



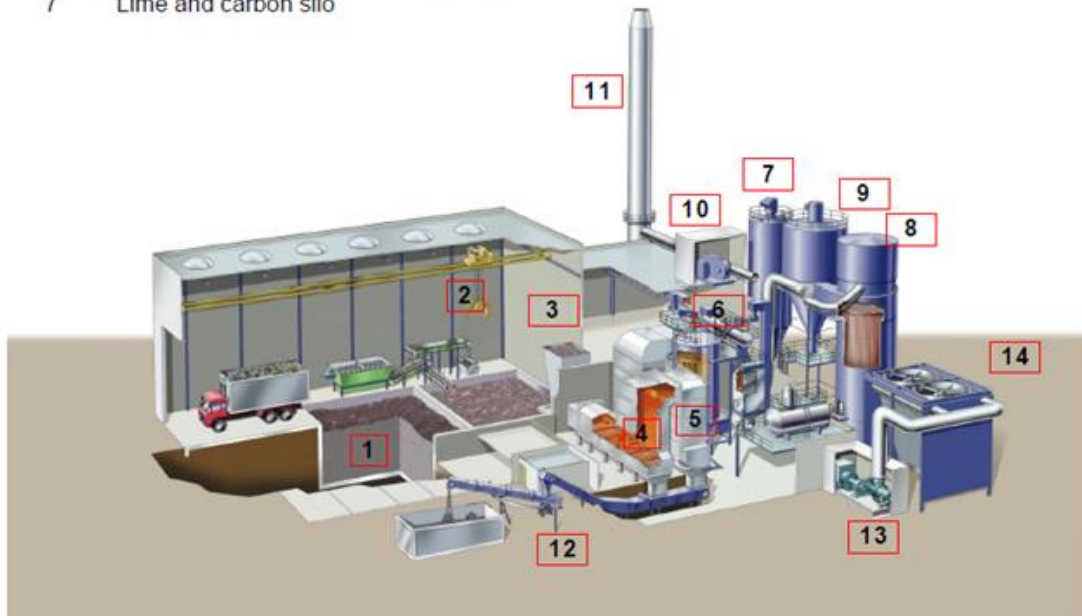
ENERGOS

Waste to Energy
Gasification Technology
25 years track record

Proven, Small-scale Energy Recovery from Residual MSW and Commercial & Industrial Waste

ENERGOS Energy from Waste Plant

- | | | | |
|---|--|----|-----------------------|
| 1 | Fuel bunker | 8 | Bag house filter |
| 2 | Fuel crane | 9 | Filter residue silo |
| 3 | Hopper | 10 | Flue gas fan |
| 4 | Primary chamber (Gasification) | 11 | Chimney |
| 5 | Secondary chamber (High temperature oxidation) | 12 | Bottom ash extraction |
| 6 | Heat Recovery Steam generator (HRSG) | 13 | Steam turbine |
| 7 | Lime and carbon silo | 14 | Air cooled condenser |



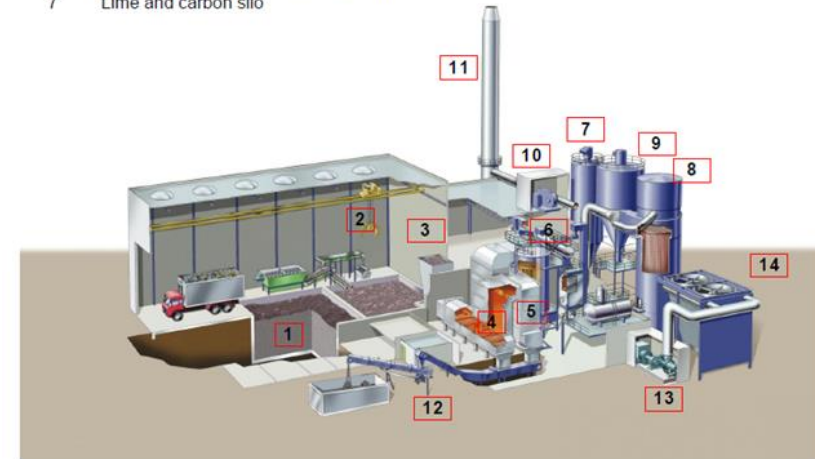
- ❑ Complies with IED 2010/75/EU directive and new BREF and BAT conclusions
- ❑ Designed for and operates at extremely low emissions without sophisticated flue gas cleaning
- ❑ 18 Gasifiers built, currently 11 Gasifiers in operation, processing total 474.000 tons of waste per year
- ❑ Plant availability of >7800 hours/year
- ❑ Proven Technology >900.000 operating hours since 1997
- ❑ Aftermarket services and spares parts since 1998

Core processes

- **Waste reception, pre-treatment and fuel transport:**
 - Waste reception (Waste bunker)
 - Pre - treatment of waste
 - Fuel storage (fuel bunker) and Fuel transport
- **Energos ACT / Advanced Conversion Technology:**
 - Thermal treatment (1. step / gasifier)
 - Heat production (2. step / oxidizer)
- Heat recovery / Boiler - HRSG
- Flue gas cleaning / Dry cleaning using lime and PAC
- Energy production / Condensing steam turbine & generator
- Ash handling
- Auxiliary Systems (water supply, fuel oil / gas supply, recovered water)

