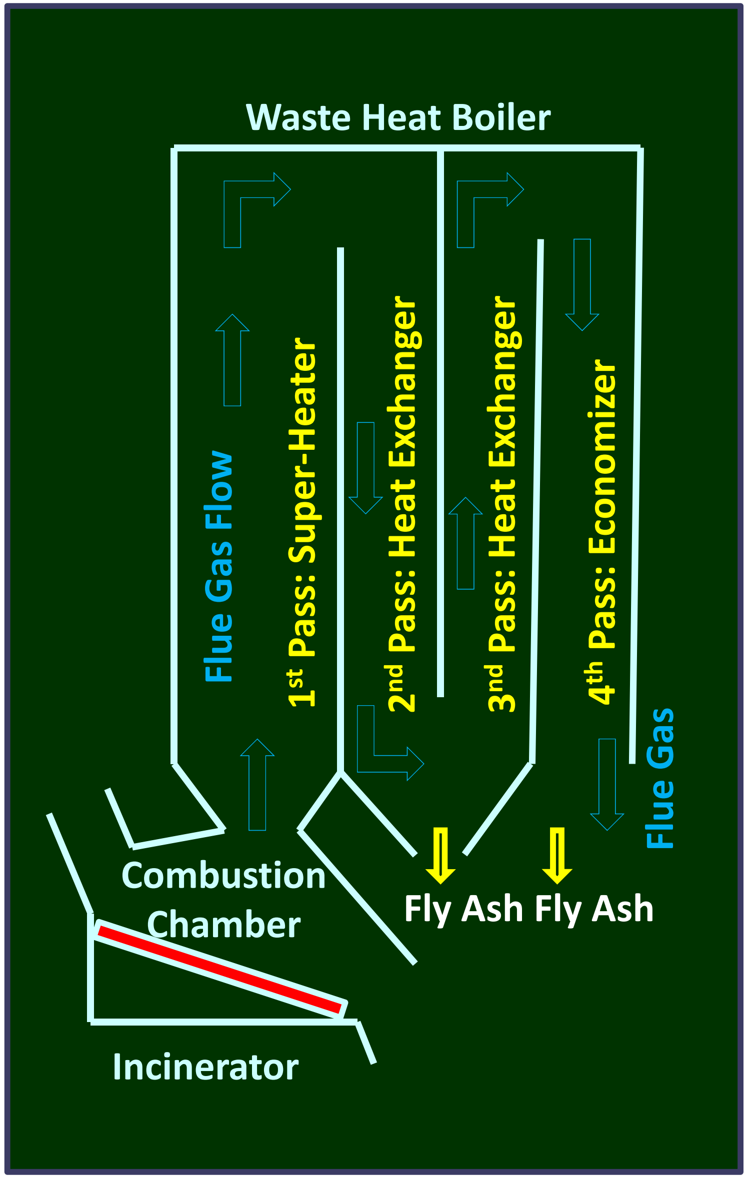
2,3,7,8-TrtraChloro Diphenyl Furan (TCDF)

Dioxins & Furans	ITEF
2,3,7,8-TCDD	1
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDD	0.5
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,4,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDD	0.1

POPs/Dioxins :

- **Destroys above 850°C during incineration**
- **Reforms during flue gas cooling at 500-250° C in presence of Chloride Ion (Cl^-) + Persistant Organic Pollutants (POPs)**

