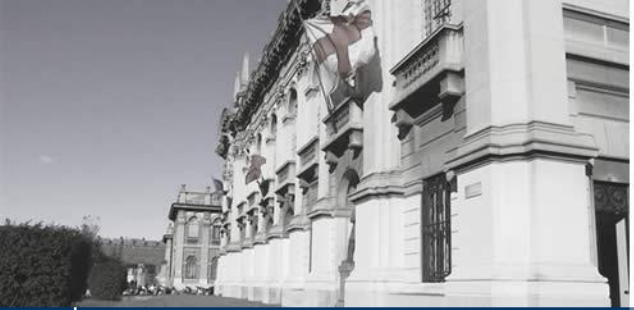

POLITECNICO DI MILANO





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A comparative analysis of two waste gasification technologies

Stefano Consonni

Dipartimento di Energia - Politecnico di Milano / LEAP Laboratory

Waste Gasification

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Waste gasification vs. conventional Waste-To-Energy: A comparative evaluation of two commercial technologies

Stefano Consonni *, Federico Viganò

Department of Energy, Politecnico di Milano, Via Lambruschini 4, 20156 Milan, Italy
LEAP (Laboratorio Energia Ambiente Piacenza), Via Bixio 27, 29100 Piacenza, Italy

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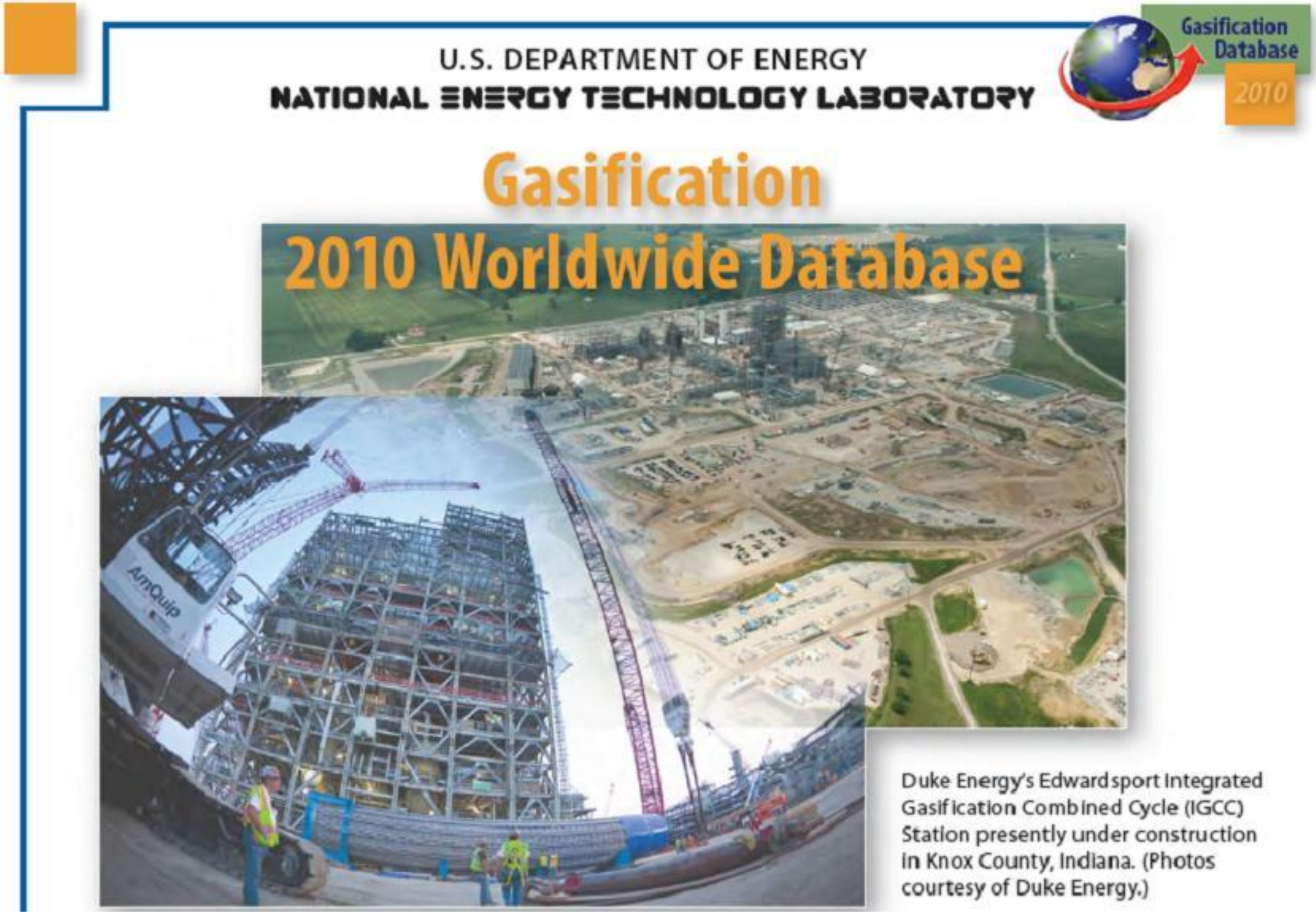
ABSTRACT

