NEST

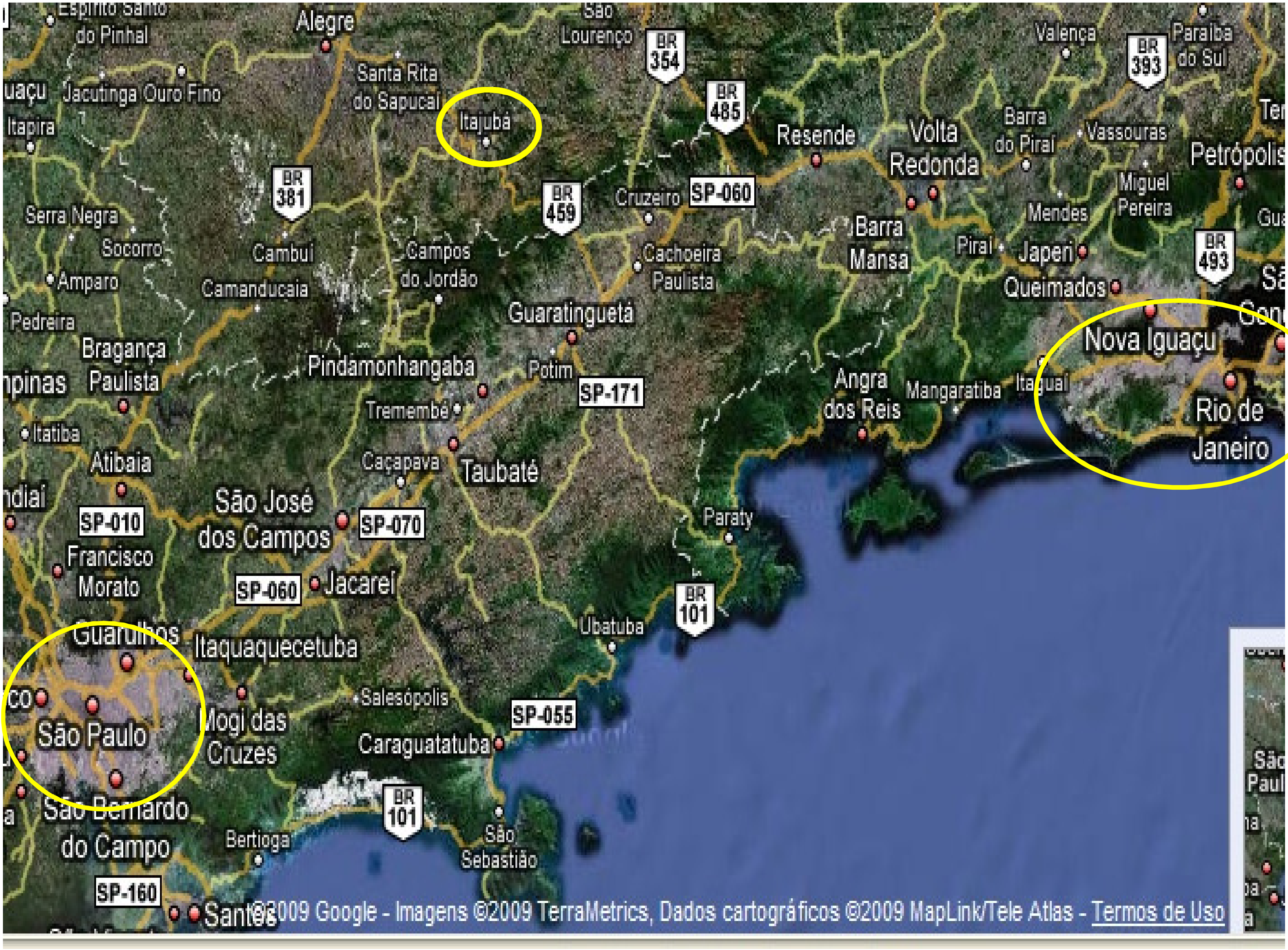
Núcleo de Excelência em Geração Termelétrica e Distribuída

Gasification technologies

Prof. Dr.Electo Silva Lora

electo@unifei.edu.br

Itajubá city location in Brazil



Itajubá: 88000 inhabitants
4 universities

FEDERAL UNIVERSITY OF ITAJUBA

FOUNDED IN 1913 BY TEODOMIRO SANTIAGO

Students: now 2200 to be increased up to 6000 in 2012

400 graduate students

Professors: now 200 up to 470 in 2012

FEDERAL UNIVERSITY OF ITAJUBA

NEST

Núcleo de Estudos em Sistemas Térmicos

Mechanical Engineering Institute

EXCELLENCE GROUP IN THERMAL POWER AND DISTRIBUTED GENERATION - NEST


Professor
Dr. Electo S. Lora


Professor
Dr. Marco A. R. Nascimento


Professor
Dr. Osvaldo J. Venturini


Professor
Dr. Vladimir M. Cobas


Professor
Dr. Ricardo D. M. Carvalho


MSc Luis F. V. Flores

++++ 1 researcher, 12 PhD and 6 MSc graduate students

Our laboratories

Bubbling bed

Gas microturbines and chiller

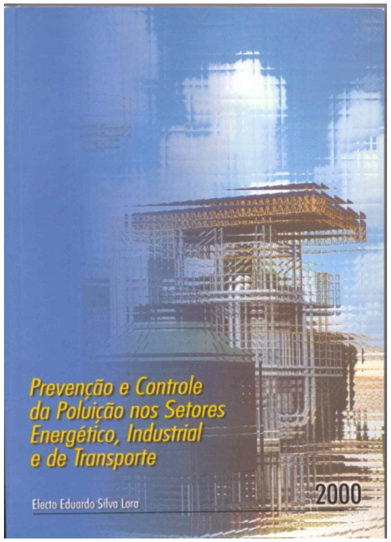
Steam cycle

Refrigeration and air conditioning

Traning center for power plants operators

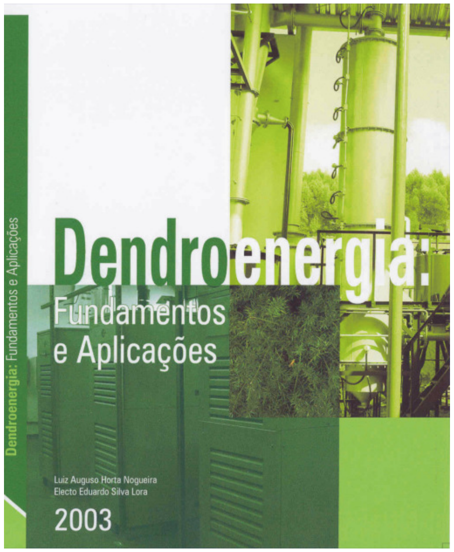
Solo Stirling engine

ETC…..


Prevenção e Controle da Poluição nos Setores Energético, Industrial e de Transporte