Reformation of Dioxins in Waste Heat Boiler



Dioxins Re-formation in Boiler

Unit: mg I-TEQ/Ton Waste

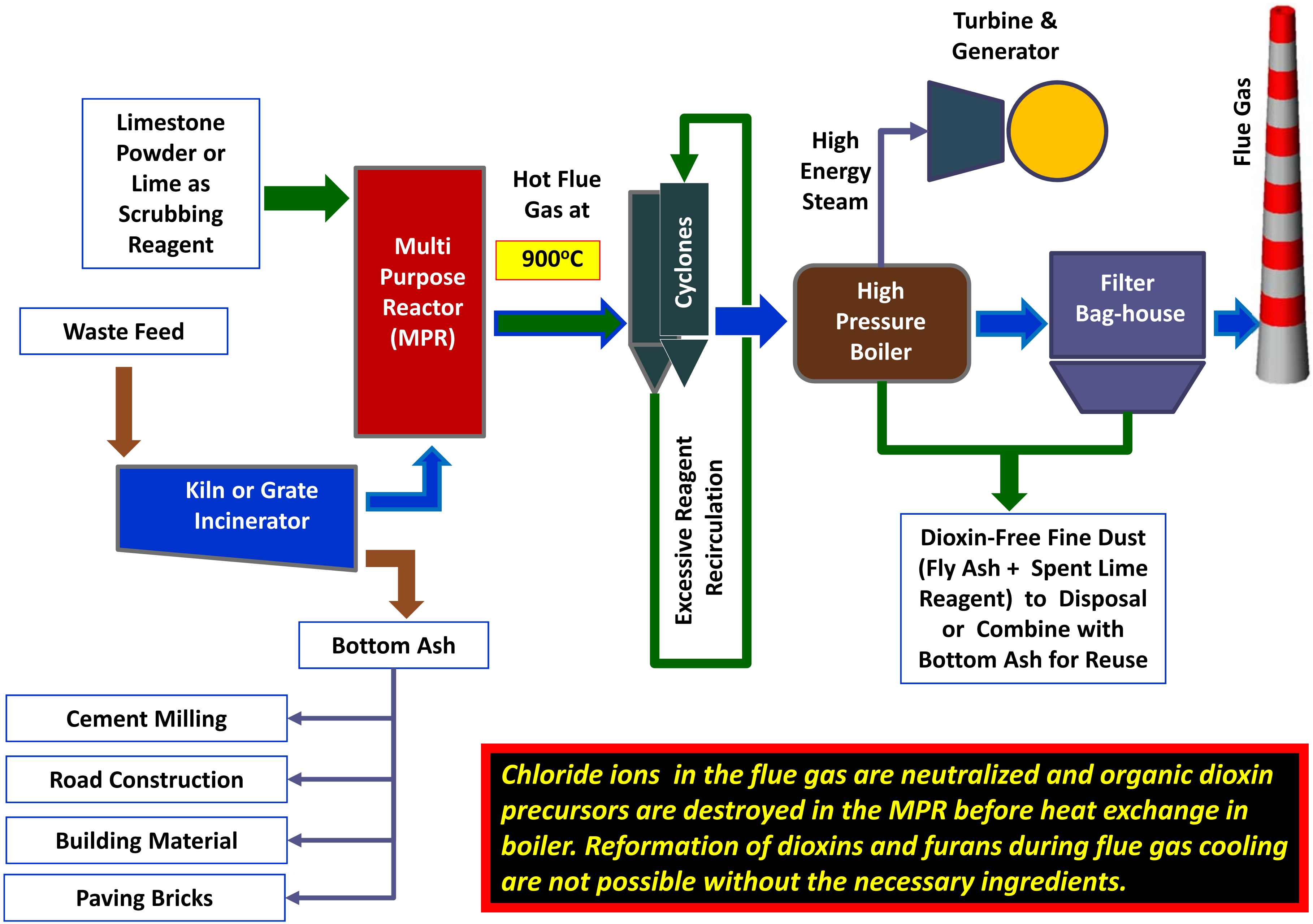
Dioxin Type	Temperature 800-400 ° C (2nd – 3rd Pass)	Temperature 400-220 ° C (4th Pass)
OCDD	0.6	265
HpCDD	0.2	124
HxCDD	0.1	105
PeCDD	0.1	75
TCDD	0.1	25
PCDD	101	594

Dioxins: Concentrations at Different Locations

Location	Minimum	Maximum
Combustion Chamber	3	30
Flue Gas After Boiler	20	190
Fly Ash	35	630

Source: Ferdinand Engelbeen, Dioxin L., 1996

MPR Enhanced Waste-to-Energy (M-WTE)



Chloride ions in the flue gas are neutralized and organic dioxin precursors are destroyed in the MPR before heat exchange in boiler. Reformation of dioxins and furans during flue gas cooling are not possible without the necessary ingredients.