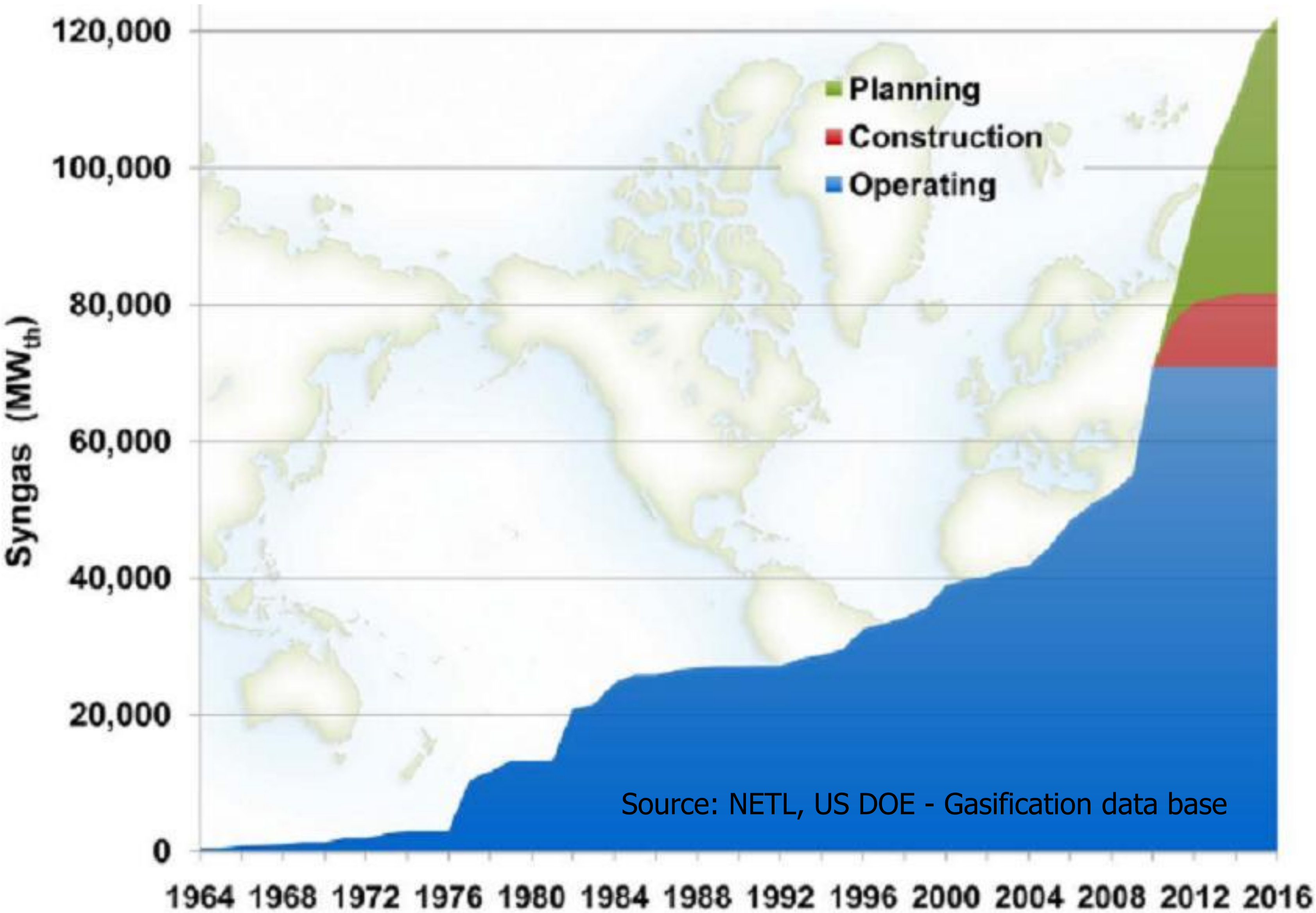
A number of waste gasification technologies are currently proposed as an alternative to conventional Waste-to-Energy (WtE) plants. Assessing their potential is made difficult by the scarce operating experience and the fragmentary data available. After defining a conceptual framework to classify and assess waste gasification technologies, this paper compares two of the proposed technologies with conventional WtE plants. Performances are evaluated by proprietary software developed at Politecnico di Milano and compared on the basis of a coherent set of assumptions. Since the two gasification technologies are configured as "two-step oxidation" processes, their energy performances are very similar to those of conventional plants. The potential benefits that may justify their adoption relate to material recovery and

Gasification is NOT a new technology !



Duke Energy's Edwardsport Integrated Gasification Combined Cycle (IGCC) Station presently under construction in Knox County, Indiana. (Photos courtesy of Duke Energy.)

Cumulative capacity and planned growth



Waste gasification

- **Motivations shared with gasification of fossil fuels:**
  - generation of high-quality energy carrier
  - adoption of internal combustion engines
  - syngas clean-up ahead of combustion
  - production of highly-valued chemicals
  - production of liquid fuels / hydrogen
- **Additional motivations:**
  - reducing conditions limit generation of dioxins/furans (although emissions depend on processes downstream)
  - production of inert solid residues
  - gas-phase combustion easier to control and operate
- **Problems:**
  - feedstock size --> mechanical pre-treatment
  - sensitivity to feedstock properties --> reliability, operability
  - (very) low heating value of feedstock
  - small scale --> oxygen-blown gasification very costly

A crucial feature of waste gasification

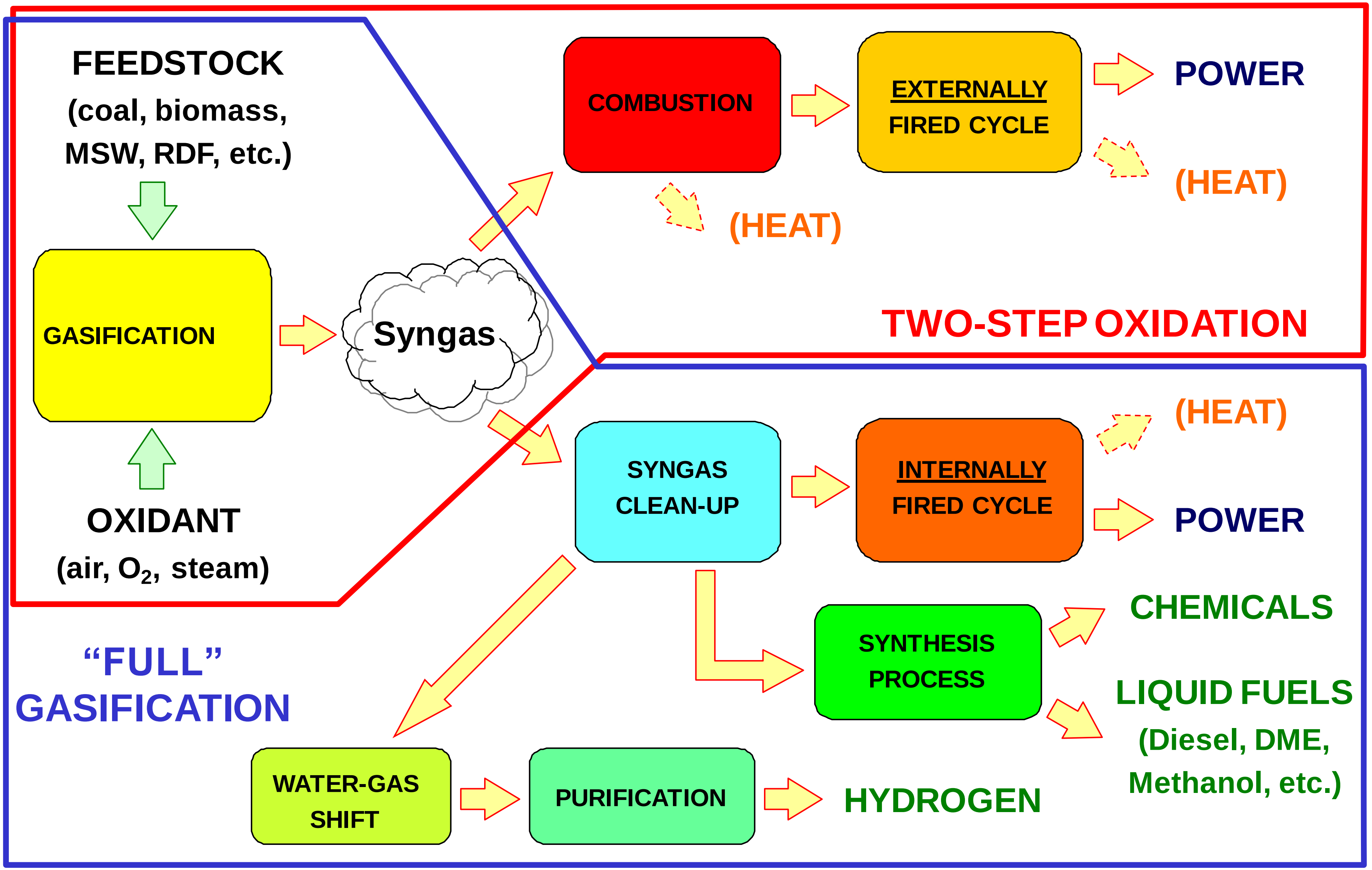
- **Cleaning the syngas is so difficult and costly**
- **Recovery thermal energy from syngas is so difficult/costly**
- **Pressurizing the gasification island is so challenging**
- **Scale is typically so small**

that rather than producing power by high-efficiency systems like Combined Cycles or combustion engines

waste gasification plants typically adopt the same power system of conventional combustion plants: steam cycle

by doing so however, the efficiency achievable by waste gasification is seriously hampered