ENERGOS Energy from Waste Plant

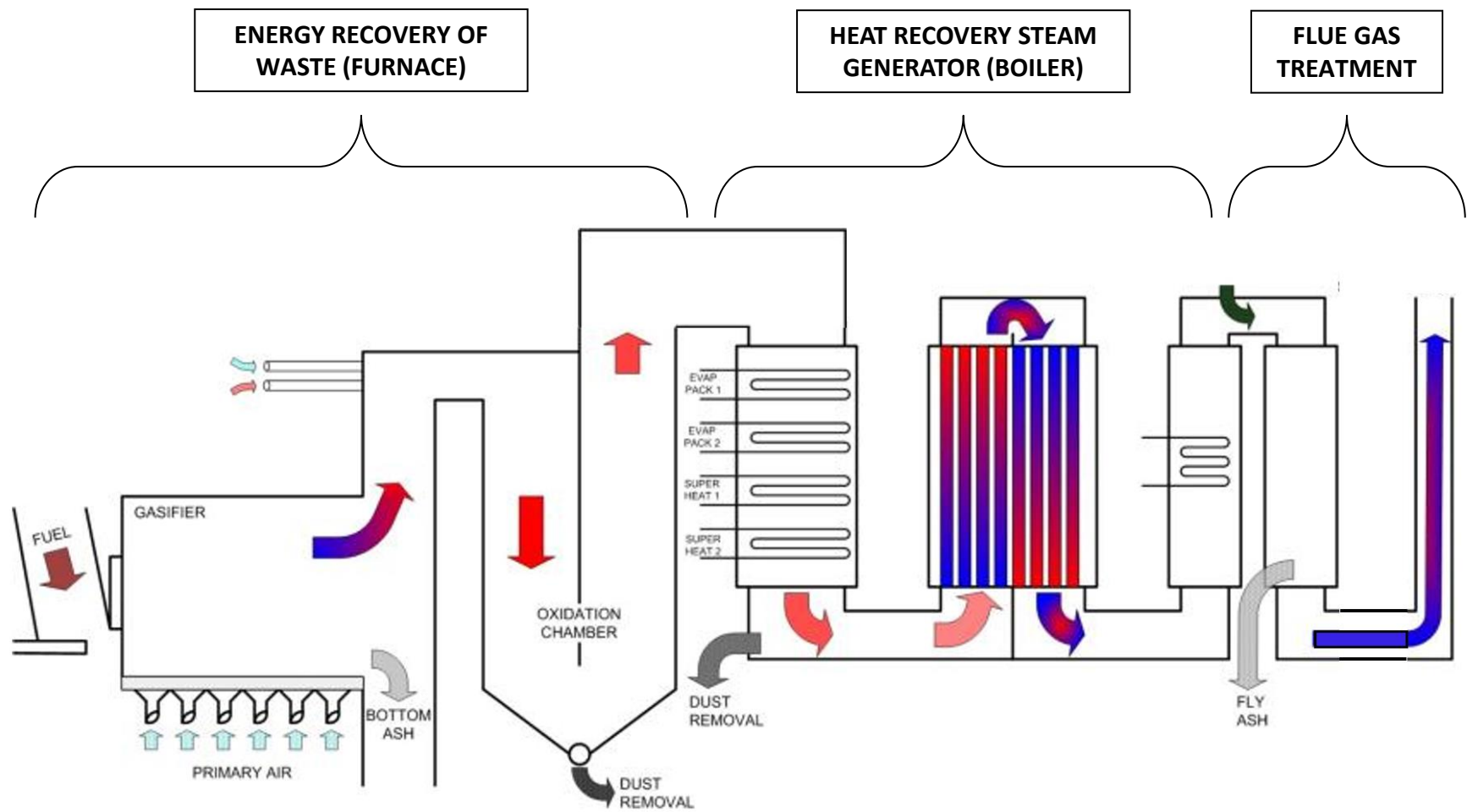
- | | | | |
|---|--|----|-----------------------|
| 1 | Fuel bunker | 8 | Bag house filter |
| 2 | Fuel crane | 9 | Filter residue silo |
| 3 | Hopper | 10 | Flue gas fan |
| 4 | Primary chamber (Gasification) | 11 | Chimney |
| 5 | Secondary chamber (High temperature oxidation) | 12 | Bottom ash extraction |
| 6 | Heat Recovery Steam generator (HRSG) | 13 | Steam turbine |
| 7 | Lime and carbon silo | 14 | Air cooled condenser |



- Fuel handling (1, 2, 3)
- Gasifier (4)
- Oxidizer (5)
- Boiler (6)
- Flue gas cleaning (7, 8, 9)
- Steam turbine (13)

ENERGOS Technology

The Process



Waste reception, pre-treatment and fuel transport

- **Waste reception:**
 - **Waste delivery:** Stored in the waste bunker (crane operation)
 - **Energos plants accepts different kinds of waste (*Energos waste specification*)**
- **Pre-treatment of waste:**
 - **Fuel production:** Shredding and (ferrous) metal rejection
 - **The fuel meets requirements in *Energos fuel specification***
 - **Fuel storage in the fuel bunker (crane operation)**
- **Fuel transport:**
 - **To gasifier via the fuel hopper by using cranes, conveyor belts or screws**
- **Fuel example:**
 - **Municipal solid waste (MSW); shredded or further pre - prosessed to RDF**