Roles of the Multi-Purpose Reactor (MPR)

In Incineration Process

- **Secondary combustion chamber**
  - High temp. long retention time for POP destruction
- **High temperature scrubber**
  - High temperature dry scrubbing of acid gases
  - Front-of-pipe approach for dioxin prevention

In Calcination Process

- **Preheater**
  - Preheating of cement kiln feed or limestone powder
- **Calciner**
  - Calcination of limestone powder into lime

In Power Generation

- **High temperature flue gas producer**
  - Provides high temperature flue gas for power generation

Functions of Multipurpose Reactor (MPR)

Raw Meal with Limestone ($CaCO_3$)

Clean Flue Gas to Boiler
- POPs – Destroyed at High Temp.
- Acid Gases – Neutralized by Lime

Multi-Purpose Reactor

Reaction Temperature : 850 – 900°C

Retention Time : > 6 Sec.

Reactions:
- Calcium Carbonate to Lime
- POP High Temperature Destruction
- Acid Gases Neutralization

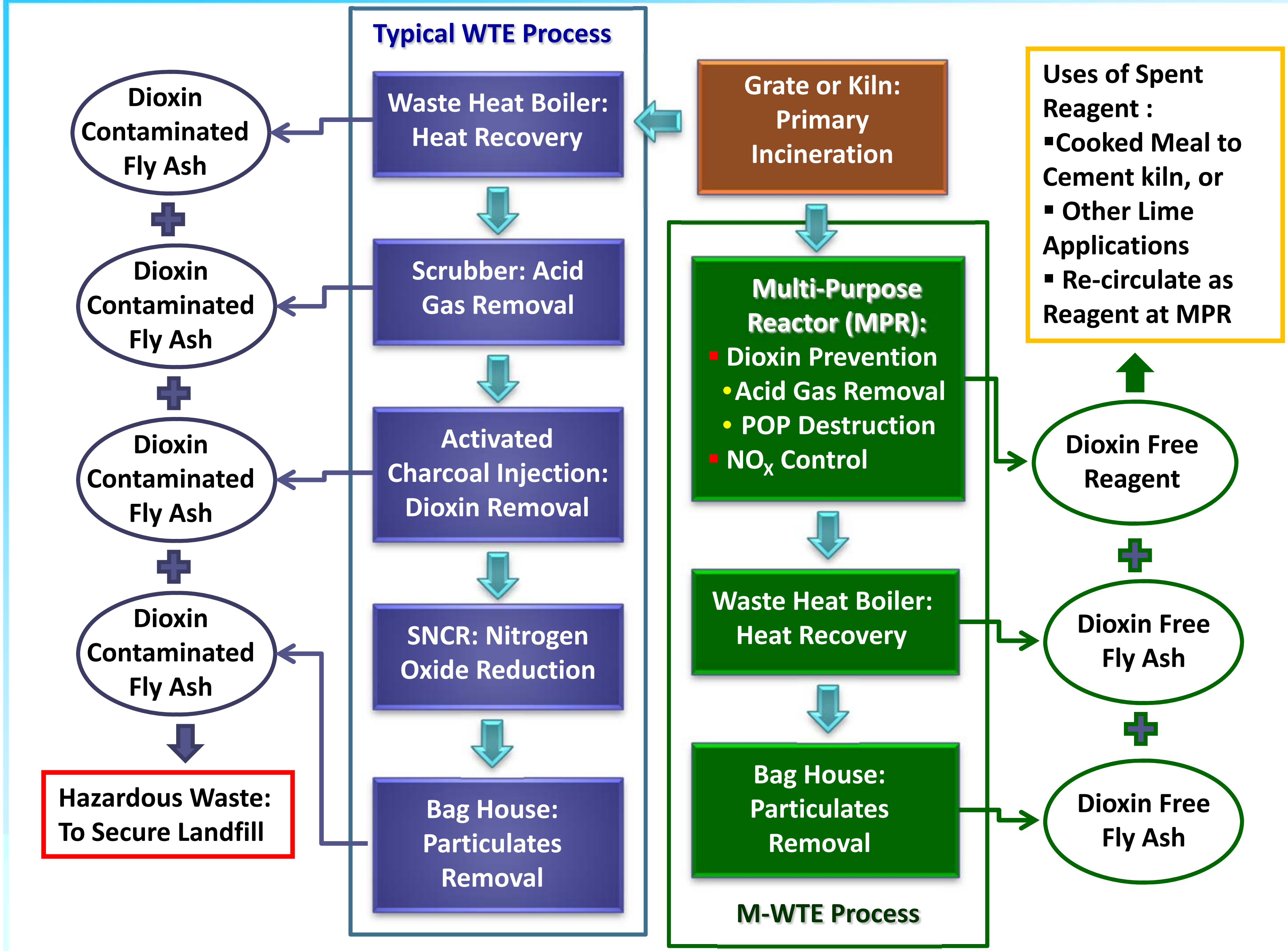
Flue Gas with :
- Persistent Organic Pollutants
- Acid Gases
  - Hydrogen Chloride Gas (HCl)
  - Sulphuric Oxides (SO_X)