Basic gasification-based concepts



Waste gasification plants

In summary, <u>nearly all waste gasification technologies proposed are "two-step oxidation" processes</u> coupled with the same power system of conventional combustion plants: externally-fired steam cycle

↓

At most, waste gasification plants can reach energy performances close to those of combustion plants

Actual performances are likely to be lower, due to:

- **High consumption for auxiliaries**
- **Loss of (part of) thermal energy in the syngas**
- **Higher thermal losses due to less favourable dimension / shape of components operating at high temperature**

Summary of Gasification vs Combustion

	potential advantage / benefit of gasification vs. combustion	related drawbacks / issues that hinder the benefit of gasification
1	a) Syngas is easier to handle, meter and control than MSW b) homogenous, gas-phase combustion of syngas is easier and can be better controlled	a) syngas is highly toxic and explosive --> safety issues b) two-step conversion (gasification + syngas combustion/conversion) --> complexity, cost, reliability issues
2	Reducing conditions give: (i) better solid residues (metals) (ii) less dioxins, furans and NO_X	if syngas is eventually combusted, dioxins, furans and NO_X are still an issue
3	Syngas can be used, after proper treatment, in highly efficient internally-fired cycles (gas turbines, combined cycles, Otto engines)	a) syngas treatment is complex and costly b) due to losses in gasification and syngas clean-up, energy conversion efficiency is low c) at the small scale relevant to waste treat-ment, efficiency of internally-fired cycles is low

technological issue	environmental issue	energy issue

Waste gasification vs waste combustion

	potential advantage / benefit of gasification vs. combustion	related drawbacks / issues that hinder the benefit of gasification
4	syngas can be used, after proper treatment, to generate high-quality fuels or chemicals	a) required syngas treatment very demanding and costly b) at the small scale typical of waste treatment plants, fuel/chemicals synthesis is extremely expensive
5	gasification at high pressure enhances the opportunities to increase energy conversion efficiency and reduce costs	pressurized waste gasification poses formidable challenges and has not been attempted by any technology developer

economic issue	technological issue

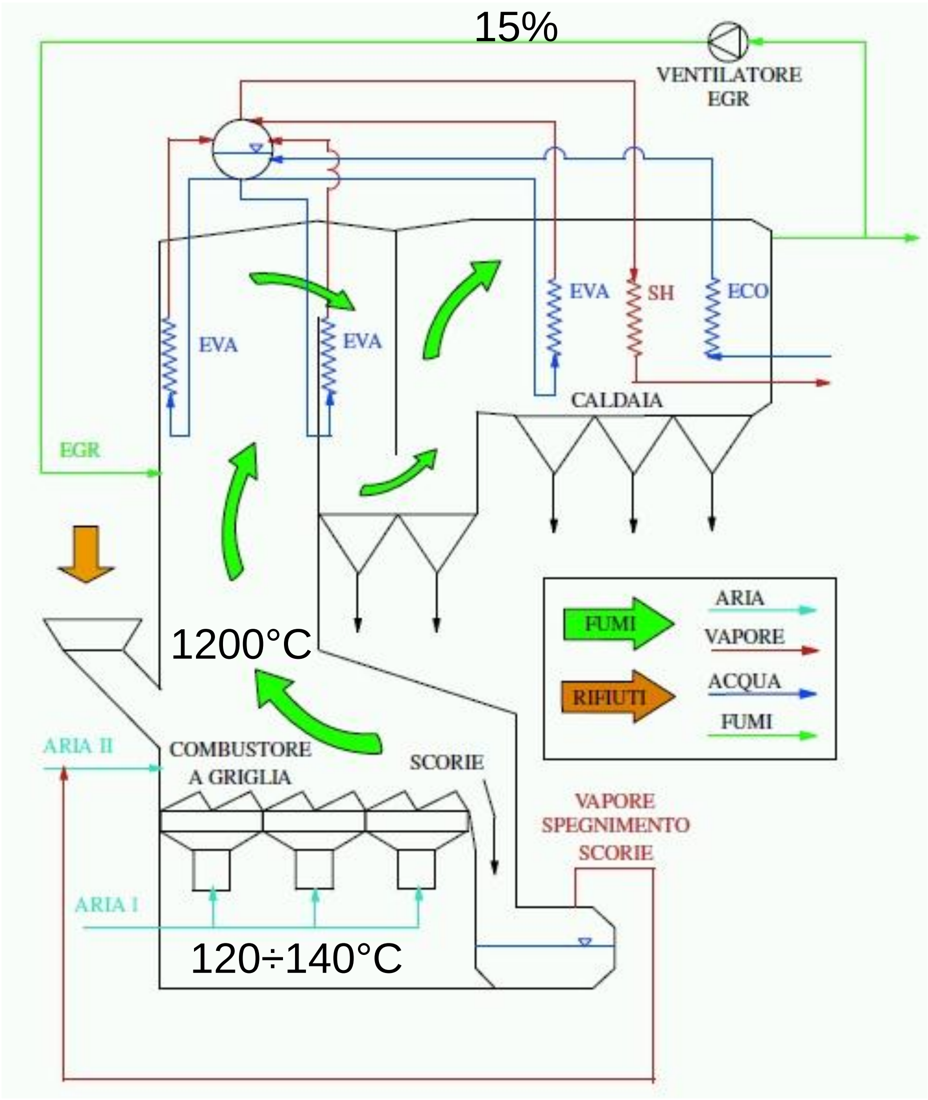
no free lunch …

Technologies considered

Technology:	Conventional WtE with grate combustor	Fluidized bed (Ebara) + syngas combustion	Grate gasifier (Energos) + syngas combustion
Distinctive aspects	-	vitrified solid residues	NO_X control
Thermal treatment	Direct combustion	Two-step oxidation	Two-step oxidation
Oxidant	Air	Air	Air
Gasifier	-	Fluidized bed, Adiabatic	Grate, Adiabatic
Combustion conditions	heterogeneous, solid-gas	heterogeneous, solid-gas	homogeneous, gas-phase
Combustor	Cooled by boiler tube banks	Cooled by stand-alone circuit	Adiabatic
Flame temperature	below ash melting	above ash melting	below ash melting
Boiler	Integrated with combustor	Heat Recovery Steam Generator (HRSG)	Heat Recovery Steam Generator (HRSG)
Power cycle	steam Rankine cycle	steam Rankine cycle	steam Rankine cycle
Cycle parameters	variable with plant size	p_{ev} 30 bar T_{sh} 325°C	variable with plant size
Syngas cleanup	-	Not desirable	Not applied but potentially applicable