Fuel bunker with crane and fuel hoppers



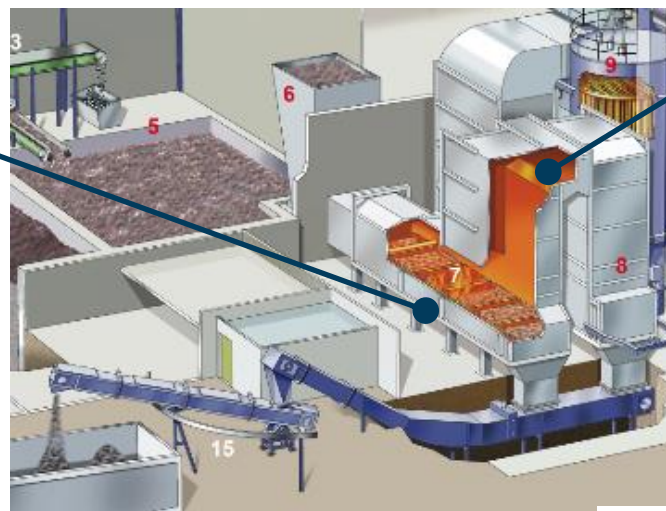
Energos Advanced Conversion Technology (ACT)

- Energos' Advanced thermal Conversion Technology (ACT):
 - Uses thermal conversion to produce syngas
 - ACT technologies are designed to recover energy in the form of electricity, heat, gas or fuels, principally using the processes of Pyrolysis or Gasification.
- The production of syngas occurs in the first part of the process, i.e. primary chamber:
 - Syngas typically contains hydrogen (H_2), carbon monoxide (CO) and lower hydrocarbons like methane (CH_4)
- The syngas is combusted in the second part of the process, i.e. secondary chamber.
- Energos Advanced Conversion Technology (ACT):
 - Energos' Advanced thermal Conversion Technology (ACT) is an Energy-from-Waste (EfW) technology that has been commercialized to make renewable and alternative energy products from a variety of waste materials.
 - Energos' technology can process virtually any carbonaceous material, converting it into forms of usable energy that can be consumed at the source (steam from boiler) or supplied to customers via a network (electricity or district heating)

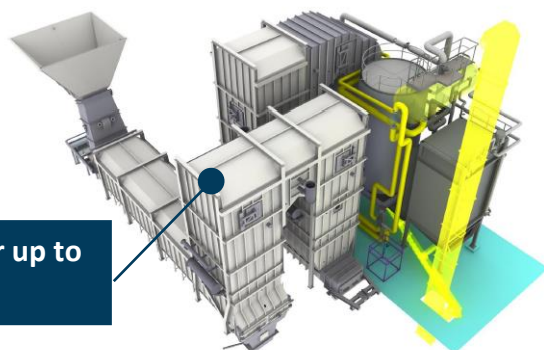
Primary chamber: Gasifier
Secondary Chamber: Oxidizer

A two-stage thermal process enables excellent process control eliminating need for sophisticated flue gas cleaning systems

1st stage is gasification which limits the supply of oxygen into the system to enable partial combustion providing enough heat to run the gasification process. Thermal treatment converts the fuel into syngas

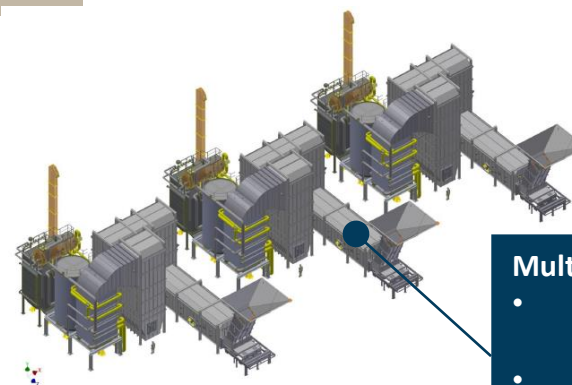


2nd stage is a controlled oxidation of the syngas generated in the gasification stage



Single Gasifier up to 144 ton/day

Modular Design - Nominal capacity 5 – 6 ton / hour / line



Multiple Lines

- 2 Gasifiers up to 288 ton/day
- 3 Gasifiers up to 432 ton/day

The Energos gasifier & EU Industrial Emissions Directive (2010/75/EU)

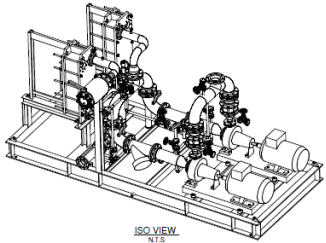
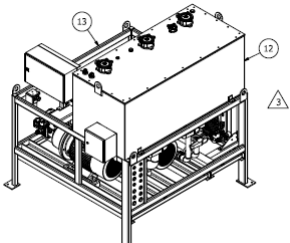
- Annex 1 – 5. Waste management / Category 5.2 Waste incineration:
 - 5.2 Disposal or recovery of waste in waste incineration plants or in waste co-incineration plants:
 - (a) non-hazardous waste with a capacity exceeding 3 tonnes per hour.
- Chapter IV / Article 42 on waste incineration and waste co-incineration:
 - “1. This Chapter shall apply to waste incineration plants and waste co-incineration plants which incinerate or co-incinerate solid or liquid waste.”
 - “If processes other than oxidation, such as pyrolysis, gasification or plasma process, are applied for the thermal treatment of waste, the waste incineration plant or waste co-incineration plant shall include both the thermal treatment process and the subsequent incineration process.”
- Article 3 / Definition (40) reads as follows:
 - ‘waste incineration plant’ means any stationary or mobile technical unit and equipment dedicated to the thermal treatment of waste, with or without recovery of the combustion heat generated, through the incineration by oxidation of waste as well as other thermal treatment processes, such as pyrolysis, gasification or plasma process, if the substances resulting from the treatment are subsequently incinerated;

Energos furnace with support systems (2 Box design)