Cooked Meal with Lime (CaO)

M-WTE: A Hybrid Facility

- A lime/cooked cement feed meal production facility
  - The Multi-Purpose Reactor (MPR) converts limestone powder ($CaCO_3$) into lime (CaO) , produces lime for acid gas scrubbing and subsequent after-use applications, e.g. paving brick production or use as cement kiln cooked meal feed
- A versatile, dioxin free incinerator
  - Two stage incineration process with MPR
  - High temperature (900 °C) and long retention time (6 seconds)
  - Front of pipe chlorine removal and enhanced removal of persistent organic pollutants (POP) for dioxin prevention
- High efficiency waste-to-resources facility
  - High temperature flue gas for power generation
  - Turns wastes into power and non toxic reusable material
  - Near “zero” residue when in symbiosis with cement plant
  - Maximum synergies with other energy intensive industries or lime based industries

Front-of-Pipe Approach to Dioxin Prevention



Wastes that can be Treated by M-WTE

- Used tyres
- Plastics
- Paper
- Wood
- Glass
- Agricultural wastes
- Refuse derived fuel
- Oil, grease and solvents
- Green wastes
- Coal ash
- Distillation bottom
- Desulphurization gypsum
- Oil tank cleaning waste
- Sewage sludge
- Industrial WWTP sludge
- Municipal solid waste
- Metal refining slag
- Toxic heavy metal sludge
- Construction waste
- Clinical waste
- Electronic scraps
- Leachate
- Concentrated
- Animal carcass
- High toxic substance
- Ore processing waste

M-WTE Design & Environmental Considerations

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M-WTE Design & Environmental Considerations

Environmental Performance Considerations

- **Acid Gases Removal/ POP Destruction**
  - High temperature lowers scrubbing efficiency
  - Compensated by stoichiometrically excessive reagent, extended retention time at 850-900 °C
- **NOx**
  - Control of reaction temperature and oxygen level
  - Removal using SNCR with ammonia injection
- **Heavy Metals / Particulates**
  - MPR reagent matrix retention of Pb and Cd
  - Bag-house temperation control for Hg
- **Carbon Monoxide**
  - Assure oxygen supply level
  - Destruction at MPR

M-WTE Design & Environmental Considerations

Process Considerations

- **MPR Scrubbing Reagent Formulation**
  - Raw meal conversion to lime for acid gas scrubbing and after use applications
  - Quantities flexible and linked to demand for after use application
- **Alkali Chloride & Sulphate Removal**
  - By-pass and washing for $CaCl_2$ removal if needed
- **Waste Heat Utilization**
  - Clinker cooler air for waste pre-heating / drying
  - Pre-heater flue gas to economizer section for heat recovery
- **Power Generation**
  - High temperature flue gas to waste heat boiler
- **Host Cement Facility Relationship**
  - Potential for C-POWER application in parallel with cement plant