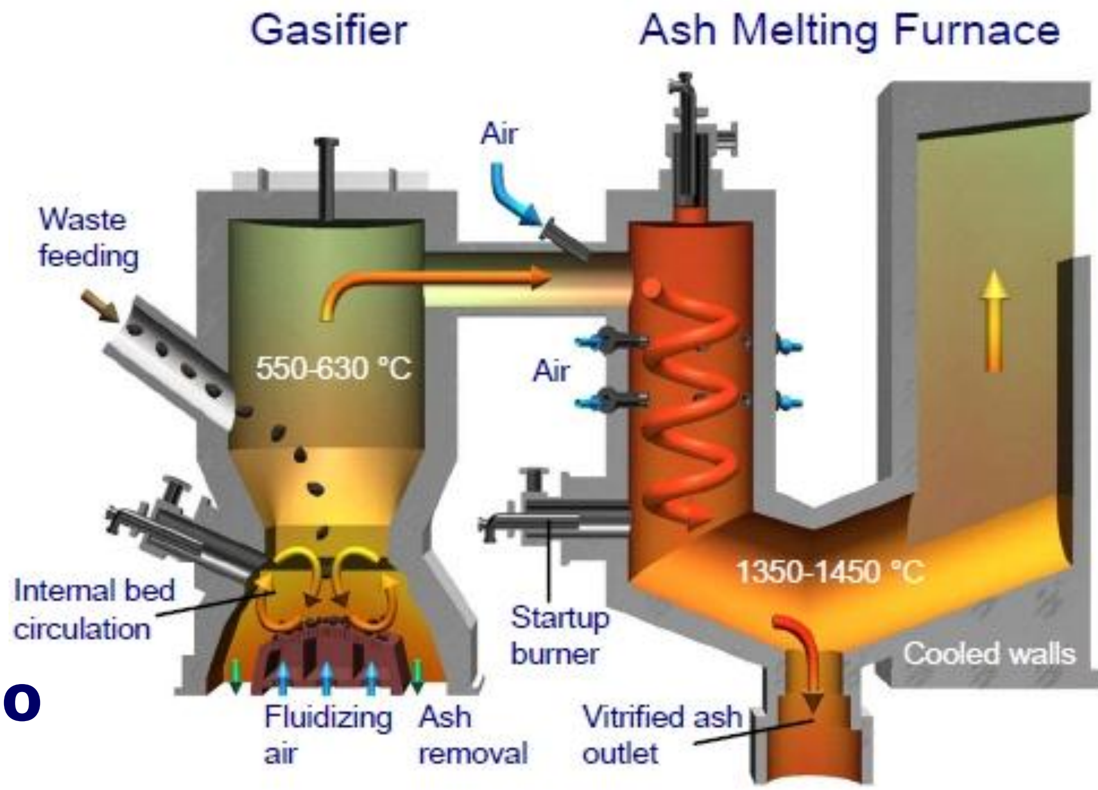
Conventional Grate (CG) combustor

- Well-known technology
- moderate EGR
- Integrated boiler
- Aux consumption calibrated with data of actual plants

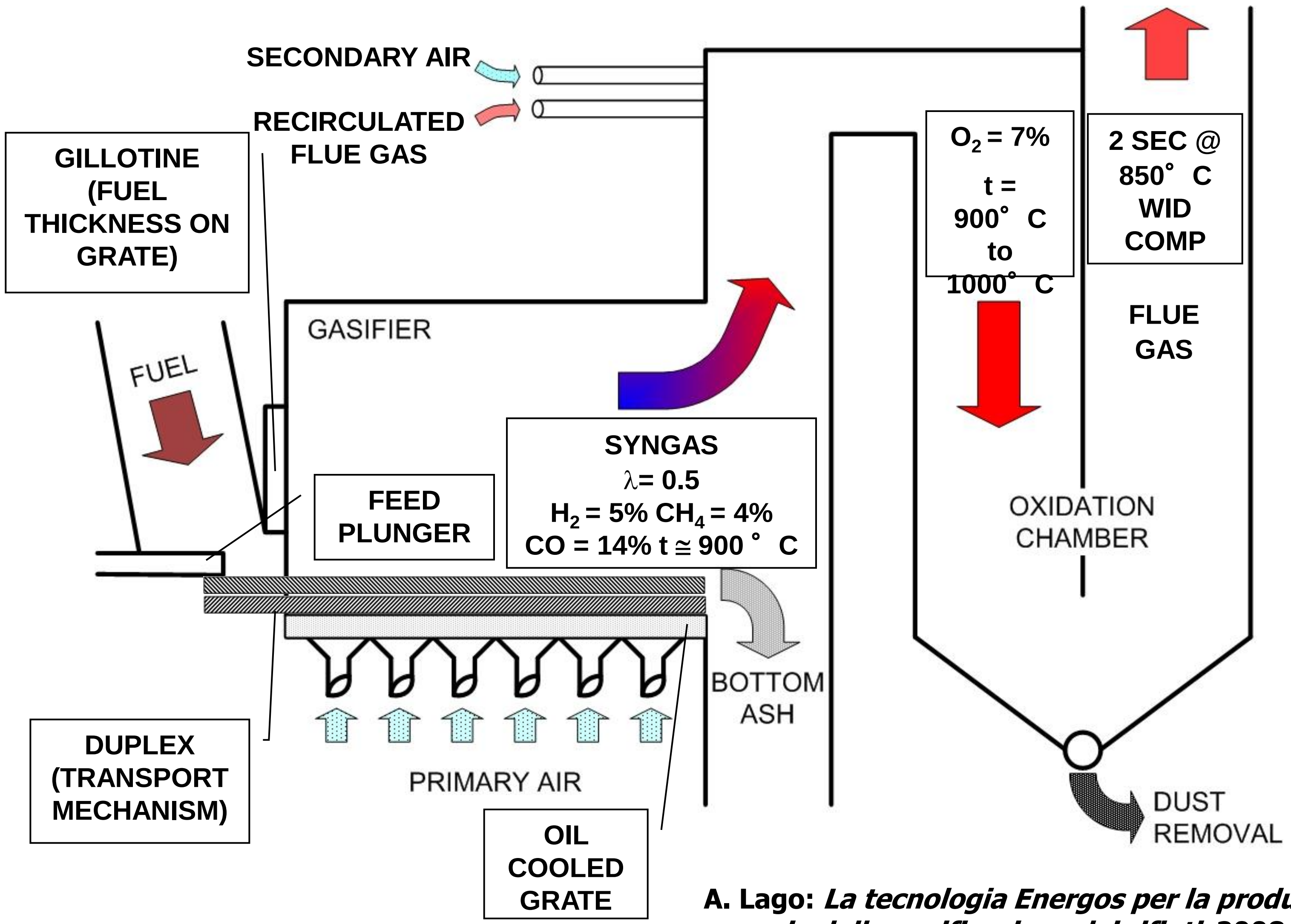


Low Temperature Fluidized Bed Gasifier (LTFBG): Ebara

1) Fluidized bed gasification at ~600° C
2) Adiabatic combustion of syngas (+solids) at ~1400° C
3) Heat Recovery Steam Generator (HRSG)
4) Flue gas treatment downstream of HRSG
5) Heavy ashes and metals discharged from gasifier
6) Vitrified slag discharged from combustor
7) Medium-small scale: 10-100.000 tonn/anno