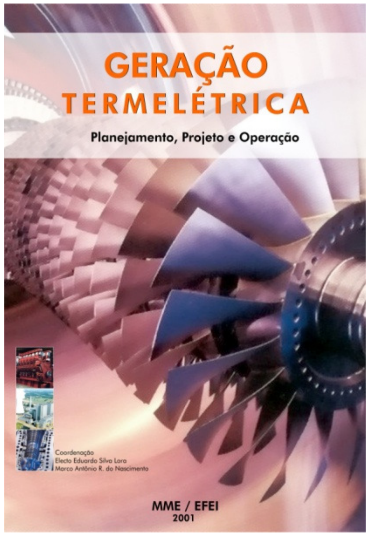
Electo Eduardo Silva Lora

2000


Dendroenergia: Fundamentos e Aplicações

Luiz Augusto Horta Nogueira
Electo Eduardo Silva Lora

2003

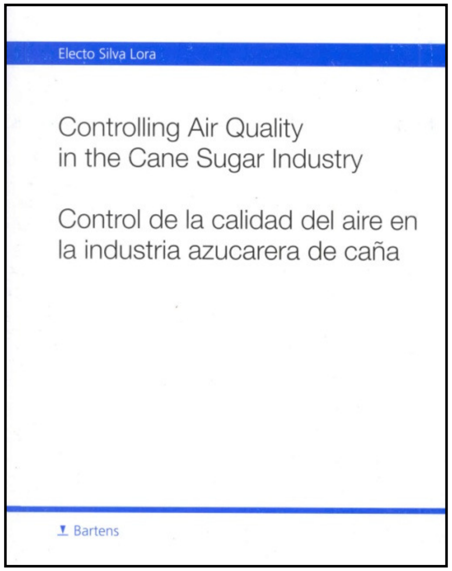

GERAÇÃO TERMELÉTRICA

Planejamento, Projeto e Operação

Coordenação
Electo Eduardo Silva Lora
Marco Antônio R. do Nascimento

MME / EFEI
2001

PUBLISHED BOOKS


Electo Silva Lora

Controlling Air Quality in the Cane Sugar Industry

Control de la calidad del aire en la industria azucarera de caña

Bartens


Geração Distribuída

Aspectos Tecnológicos, Ambientais e Institucionais

Electo Eduardo Silva Lora
Jamil Haddad
Coordenadores

EDITORA INTERCIÊNCIA


BIOMASSA para energia

Organização
LUÍS AUGUSTO BARBOSA CORTEZ
ELECTO EDUARDO SILVA LORA
EDGARDO OLIVARES GÓMEZ

IN 2009


BIOCOMBUSTÍVEIS

Coordenadores
Electo Eduardo Silva Lora
Osvaldo José Venturini

Editora Interciência

2008

NEST at internet

www.nest.unifei.edu.br

UNIVERSIDADE FEDERAL DE ITAJUBÁ

Núcleo de Excelência em Geração Termelétrica e Distribuída

Selecione o idioma

BIOENERGY

NEST

Núcleo de Excelência em Geração Termelétrica e Distribuída

ACTIVITIES

PROCESS INTEGRATION

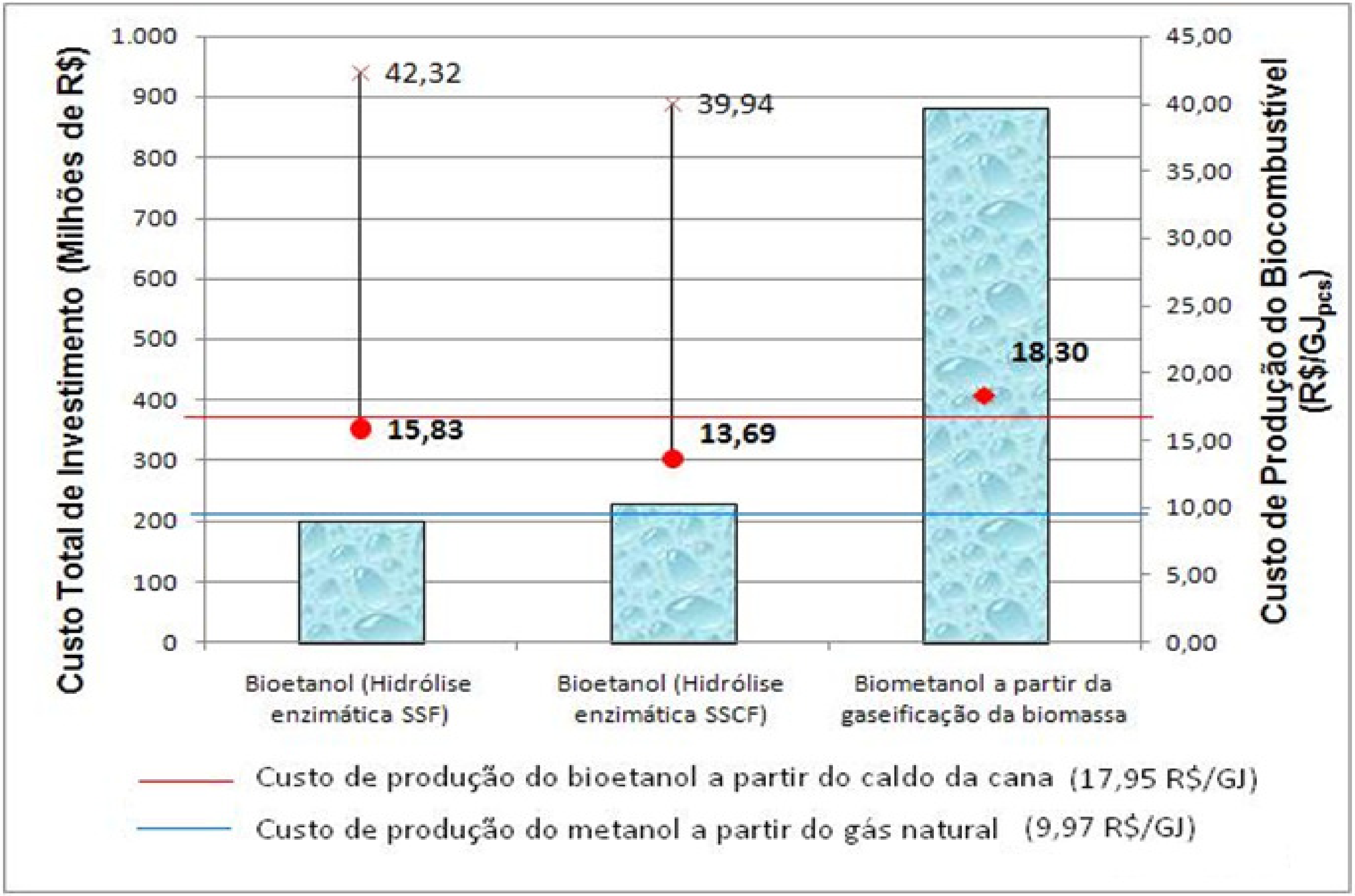
BIOMASS GASIFICATION

H_2 SYNGAS FOR SOFC

BIODIESEL AND SYNGAS IN GMT

BIOFUELS LCA AND SUSTAINABILITY

BIOMASS STIRLING ENGINES


Custo Total de Investimento (Milhões de R$)
1.000
900
800
700
600
500
400
300
200
100
0
Custo de Produção do Biocombustível (R$/GJ$_{pcs}$)
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
42,32
39,94
18,30
15,83
13,69
Bioetanol (Hidrólise enzimática SSF)
Bioetanol (Hidrólise enzimática SSCF)
Biometanol a partir da gaseificação da biomassa
Custo de produção do bioetanol a partir do caldo da cana (17,95 R$/GJ)
Custo de produção do metanol a partir do gás natural (9,97 R$/GJ)

CONSTRAINTS IN SUSTAINABILITY ASSESTMENT OF BIOFUELS

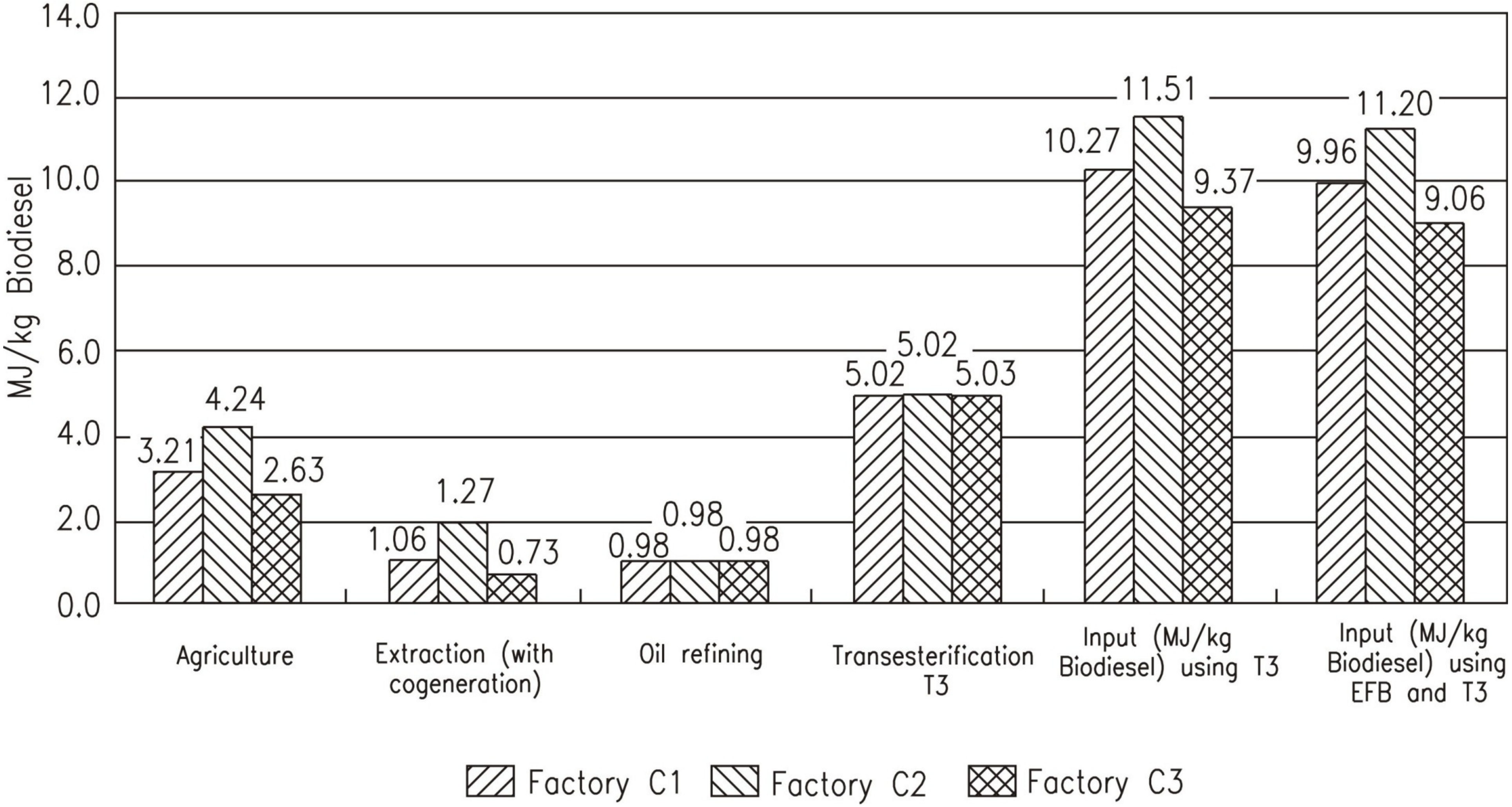
Prof. Electo Silva Lora, NEST/IEM/UNIFEI

The NEST/UNIFEI sustainability studies experience

Since 2004 NEST/UNIFEI is carrying out different biofuels related LCA studies:

- Palm oil biodiesel,
- Ethanol stillage treatment,
- Methanol from sugarcane bagasse.