C-POWER

(Cement Processing Oxidative Waste and Energy Recovery)

M-WTE in Symbiosis with Cement Plant

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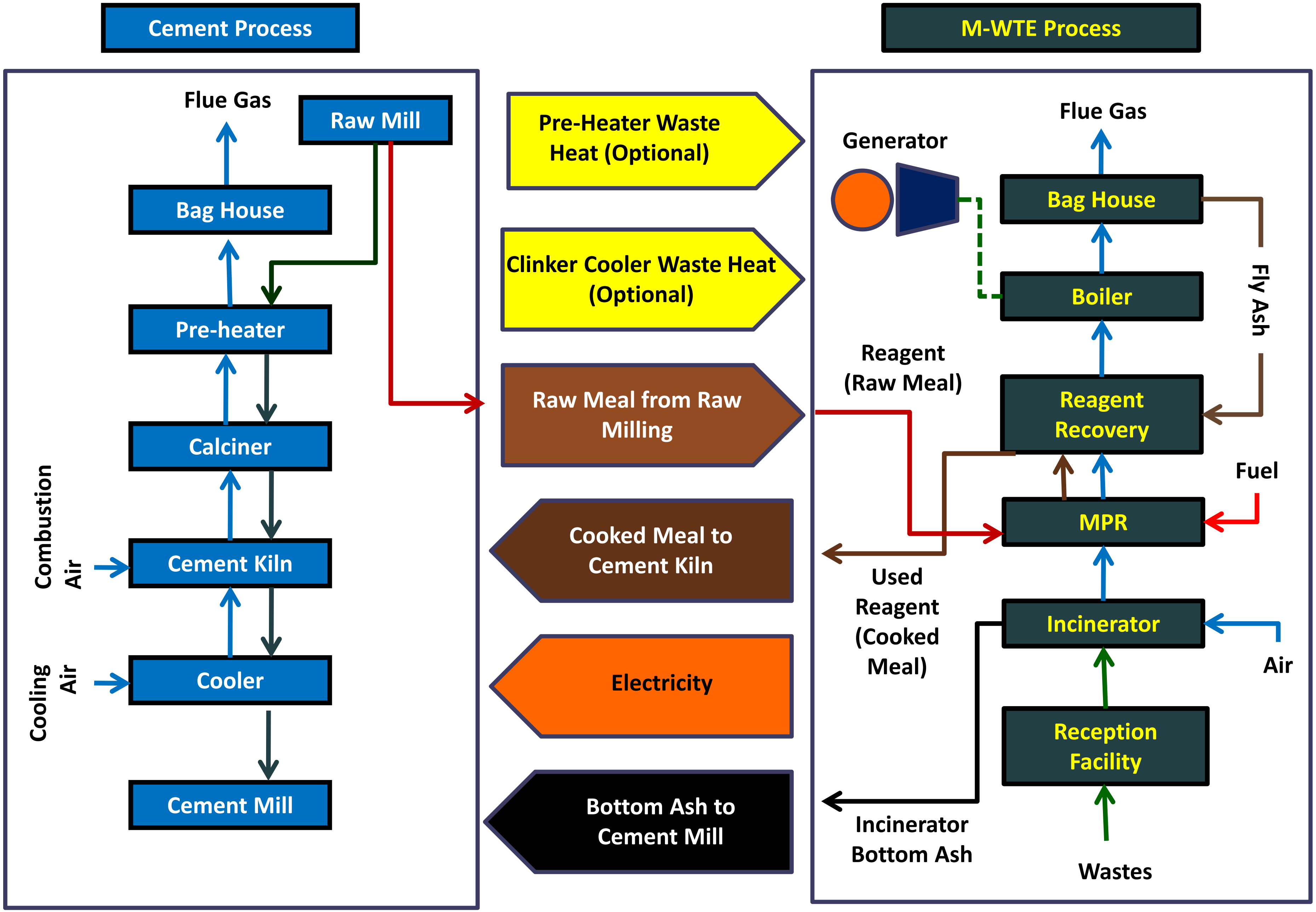
C-Power: M-WTE in Symbiosis with Cement Process