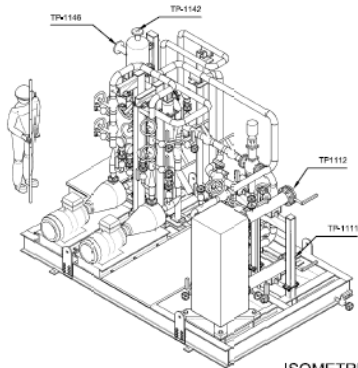


Installing the gasifier

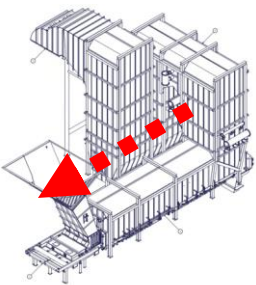
Hydraulic power pack



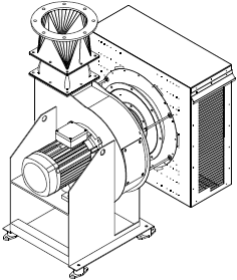
Water cooling system



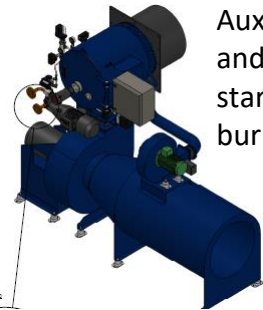
Thermal oil cooling system



Combustion, purge and flue gas fans



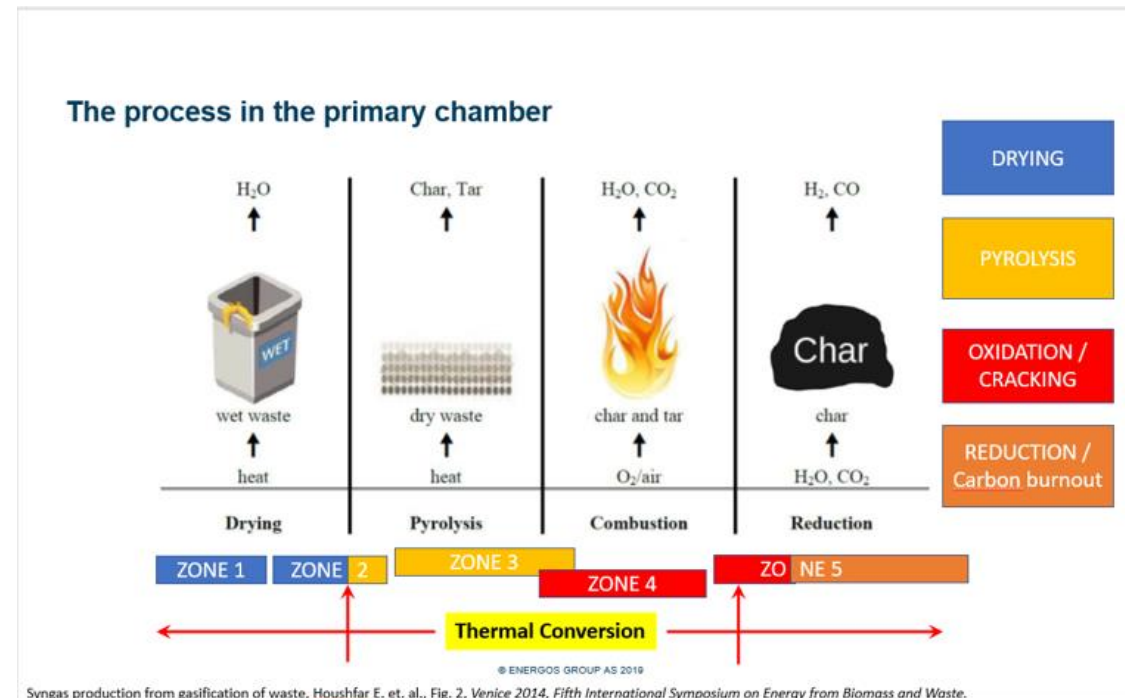
Auxiliary and start-up burner