Example I- LCA Palm oil biodiesel Inventory stage




15

For references look at:

Renewable and Sustainable Energy Reviews 13 (2009) 1275–1287

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

ELSEVIER

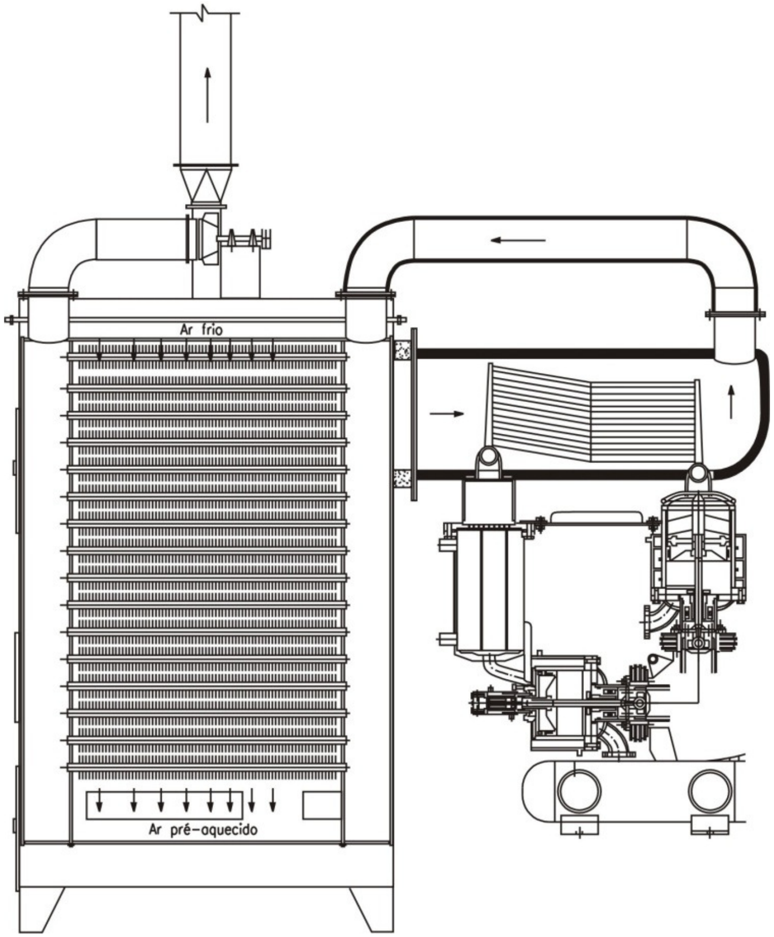
Biofuels: Environment, technology and food security

José C. Escobar[a], Electo S. Lora[a,*], Osvaldo J. Venturini[a], Edgar E. Yáñez[b], Edgar F. Castillo[c], Oscar Almazan[d]

BIOMASS STIRLING AMAZON

Project coordinator

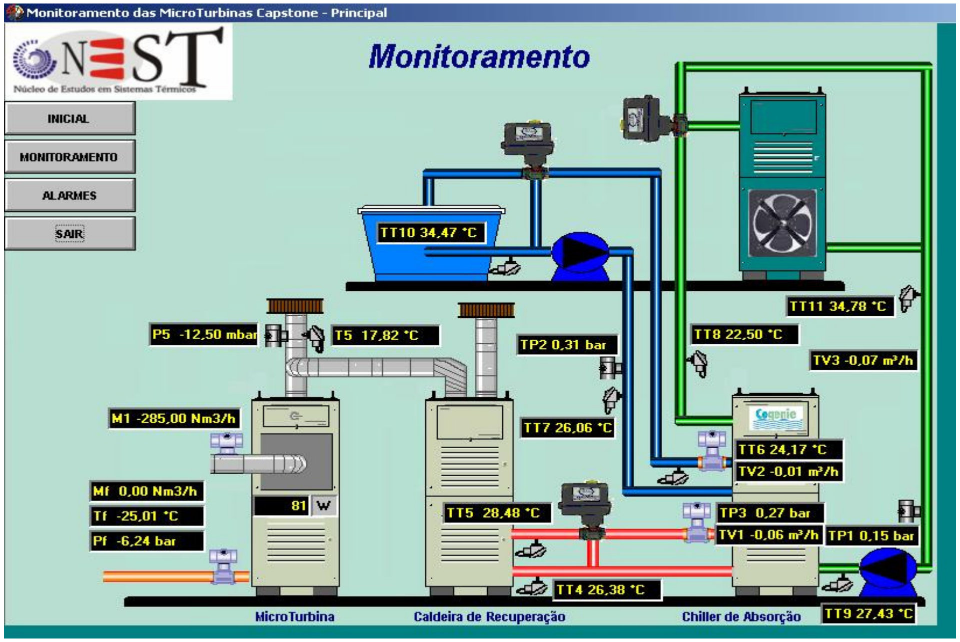
Dr. Vladimir Melian Cobas



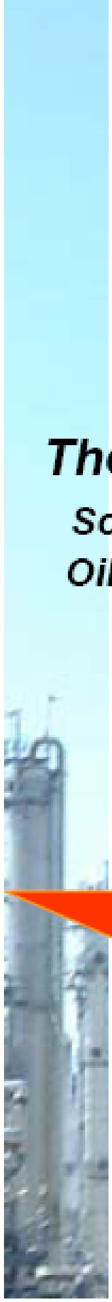
COGENERATION SYSTEM MGT/ABSORPTION CHILLER

Project coordinator

Dr. Osvaldo Jose Venturini



Biorefining Approaches for Lignocellulose



- Thermochemical

Thermolytic
Solids
Oils

Gasification, Pyrolysis

- Synthesis gas
  - (CO + H_2 + other)

Catalytic Synthesis

Syngas Fermentation

- Hydrocarbons, mixed alcohols, hydrogen, ammonia, SNG, ethanol, higher alcohols…

- Biochemical

Pretreatment, Hydrolysis
(cell wall deconstruction)

Hydrolytic
Cellulose
Hemicellulose

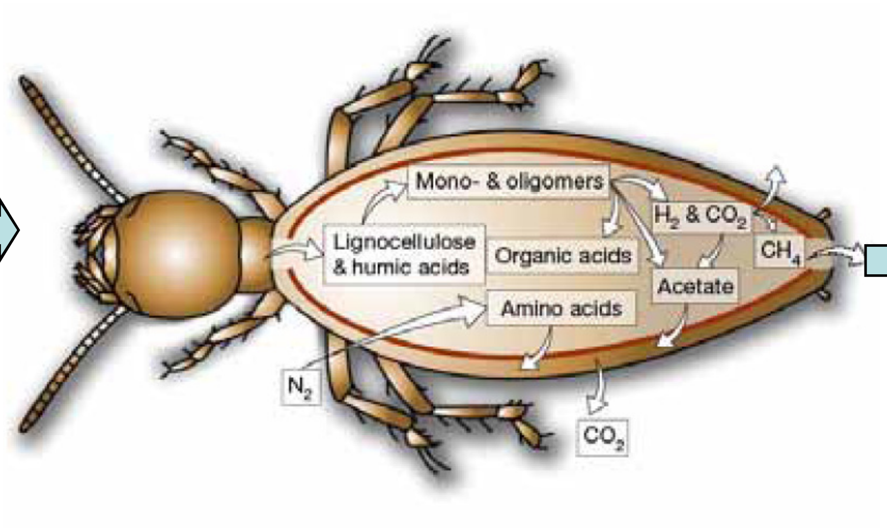
- Sugar monomers, acids

Fermentation

- Ethanol, higher alcohols, biomethane, hydrogen, acids…

BUT...2nd generation biofuel does not affect food security...as we don´t eat cellulose ... But someone does..