C-POWER: Symbiotic Advantages with Cement Plant

Treats Massive Quantities of Waste

- Non invasive technology allows mass burning of waste without affecting cement quality

Increase Cement Production

- Additional calcined material to increase kiln production

High Temperature Waste Heat-to-Power

- Combine LTWHR of cement plant to allow HTWHR after MPR

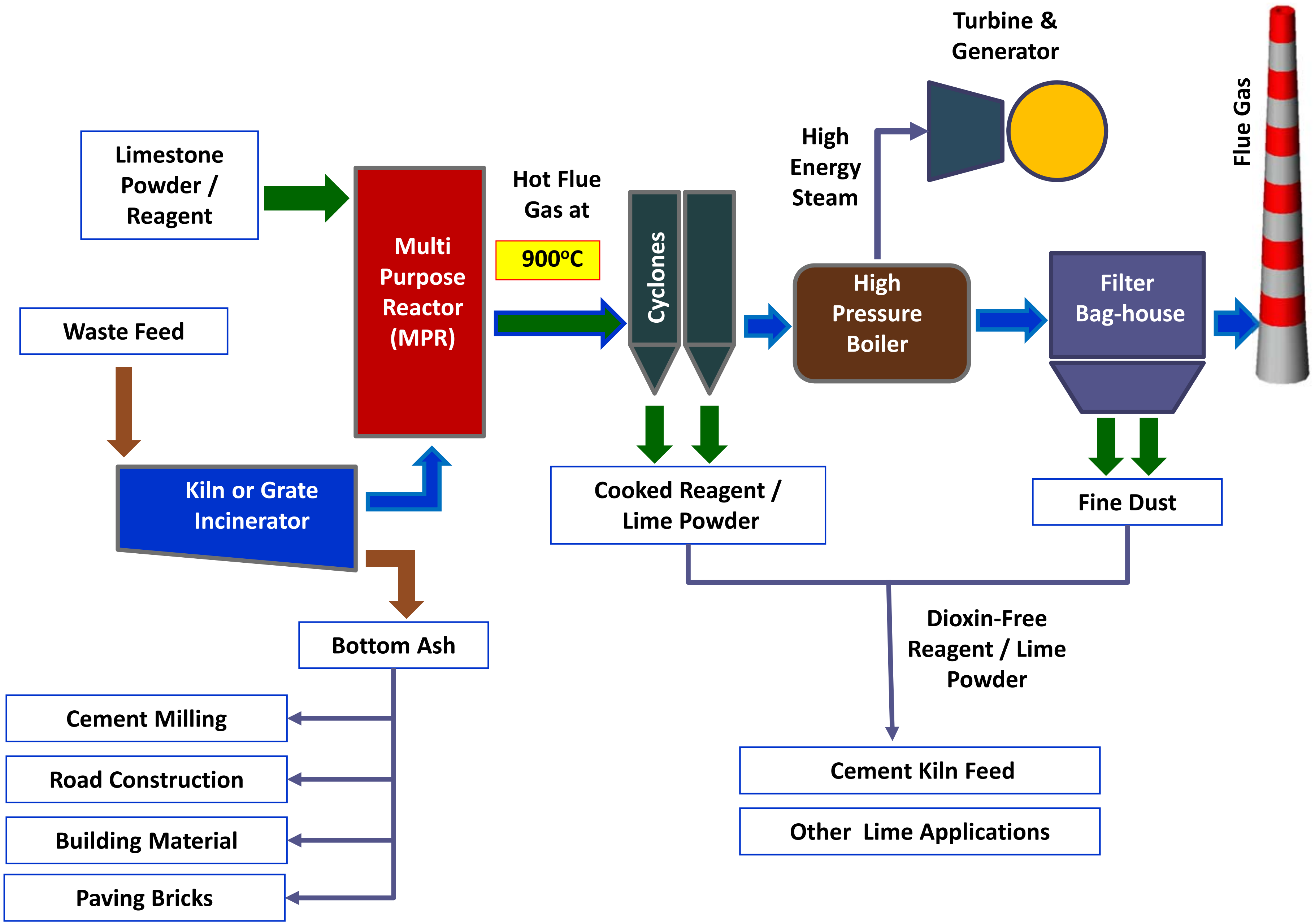
Enhanced Environmental Performance

- Pre-emptive chlorine removal prevents dioxins
- Bottom ash and fly ash re-used, no residues to manage