- 1. stage: Gasifier
- 2. stage: Oxidizer

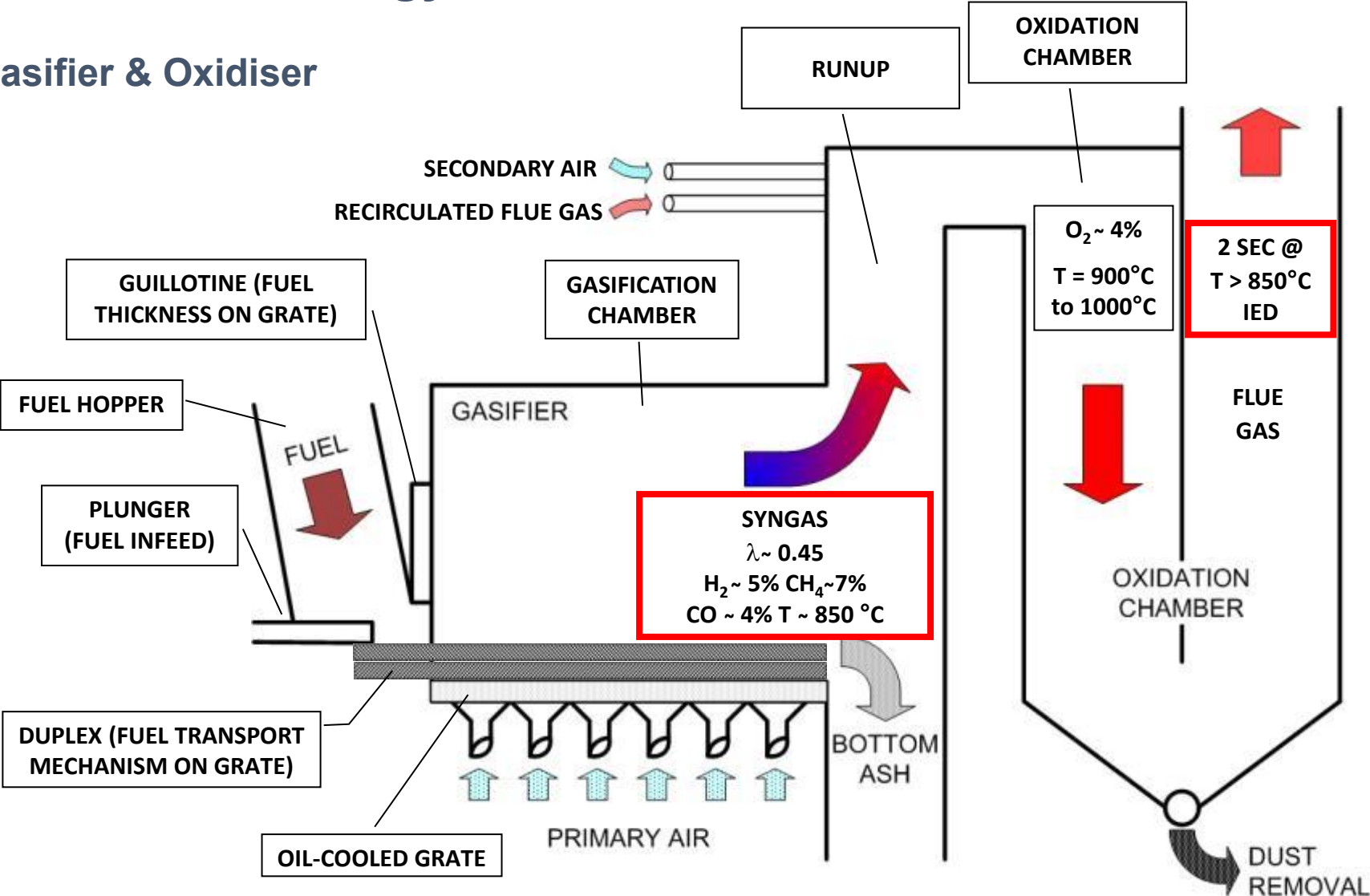
Primary chamber / Gasifier: Processes during gasification

- **Drying**
 - Removal of moisture
- **Pyrolysis**
 - Thermal conversion of the fuel
- **Oxidation**
 - Sub-stoichiometric reaction with oxygen
- **Cracking**
 - Larger molecules split into smaller
- **Reduction**
 - Conversion of the solid char