Our prefered Books (Kamasutra) and furniture



Mehane Biofuel

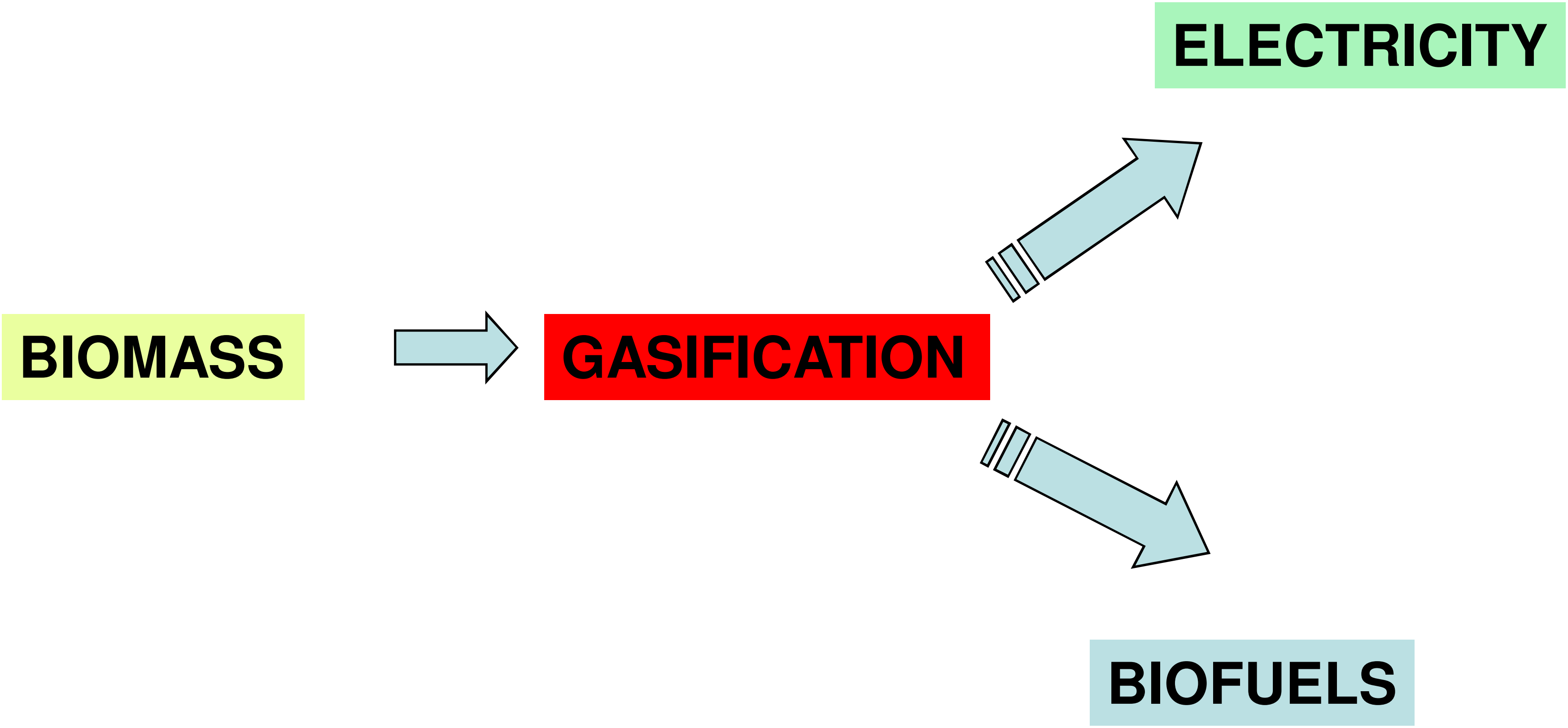
Termite Biorefinery

We are trying to imitate them..

Gasification

Thermo-chemical biomass conversion with the supply of sub-stoichiometric quantities of oxygen into a fuel gas with high CO, H_2 and CH_4 content.

The resulting gas composition and it calorific value f (type of gas used as gasification agent and of the reactor pressure).



BIOMASS

GASIFICATION

ELECTRICITY

BIOFUELS

$$CH_{1.44}O_{0.66} + wH_2O + mO_2 + 3.76mN_2 = x_1H_2 + x_2CO + x_3CO_2 + x_4H_2O + x_5CH_4 + 3.76mN_2$$

Biomass gasification

→ Mixture of gases

→CO, CH_4, H_2
Fuel compounds

→CO_2, H_2O, (N_2), C_xH_y:
Combustion products

Reactor types

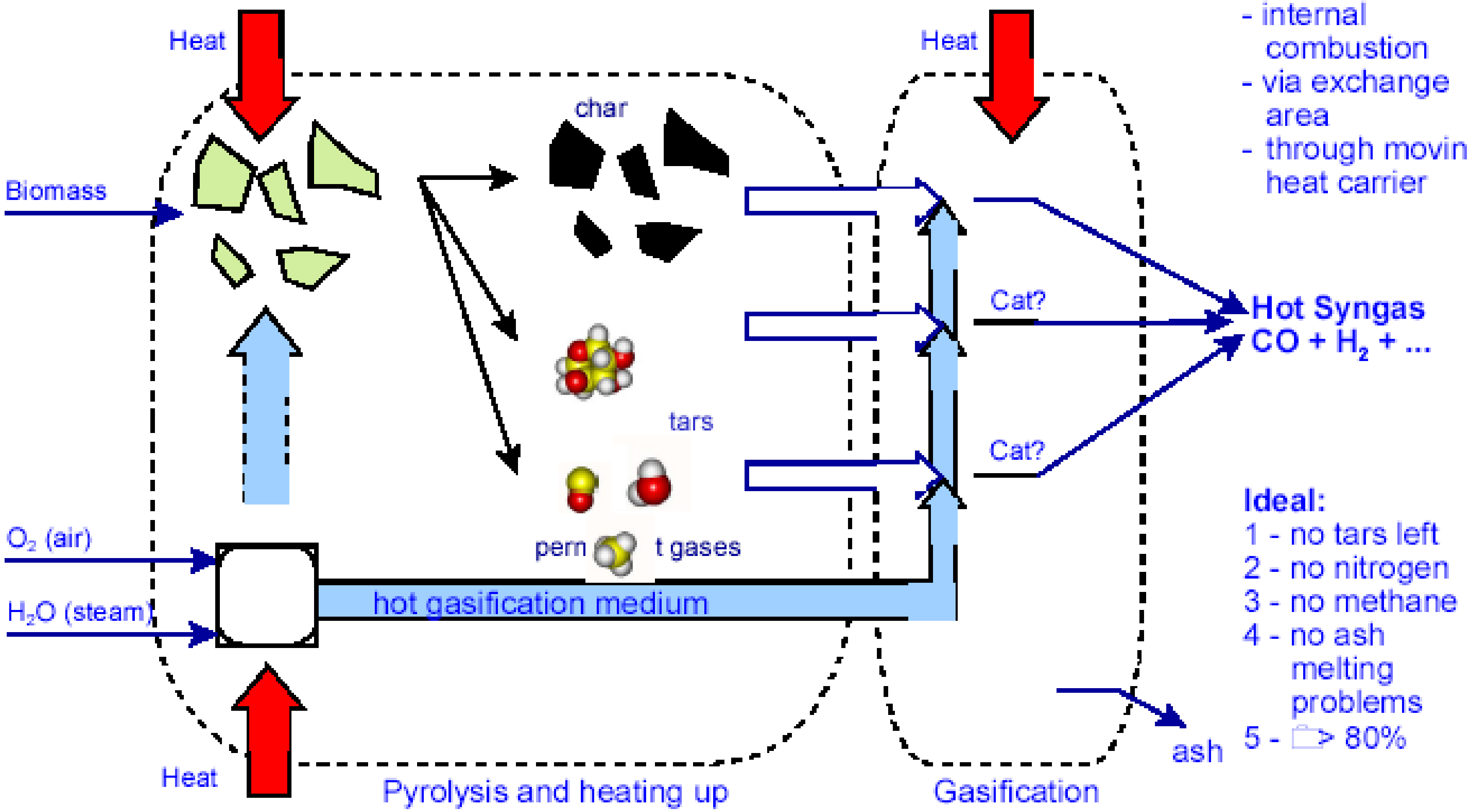
→ Fixed beds
→Updraft, downdraft and cross flow

→ Fluidized bed
  → Boubling or circulating
  → Atmospheric or circulating

→Entrained flow

Gasification stages

1. **Pyrolysis or thermal decomposition stage** volatilization – it takes place at temperatures close to 600oC;
2. **Oxidation of a part of the fuel fixed carbon** – the thermal energy source for the volatilization and gasification processes;
3. **Gasification** – it includes heterogeneous reaction between the gases and the coke, as well as homogeneous reactions between the products that have already been formed;
4. **Tar cracking** – a thermal destruction process of the molecules of the tar forming counponds obtaining CO, CO2, CH4 and other gases as products;
5. **Partial oxidation of the pyrolysis products**.