Energy & Material Efficiency

- Full recovery of material & energy from wastes
- Reduction of fossil fuel (coal) and limestone usage thus CO_2 reduction

M-WTE/C-POWER: “0” Residue Configurations



Revenues from C-POWER

- Increase in cement production capacity
  - 15% cement production increase with no system upgrade
  - Up to 50% production increase with system upgrade
- Waste tipping fees
  - Municipal garbage: government concession services
  - Industrial & hazardous wastes: service charter to waste producers
- Certified Emission Reduction credits trading
  - UN approved CDM methodologies
    - Fossil fuel alternative: biomass fraction as waste derived fuels
    - Limestone displacement : slag and ash as raw material replacement
    - Alternative treatment for organics : avoidance of biogas at dump
- Electrical power generation
  - Superior performance to conventional WTE facilities
  - Up to 30% energy conversion (e.g. 450kwh/MT @ LHV 1300KCal/Kg)

CDM Methodologies Applicable to C-POWER/M-WTE

Methodology Number	Description	Number of registered Projects
ACM5 (ver 3)	Increasing the blend in cement production	36
AM33 (ver 2)	Use of non-carbonated calcium sources in the raw mix for cement processing	*6*
AM40 (ver 1.1)	Use of alternative raw materials that contain no carbonates in clinker manufacturing in cement kilns	*1*
ACM15 (consolidating AM33 and AM40)	Alternative raw materials that do not contain carbonates for clinker manufacturing in cement kilns	0
ACM3 (ver 7)	Emission reduction through partial substitution of fossil fuels with alternative fuels in cement manufacture	16
AM24 (ver 2)	Baseline methodology for greenhouse gas reductions through waste heat recovery and utilization for power generation at cement plants	11
AM25 (ver 2)	Avoided emissions from organic waste through alternative waste treatment processes	>1000

PRESENT CONTRACTS

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PRESENT BOT CONTRACTS IN WTE

	Project	Country	Description	Contract Type	Contract Price	Estimated Starting Date	Revenues per year (US$)	EBIDTA per year (US$)	Investment needed (US$)	ROI (years)
Waste to Energy	City of Buenos Aires	Argentina	30 MW WTE	BOT 25 years	USD 130/MWh	September 2011	41 283 000	34 283 000	100 000 000	2,9
	City of Ankara	Turkey	1300 TPD WTE	BOT 25 years	USD 133/MWh	September 2011	27 799 200	22 799 200	70 000 000	3,1
	City of Adana	Turkey	1300 TPD WTE	BOT 25 years	USD 133/MWh	September 2011	27 799 200	22 799 200	70 000 000	3,1
	City of Bangalore	India	500 TPD WTE	BOT 15 years	USD 110/MWh	End of 2011	17 424 000	13 424 000	50 000 000	3,7
	Terra Firma	India	500 TPD WTE	BOT 15 years	USD 110/MWh	End of 2011	17 424 000	13 424 000	50 000 000	3,7
	Srinivasa Gayathri Renewable Energy	India	500 TPD WTE	BOT 15 years	USD 110/MWh	End of 2011	17 424 000	13 424 000	50 000 000	3,7
	Libreville	Gabon	500 TPD WTE	BOT 25 years	To be negociated between 120 and 160 USD/MWH	September 2011	19 958 400	15 958 400	60 000 000	3,8
	Conakry	Guinea	500 TPD WTE	BOT 25 years	To be negociated between 120 and 160 USD/MWH	End of 2011	19 958 400	15 958 400	60 000 000	3,8
	Brazzaville	Congo	500 TPD WTE	BOT 25 years	To be negociated between 120 and 160 USD/MWH	End of 2011	19 958 400	15 958 400	60 000 000	3,8