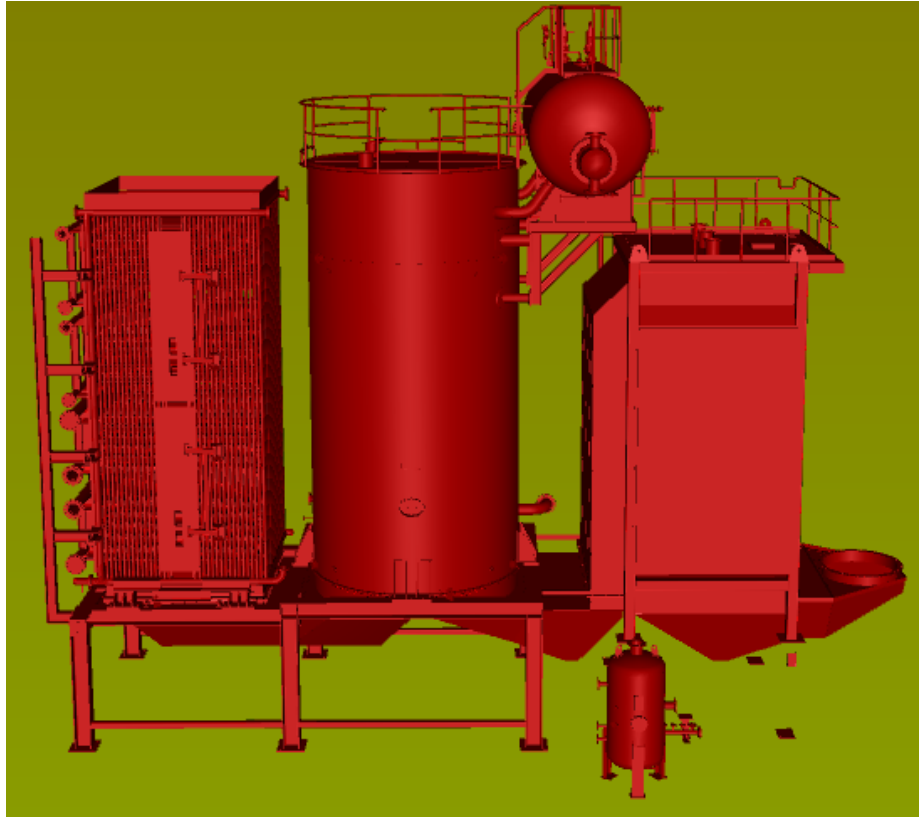


ENERGOS Technology

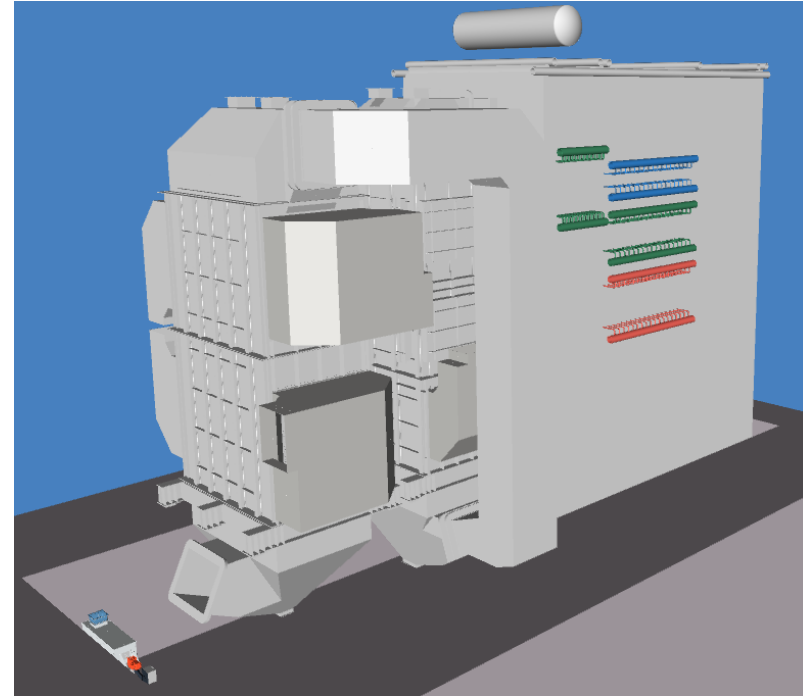
The Gasifier & Oxidiser



Heat Recovery Steam Generator (HRSG) / Boiler

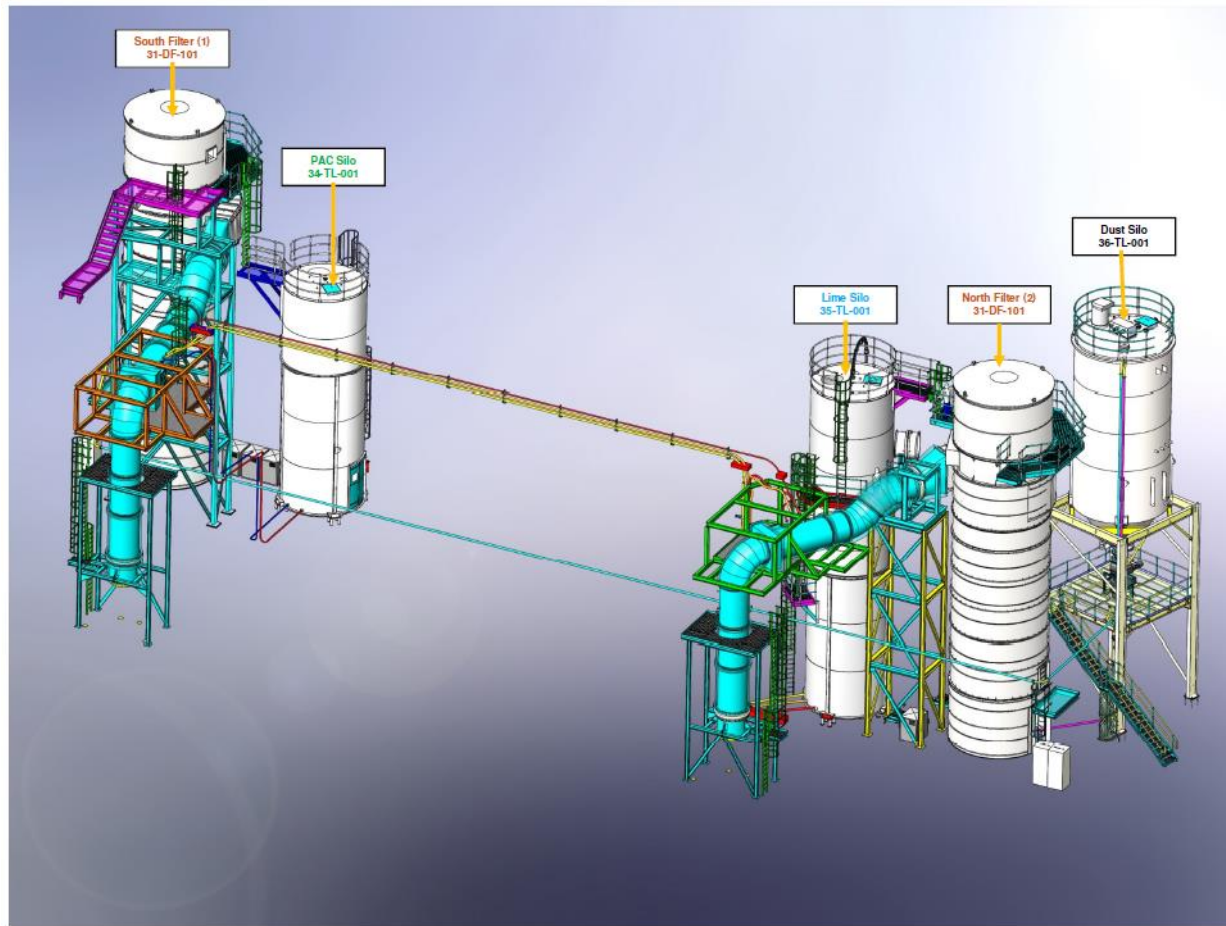


23 bara
(water tube, smoke tube)



42 bara
(water tube)