Heat supply:
- internal combustion
- via exchange area
- through moving heat carrier

Ideal:
1 - no tars left
2 - no nitrogen
3 - no methane
4 - no ash melting problems
5 - ⇨ > 80%

I- Pyrolysis.

$$\text{Biomass} + \text{heat} \rightarrow \text{core} + \text{gases} + \text{tar} + \text{condensable products} \tag{4.3}$$

II- Carbon oxidation

$$C + \tfrac{1}{2}\, O_2 \leftrightarrow CO \tag{4.4}$$

$$C + O_2 \leftrightarrow CO_2 \tag{4.5}$$

III- Gasification.

- Heterogeneous reactions.

$$C + CO_2 \leftrightarrow 2\, CO \quad \text{(Bouduard reaction)} \tag{4.6}$$

$$C + H_2O \leftrightarrow CO + H_2 \; \text{(Water gas reaction or steam carbon reaction)} \tag{4.7}$$

$$C + 2\, H_2 \leftrightarrow CH_4 \quad \text{(Methane forming reaction)} \tag{4.8}$$

- Homogenous reactions.

$$CO + H_2O \leftrightarrow CO_2 + H_2 \; \text{(Water-shift reaction)} \tag{4.9}$$

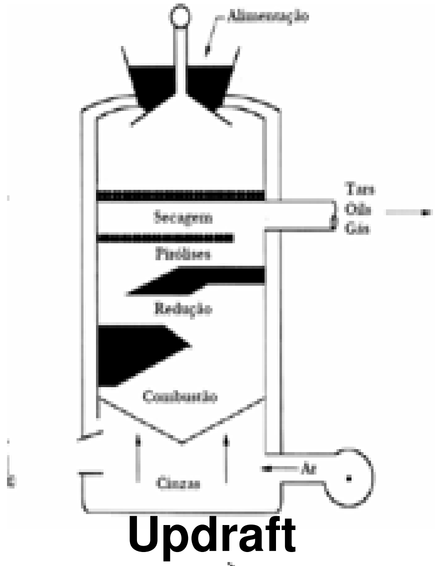
$$CH_4 + H_2O \leftrightarrow CO + 3H_2 \tag{4.10}$$

IV- Tar cracking.

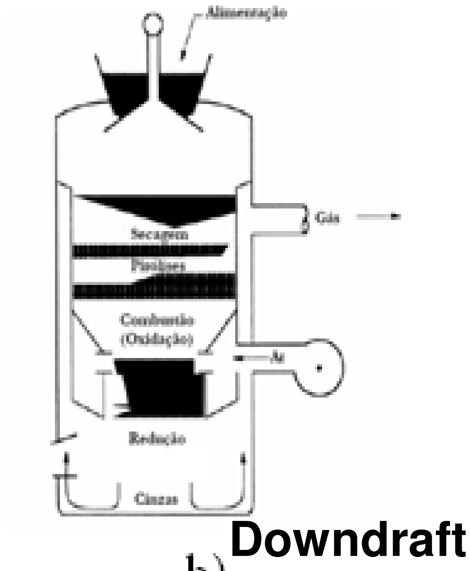
$$\text{Tar} + \text{steam} + \text{heat} \leftrightarrow CO + CO_2 + CH_4 \tag{4.11}$$

V- Pyrolysis products partial oxidation.

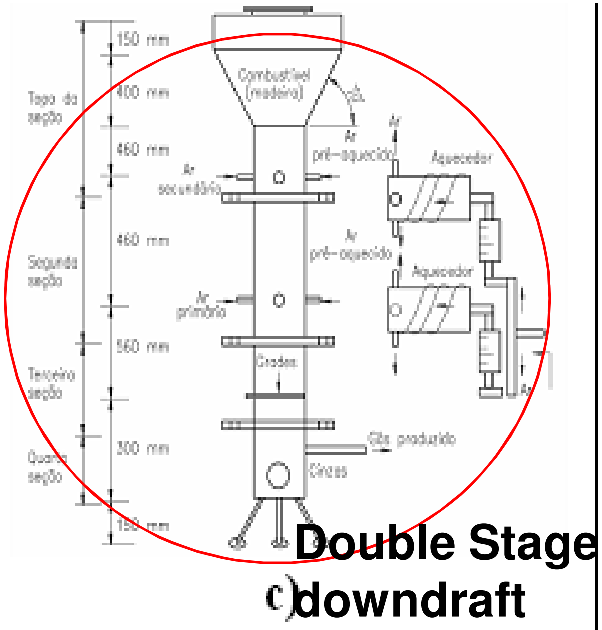
$$(CO + H_2 + CH_4) + O_2 \leftrightarrow CO_2 + H_2 \tag{4.12}$$


Alimentação
Tars
Oils
Gás
Secagem
Pirólises
Redução
Combustão
Cinzas
Ar
Updraft

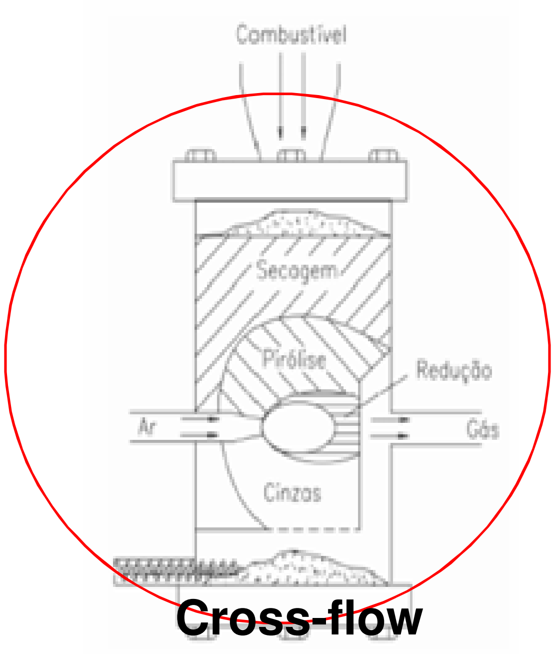
a)


Alimentação
Gás
Secagem
Pirólises
Combustão
(Oxidação)
Ar
Redução
Cinzas
Downdraft

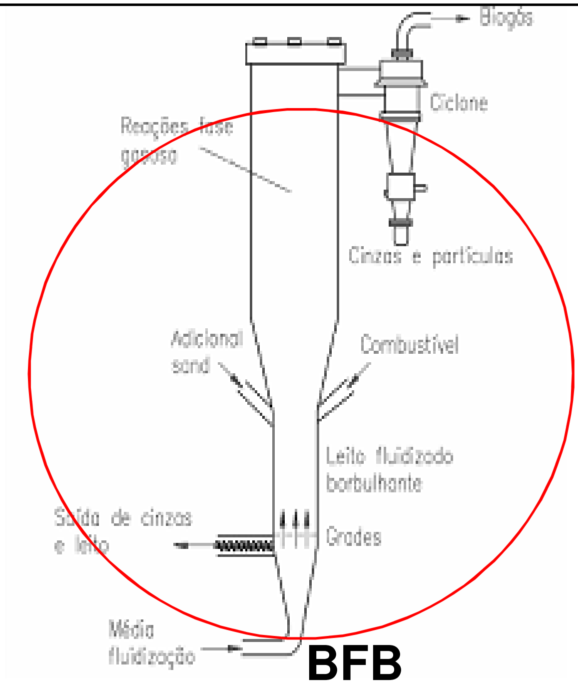
b)


150 mm
400 mm
460 mm
460 mm
560 mm
300 mm
150 mm
Topo da seção
Segunda seção
Terceira seção
Quarta seção
Combustível (madeira)
Ar pré-aquecido
Ar
Aquecedor
Ar secundário
Ar pré-aquecido
Aquecedor
Ar primário
Grades
Gás produzido
Cinzas
Ar
Double Stage
downdraft

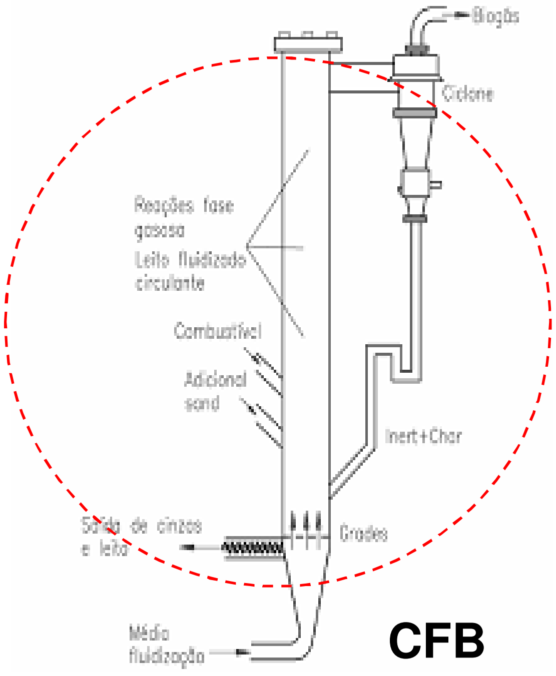
c)


Combustível
Secagem
Pirólise
Redução
Ar
Gás
Cinzas
Cross-flow

d)