OUR VISION

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Satarem's positionning: Walking the talk

Recognized expertise
↓
Cement plants and waste management

Developing countries

Role in local economic development
↓
Hiring and training local staff

Transfer of Know how

Focus on environmental priorities
↓
Carbon credit eligibility

Reflected in our contracts/ guarantees
↓
Turnkey contracts

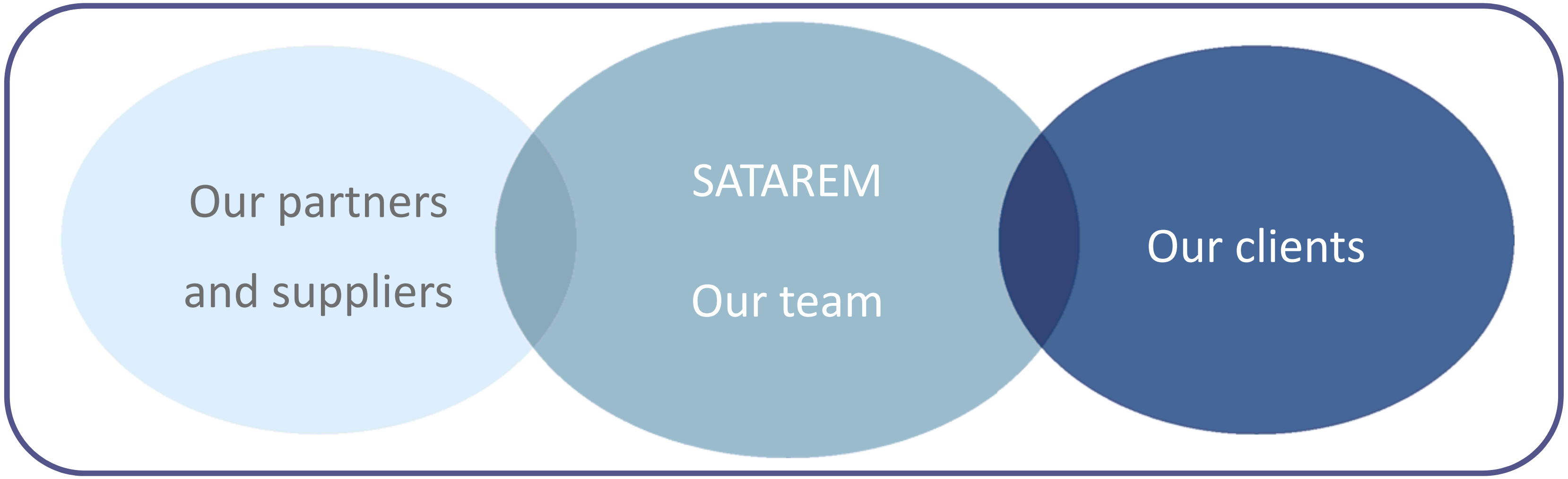
Performance and availability guarantee

SATAREM's vision of its impact on the environment

- SATAREM's core values include (i) minimizing the environmental impact due to our activities and (ii) supporting sustained economic growth

  - We adopt a unique positioning to ensure complete fulfillment of our commitments
  - We develop environmentally friendly projects and integrate local population to their implementation
  - We pay special attention to defending our values all along our value chain

Sharing the same values along the value chain



The values we share with our partners

Cement,
Waste,
Power
sector

Our difference

⇨ Respect and promotion of the highest environmental standards

⇨ Equipments strictly compliant with European Norms / standards (emissions, water contamination, noise...

⇨ Ensure eligibility to carbon credit mechanism where possible

A step further...

⇨ Development of environmentally friendly technologies

⇨ Low environmental impact projects

⇨ Local population empowerment through employment and training of local staff

⇨ Contribution to higher education of local engineering students to form next generations of plant managers