Flue gas cleaning



ENERGOS Technology

Technology designed to minimise emissions

Component (mg/m3, Dioxins ng/m3)	EU Limits 24h average New plant	EU Limits 24h average Existing plant	ENERGOS Line 1	ENERGOS Line 2
Dust	5	5	0.063	0.033
Hg	0.02	0.02	0.00019	0.000096
Σ As, Co, Cr, Cu, Mn, Ni, Pb, Sb & V	0.3	0.3	0.0063	0.0069
CO	50	50	< 9	< 9
HF	<1	<1	0.076	0.076
HCl	6	8	4.9	6.6
TOC	10	10	< 2	< 3
NOx	120	150	44	47
NH3	10	10	0.75	0.62
SO2	30	40	19	6.2
Dioxins	0.06	0.08	< 0.002	< 0.002

ENERGOS Sarpsborg Avfallsenergi Licence
Measurement by notified body May 2022



Low emissions without a sophisticated flue gas treatment system (one bag filter only)



Low and stable Nitrogen Oxides (NO_x) without a de-NO_x'er (no SNCR/SCR)



Low and stable Carbon Monoxide (CO)



Low and stable Total Organic Compounds (TOC)

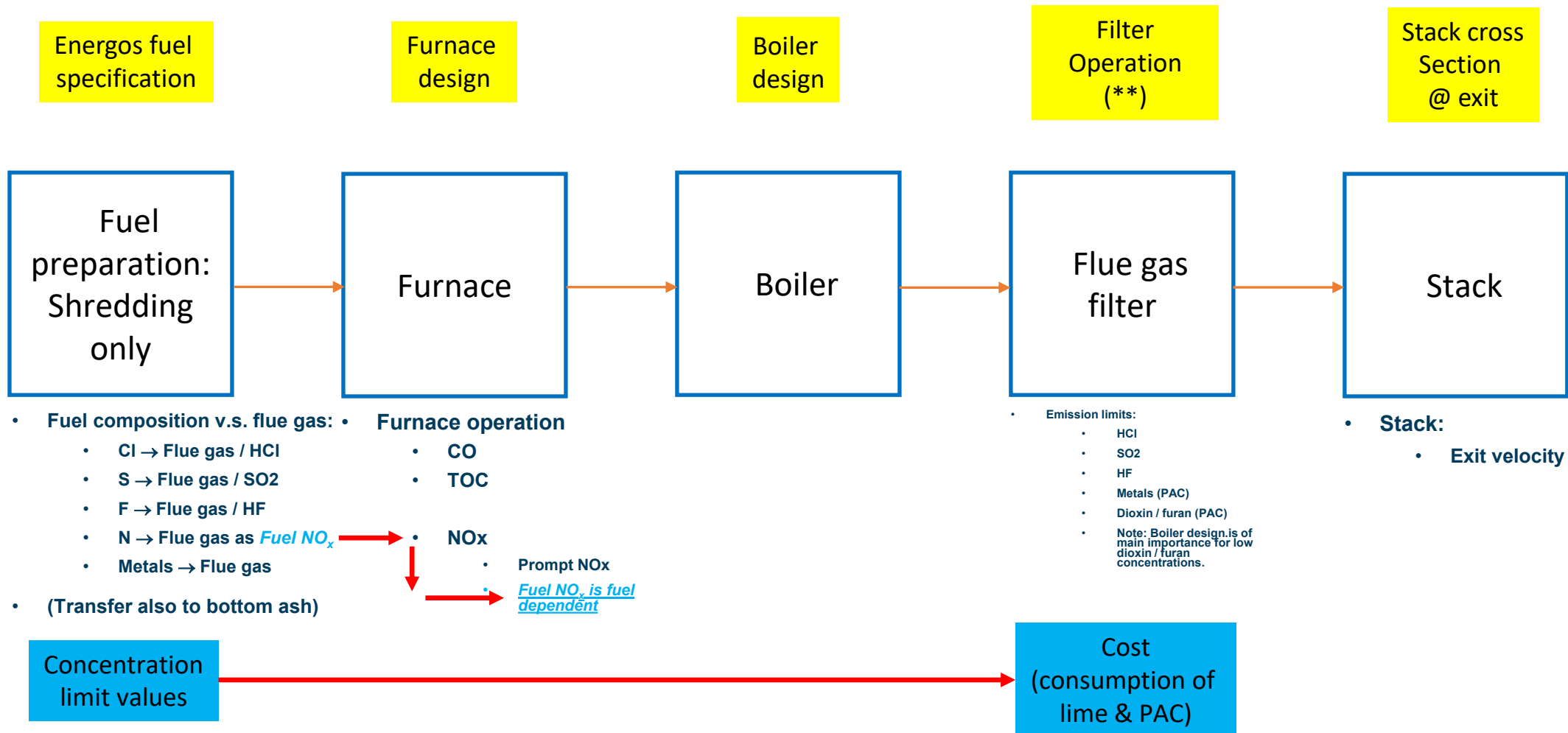


Low carbon content in bottom ash (less than 3% TOC)