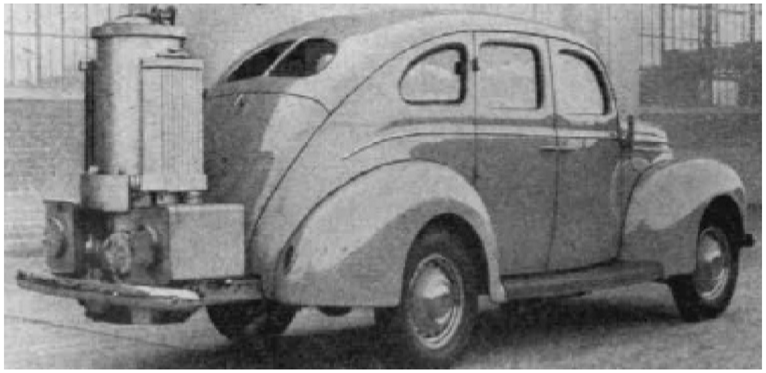

Biogás
Ciclone
Reações fase gasosa
Cinzas e partículas
Adicional sand
Combustível
Leito fluidizado borbulhante
Saída de cinzas e leito
Grades
Média fluidização
BFB

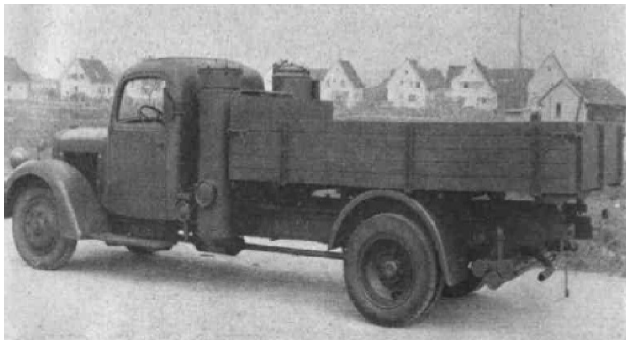
e)


Biogás
Ciclone
Reações fase gasosa
Leito fluidizado circulante
Combustível
Adicional sand
Inert+Char
Saída de cinzas e leito
Grades
Média fluidização
CFB

f)