High Temperature Grate Gasifier (HTGG): Energos

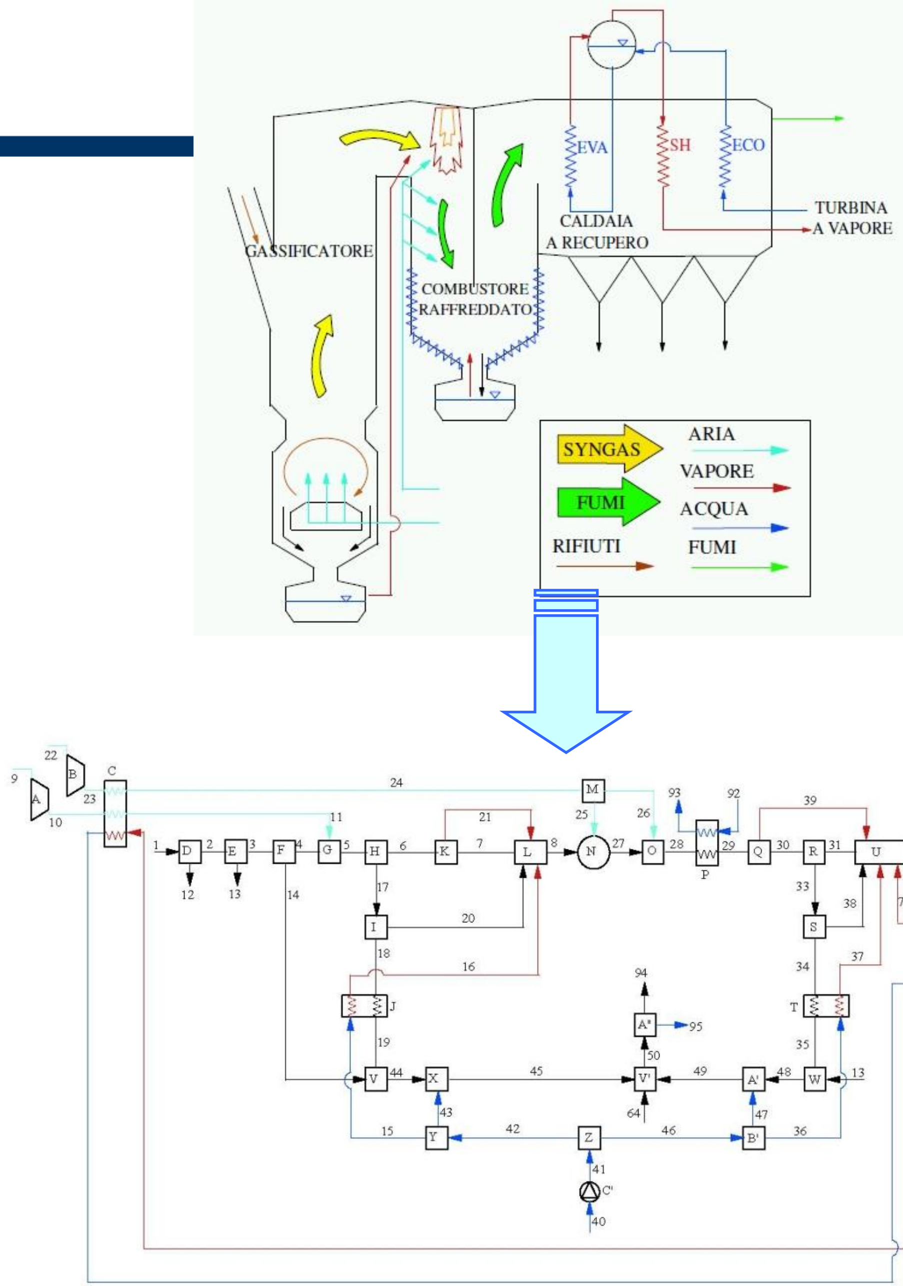


A. Lago: ***La tecnologia Energos per la produzione di energia dalla gasificazione dei rifiuti*, 2008**

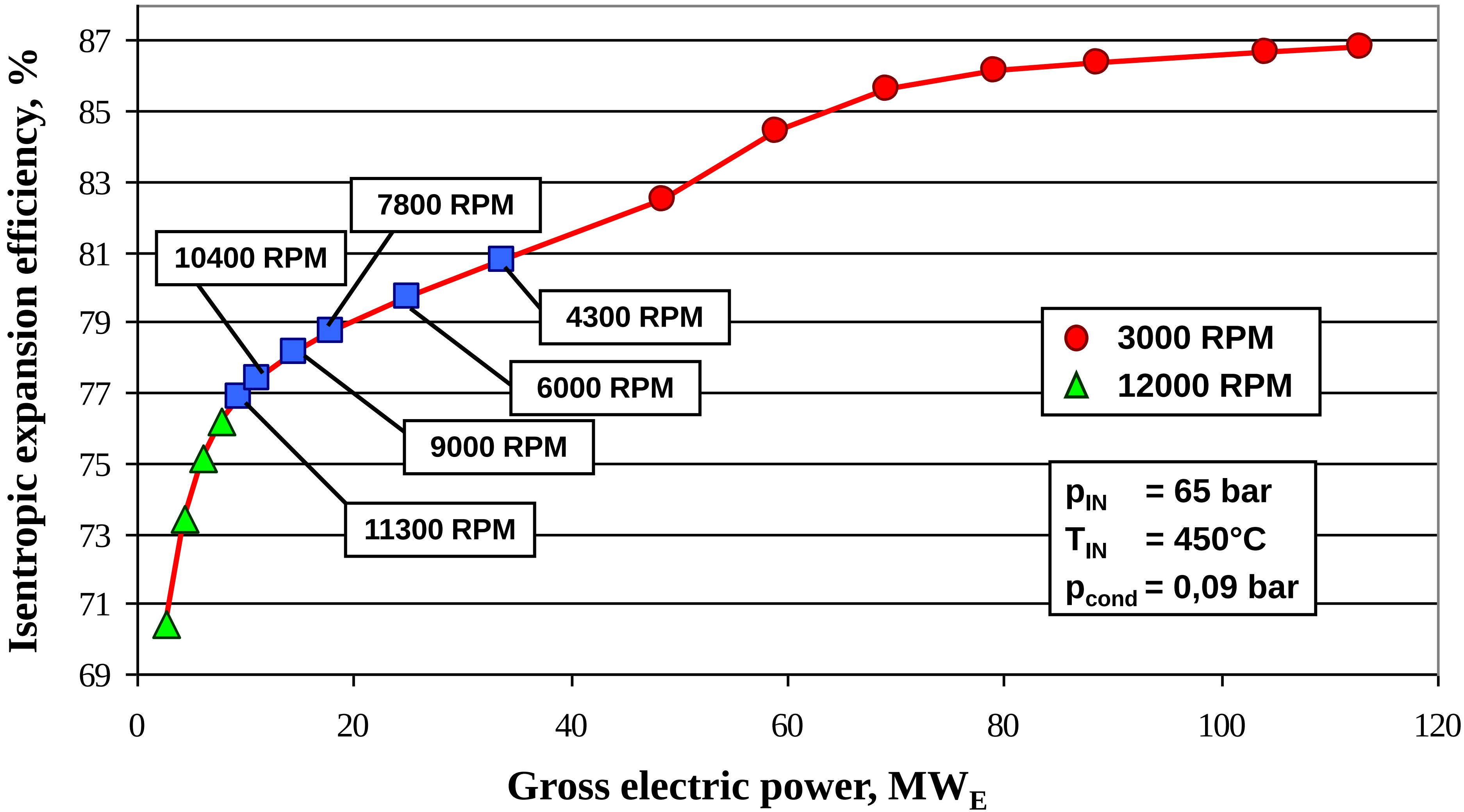
Methodology

Software GS:

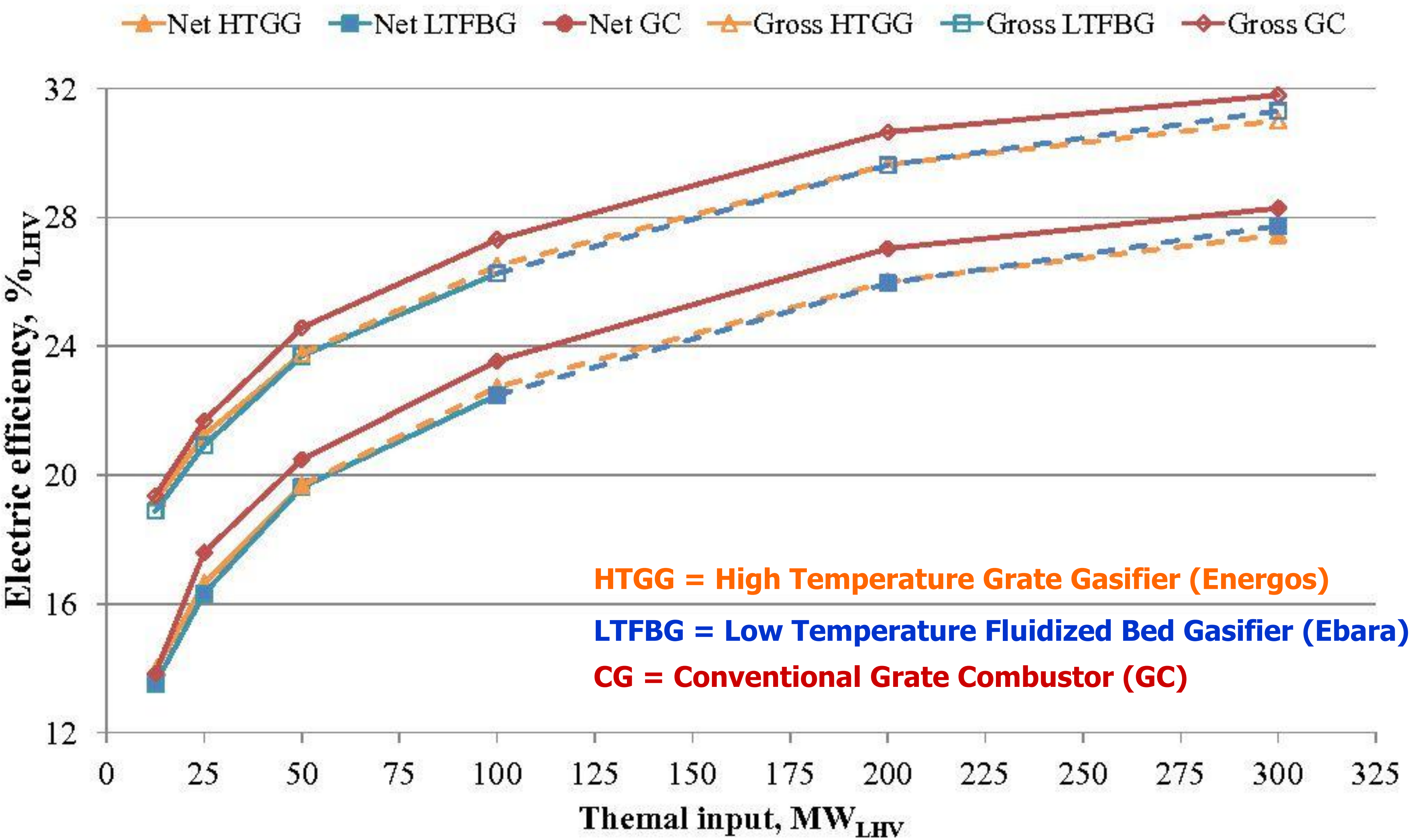
- Developed at Dept. of Energy of Politecnico di Milano
- Designed for the simulation of energy conversion plants
- Solves mass/energy balances
- Plant to be simulated is defined from a number of basic elementary components
- Iterative calculation until convergence is reached
- Syngas composition is assumed at equilibrium



Scale effects: steam turbine efficiency



Efficiency vs plant size



HTGG = High Temperature Grate Gasifier (Energos)

LTFBG = Low Temperature Fluidized Bed Gasifier (Ebara)

CG = Conventional Grate Combustor (GC)

Environmental impact

	HTGG (Energos)	LTFBG (Ebara)	GC (Grate Combustor)
NOx	Homogeneous combustion, high EGR	High combustion temperature	Heterougeneous combustion, moderate EGR
Dioxins / Furans	Intermediate combustion temperature	High combustion temperature	Intermediate combustion temperature
Bottom ash	may need treat-ment, reduced species	Vitrified, recyclable	may need treat-ment, oxidized species

In all cases, heavy flue gas treatment is mandatory. Emissions and environmental impact depend on features of flue gas treatment

Conclusions - 1

- **Much more than for the gasification of solid fuels, the prospects of waste gasification are subject to a number of technical/economic uncertainties**
- **Additional motivations with respect to the gasification of fossil fuels:**
  - **easier combustion / emission control**
  - **more favorable characteristics of solid residues**
- **However, there are additional issues:**
  - **very high sensitivity to feedstock characteristics**
  - **small scale**
  - **complexity/cost of syngas clean-up**
  - **low conversion efficiencies**

Conclusions - 2

- Technologies offered by Energos ed Ebara consist of two-step oxidation --> energy performances are similar. although lower, to the ones of conventional combustion plants
- Similarly to grate combustion plants, energy performance
  - is determined by the parameters of the steam cycle
  - crucially depends on plant size
- Emissions are mainly determined by the characteristics of the flue gas treatment system
- Specific advantages of the two technologies analyzed are:
  - relatively good NOx control (HTGG - Energos)
  - solid residues are inert, vitrified slag (LTFBG - Ebara)

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WTERT 2012 Bi-Annual Conference
Columbia University
New York, 18-19 October 2012

The MatER Study Center and the path toward sustainable waste management

***Stefano* Consonni**

Director of MatER Study Center
Dept. of Energy – Politecnico di Milano

Prejudices and misunderstandings on waste management

- **Confusion between technical and industrial feasibility**
- **The ideological battle against landfills and incinerator as the last Crusade of Good against Evil**

Widespread need for a scientifically and technically sound reference which - <u>aside from ideology and prejudice</u> - can contribute to the definition of intelligent and sustainable waste management strategies

The MatER Research Center

The MatER (Material and Energy from Refuse) is a project undertaken by LEAP Research Center with the scientific support of the Department of Energy and DIIAR of Politecnico di Milano