ENERGOS

Energos process and mechanisms related to emissions



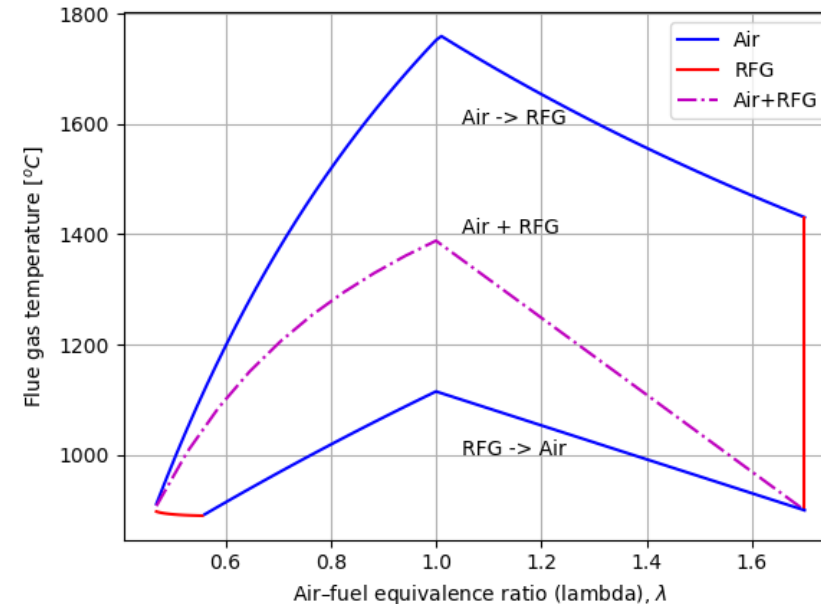
Flue gas emissions

- **CO, TOC**

Good mixing in the combustion zone.
Flue gas residence time > 2 s @ 850°C.
(IED Article 50)

- **NO_x**

Staged combustion with recirculated flue gas
for temperature control and combustion air
for O₂ control.



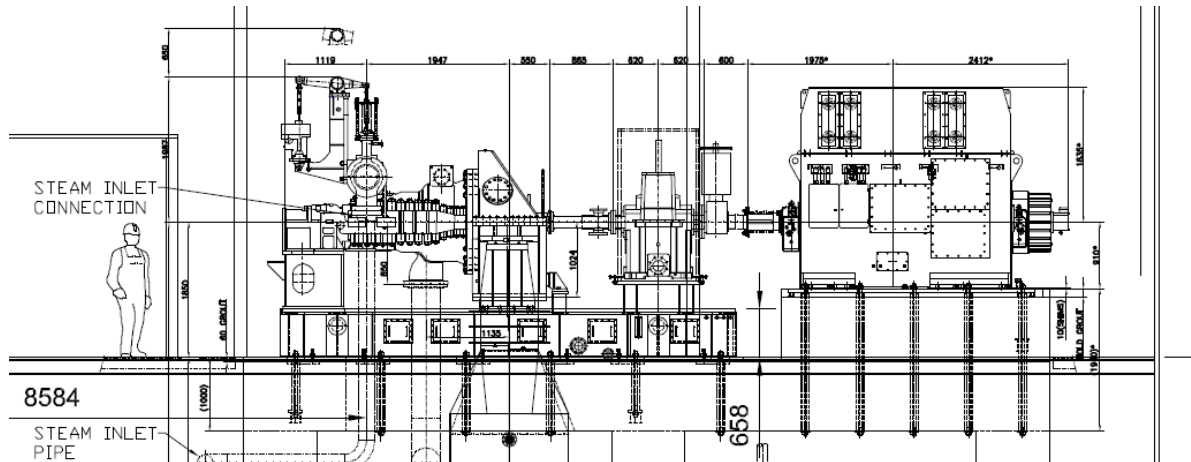
Avoid thermal NO_x formation: keep temperature < 1300 – 1400°C

Allow NO_x reduction to take place at sub stoichiometric conditions (residence time @ $\lambda < 1$ and 1000°C < T < 1200°C)

Electrical power production: Condensing Steam Turbine & Generator

- Superheated steam from the boiler system
- Exhaust steam goes to ACC

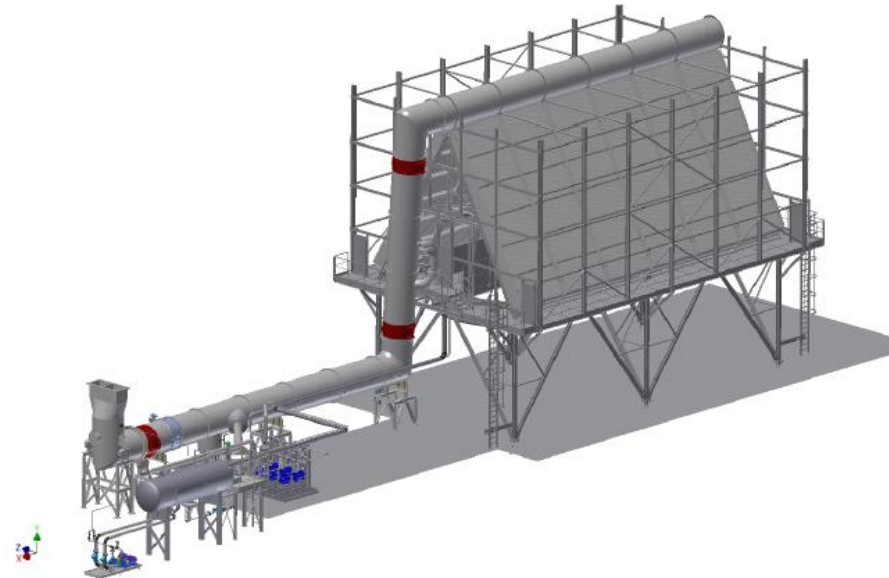
From layout drawing



Real turbine and generator

ACC – Air Cooled Condenser / A – frame design

- Cooling of the steam that exits from the turbine
- Condensate returns to feedwater tank



Disposal of ash

- **Bottom ash (gasifier) and Fly ash (oxidizer):**
 - Non-hazardous waste



Bottom ash

- **Filter dust (flue gas cleaning):**
 - Hazardous waste
- **Boiler ash:**
 - Hazardous waste