II World war



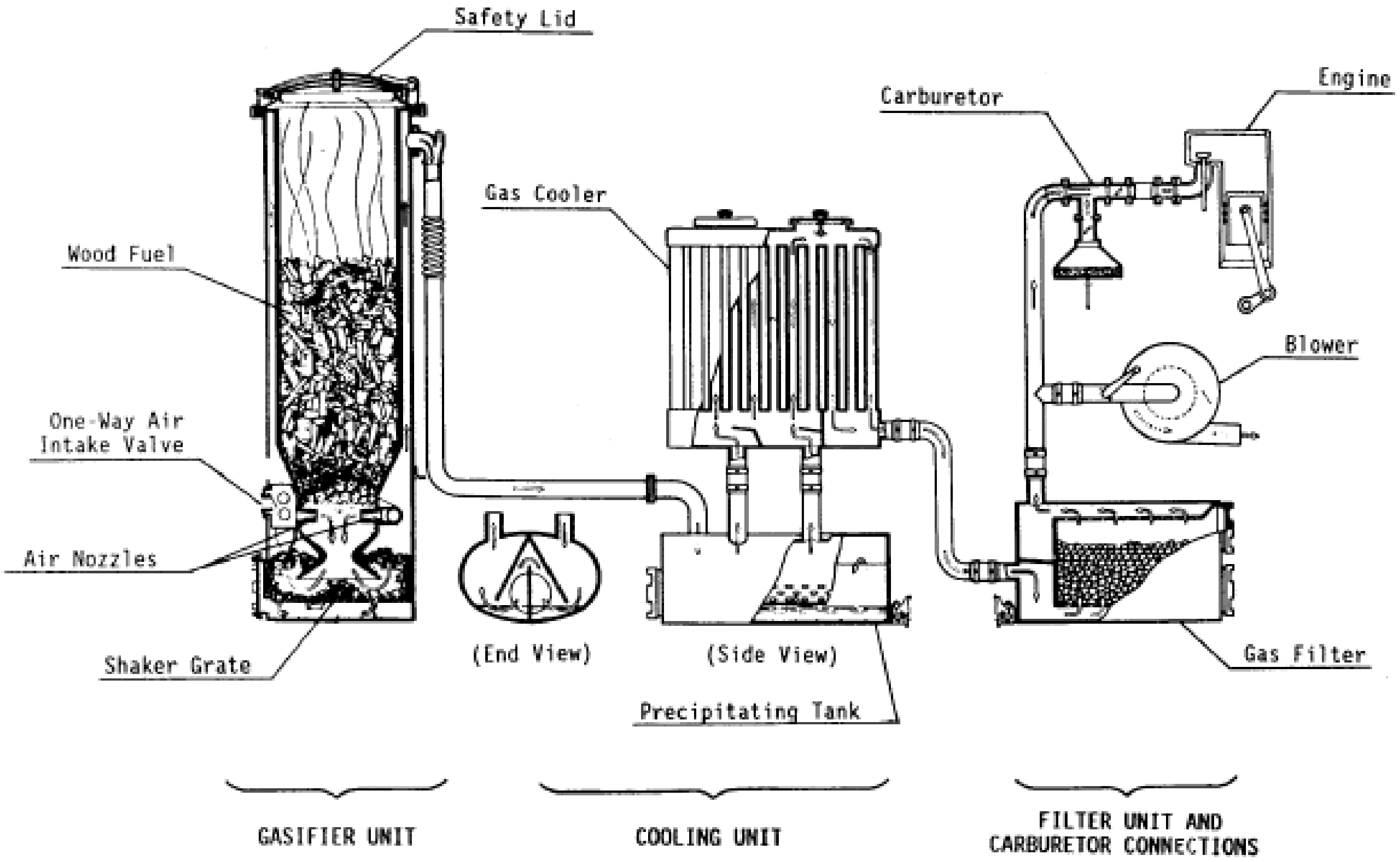


Succesfully gasification technologies

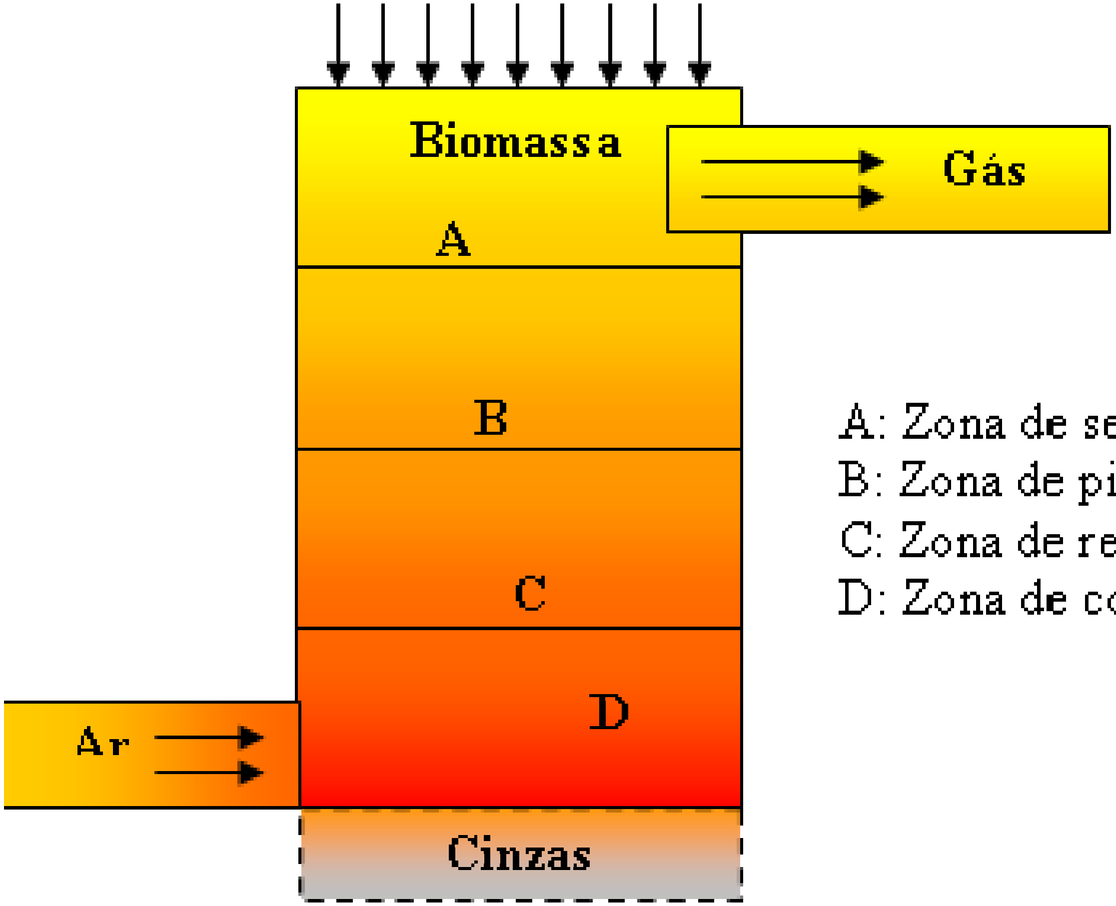
Presently

And…after a serious repowering

Aspectos gerais da gaseificação de biomassa em leito fixo

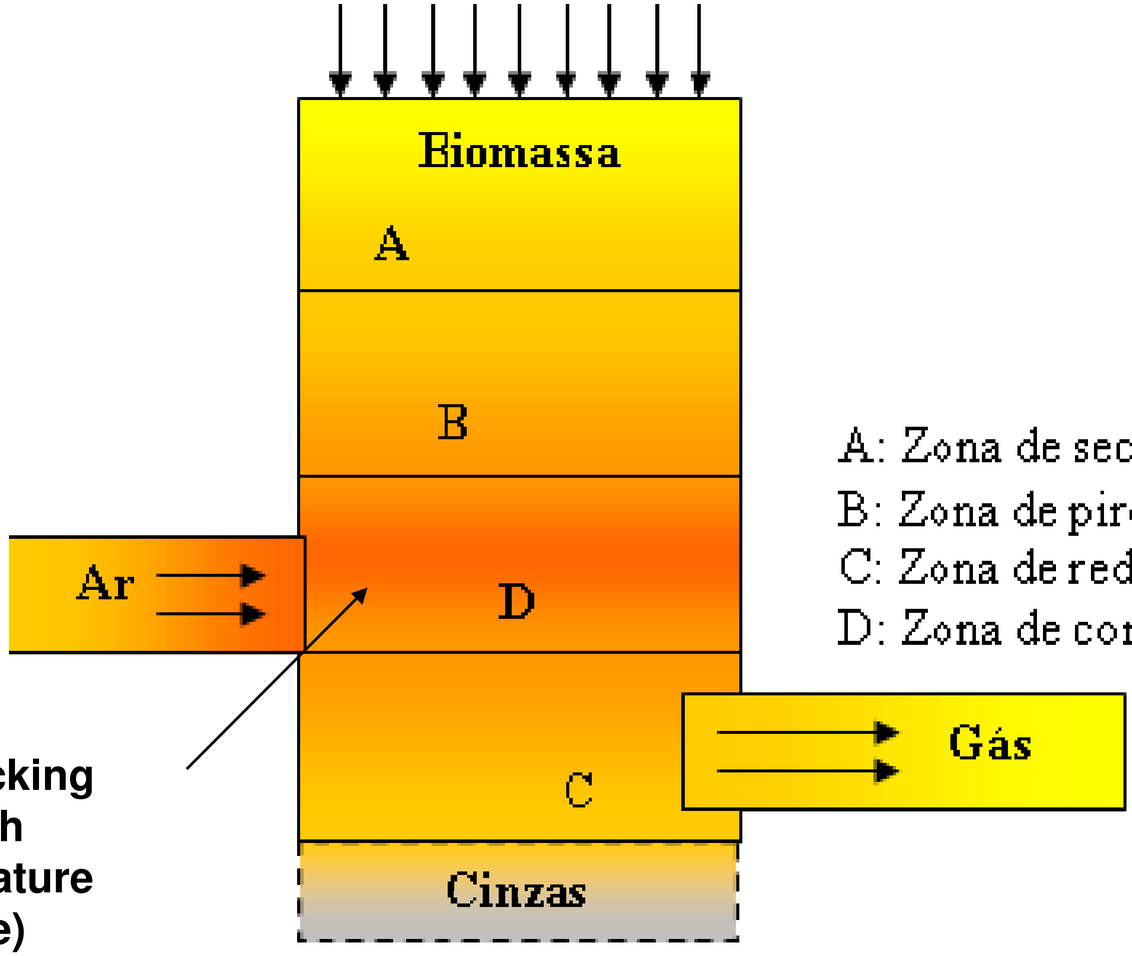


Updraft gasifiers



A: Zona de secagem
B: Zona de pirólise
C: Zona de redução
D: Zona de combustão

Downdraft



A: Zona de secagem
B: Zona de pirólise
C: Zona de redução
D: Zona de combustão

Tar cracking (High temperature zone)

IMBERT GASIFIER

Tars cracking (High temperature zone)

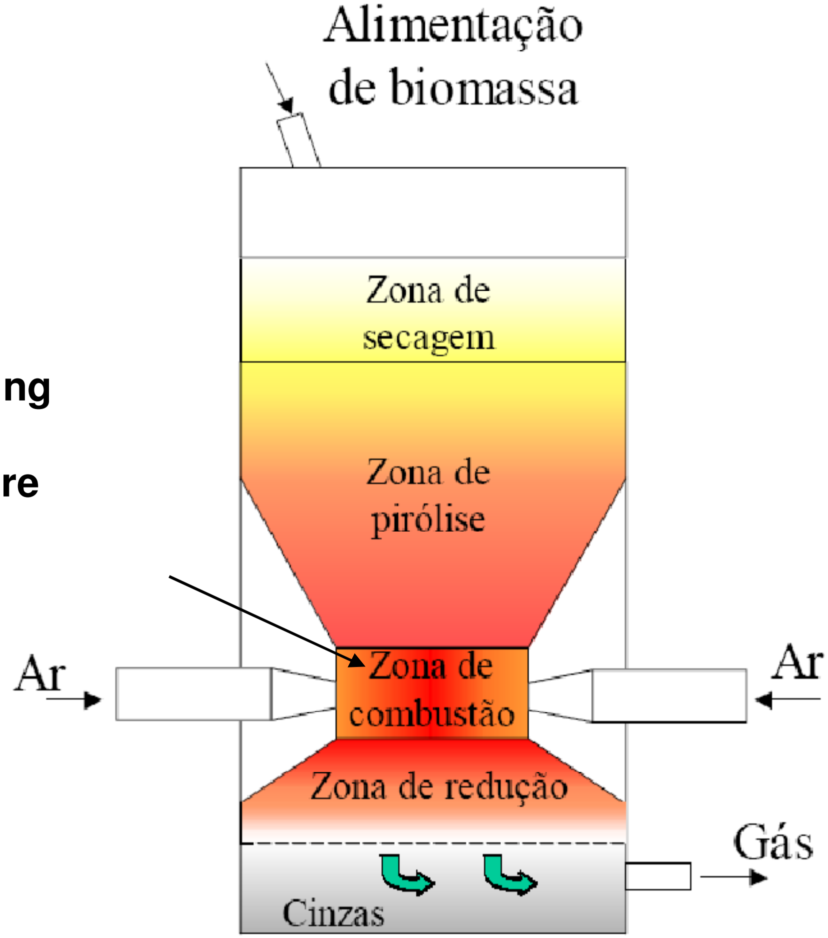
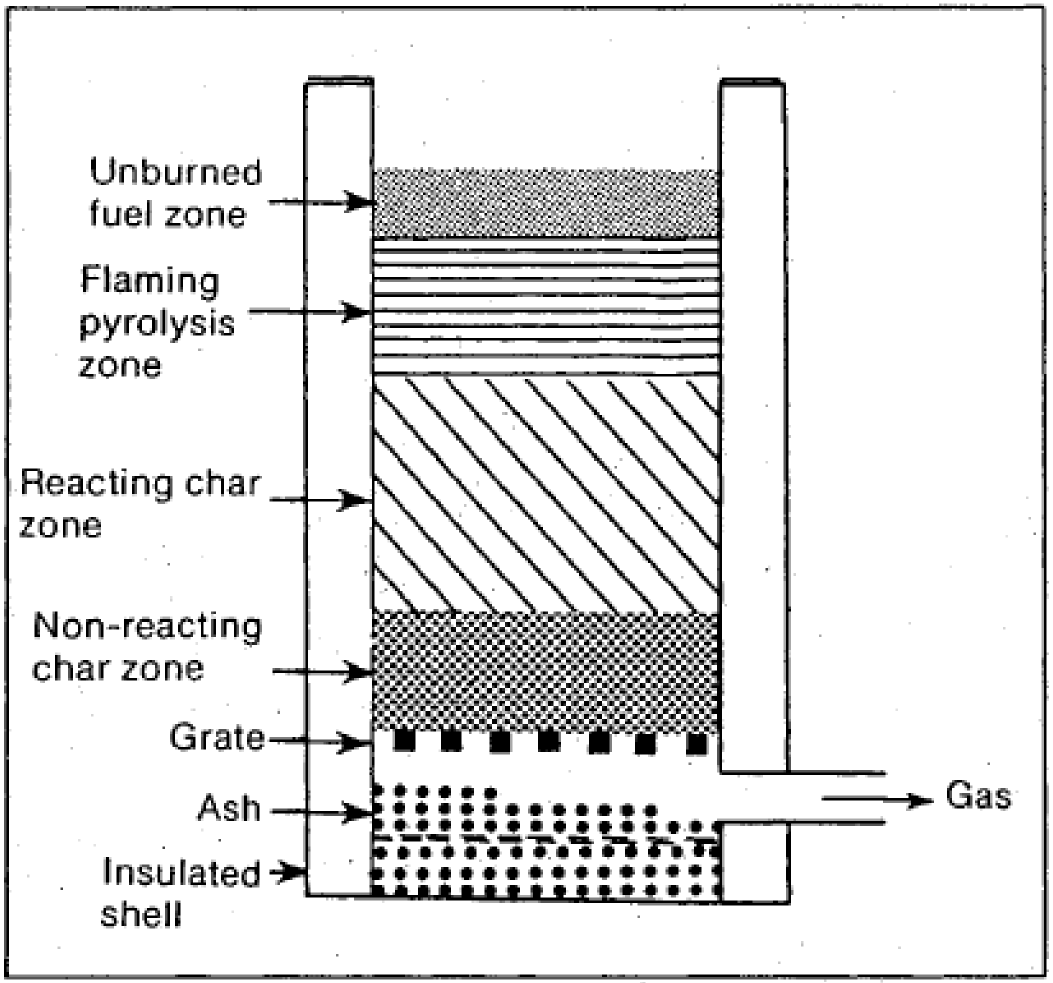


Figura 3. Esquema gaseificador em reator de leito fixo concorrente (tipo *imbert*).