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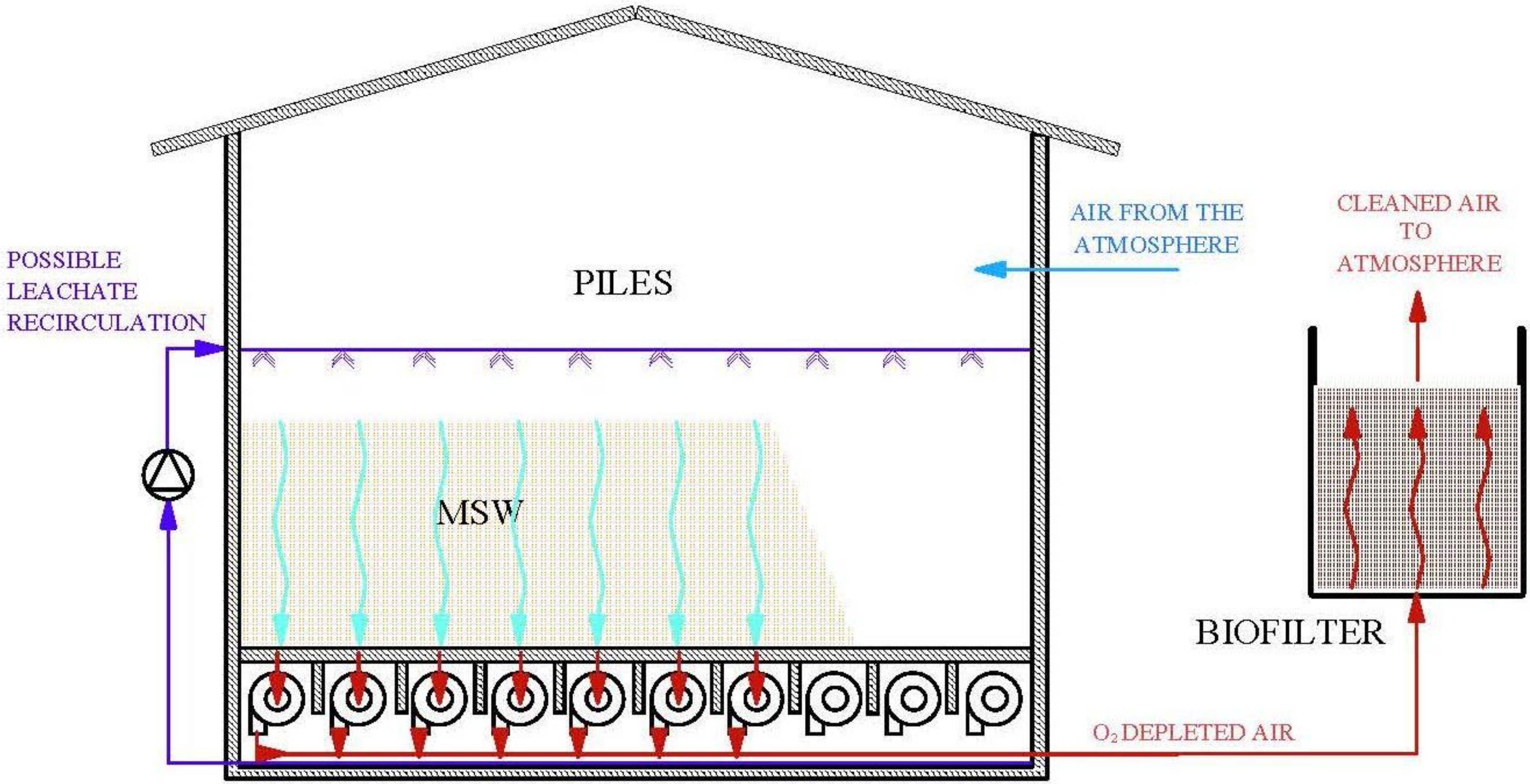
www.mater.polimi.it

The goals of MatER

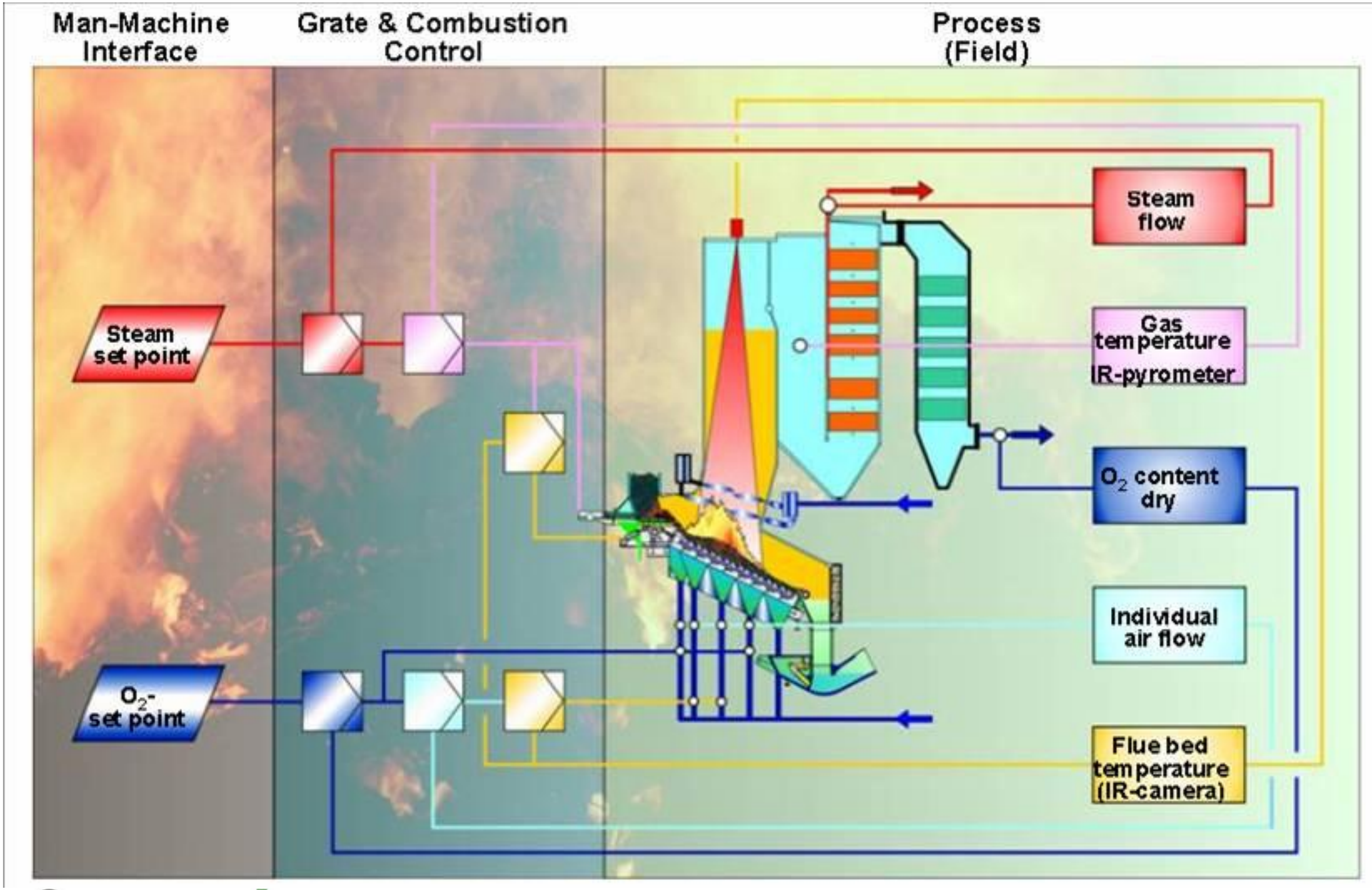
- Promote and carry out scientific research
- Arrange meetings, workshops, congresses
- Generate scientific publications
- Facilitate interaction among researchers, operators, proponents of sensible options for waste management
- Monitoring and data collection --> update performance indicators of recovery from waste
- Assess processes, technologies and strategies for the recovery from waste
- Education and training
- Contribute to the development of new regulations

GUIDELINE: SUSTAINABILITY

Reseach areas: bio-drying



Research areas: advanced control of WtE plants



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Research areas: recovery from solid residues

Treatment of solid residues from WtE plants and multi-material collection for subsequent use in production cycles

Project development

Regulatory Framework → State of the art of residues treatment → Use of treated residues → Innovative processes → Chains Tech.-econ. assessment

- Regulatory Framework
  - UE & ITA Directives
- State of the art of residues treatment
  - WtE residues recovery
  - Glass residues recovery from SC
- Use of treated residues
- Innovative processes
- Chains Tech.-econ. assessment
  - Ener. and env. balances
  - Economic analysis

Research areas / topics

- Combustion modeling and control
- Modeling and simulation of bio-drying and MBT plants
- Advanced configuration of steam cycles for electricity production or cogeneration
- Design and reliability of mechanical treatment plants
- Techniques and practices to increase the reliability of WtE plants
- Anaerobic digestion of organic fraction
- Indicators of recycling efficiency
- Indicators of energy recovery efficiency (R1)
- Comparative evaluation of recovery paths, e.g. MBT+RDF production vs WtE

The current MatER team

- Politecnico di Milano (Dept. of Energy and DIIAR)
- Federambiente
- A2A SpA
- Acegas-Aps SpA
- HERAmbiente SpA
- Iren Ambiente SpA
- Veolia Servizi Ambientali SpA
- Veritas SpA

The international network

MatER is the Italian sister organization of the Global WTERT (Waste-to-Energy Research and Technology) Council

Under construction:

WTERT-France; WTERT-India; SUR-Argentina; SUR-Mexico; SUR-Thailand

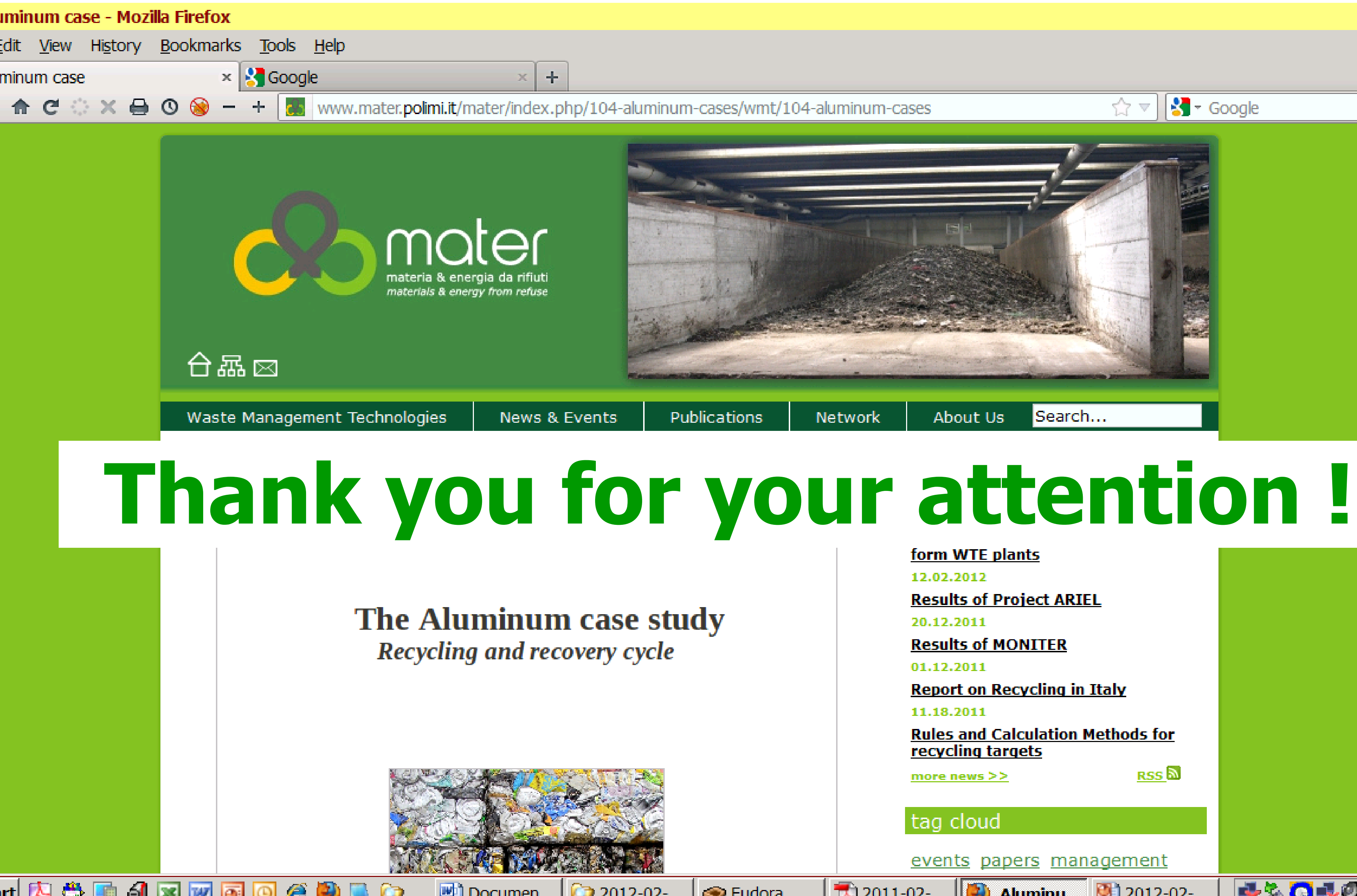
(SUR: Consortium for Sustainable Use of Resources)

MatER website

Thank you for your attention !

www.mater.polimi.it **mater@polimi.it**

MatER case studies



Thank you for your attention !

Waste Management in Italy:
a paradigm of prejudice and misunderstanding

- Emotional perception of environmental deterioration
- Expectation for "Zero Risk" e "Zero Impact"
- Absolute vs comparative assessment
- Equivocal perception of the relationship among environment, economic behaviour, profit
- Prejudice and mistrust of scientific methodology and scientific results
- Ideology as a key to interpret and overcome physical reality

Methodology

1) "Routine" activities
   - Monitor technologies and collect data
   - Meetings/Worshops/Events
   - Evaluate consequences of new regulation
   - Promote improvement of regulation / legislation
   - Support Master's / Ph.D. programs
   - MatER website and newsletter

2) Projects on specific topics - 2011
   - Anaerobic digestion
   - Recovery from the residues of thermal treatment
   - Indicators of the recovery of materials and energy

3) Projects on specific topics - 2012
   - Ecotoxicity (H14 criterion)
   - Map effectiveness of recycling and energy production (R1)
   - Advanced methods to characterize waste and residues