GASEIFICADOR *STRATIFIED* or *OPEN TOP*



OPERATIONAL PARAMETERS

Variáveis de operação:

$$F.A = \frac{\left(R_{A/C}\right)_{real}}{\left(R_{A/C}\right)_{est}}$$

De maior influência:

- Air FACTOR (Equivalence ratio)
  Typical values 0,2 0,45.

-Gasification fluid

--Pressure

Others:

- Particle size
- Moisture

- Bed temperature
depends on air factor

Double stage gasifier

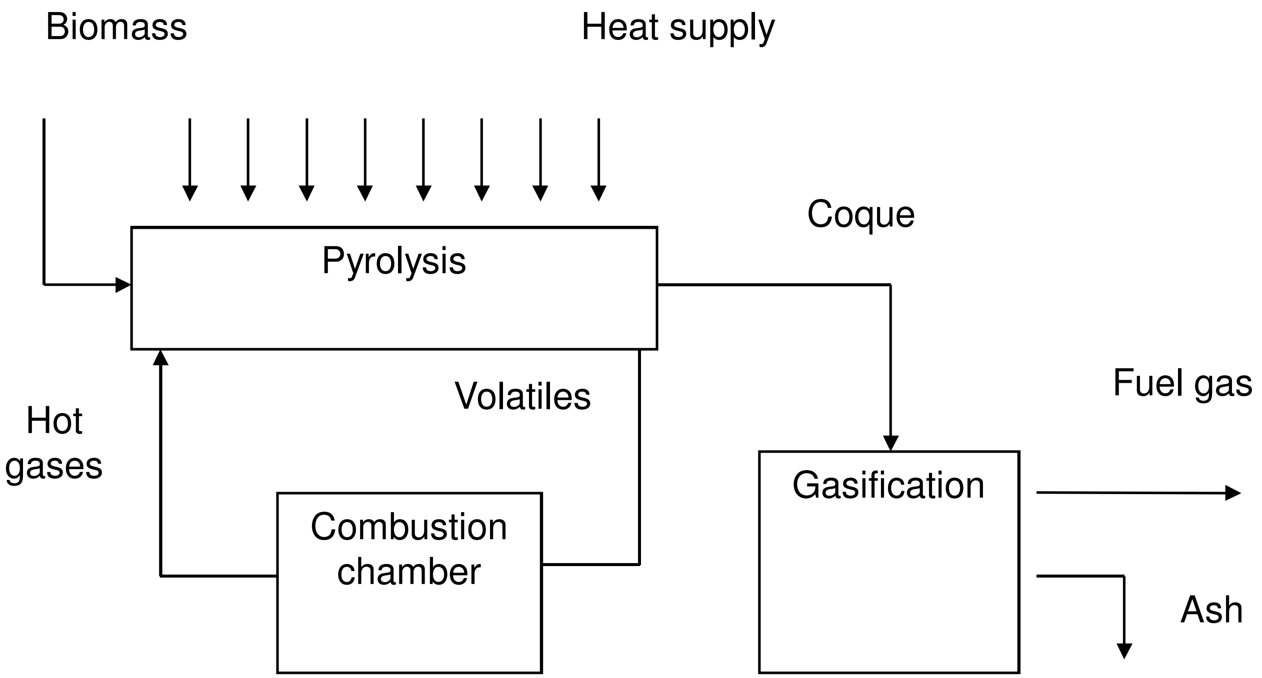
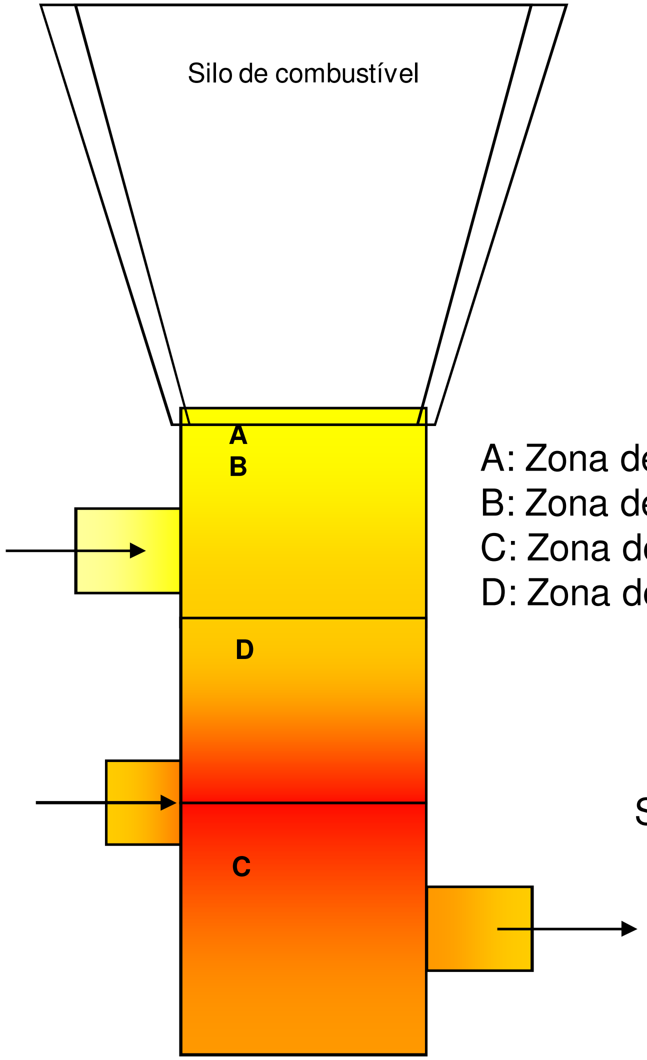


Figura 6. Esquema geral da gaseificação com duplo estágio de reação.



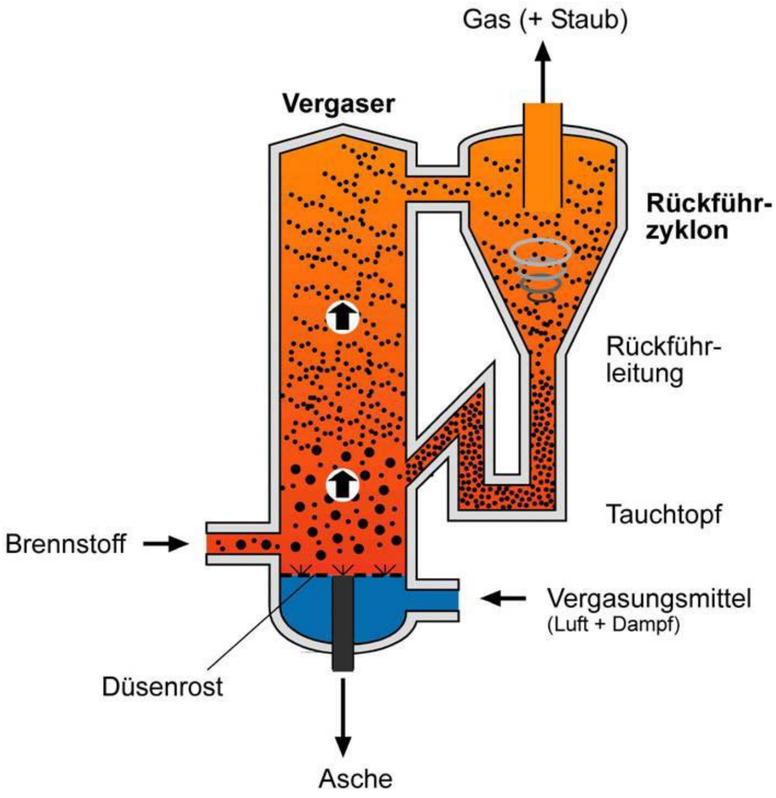
Second stage

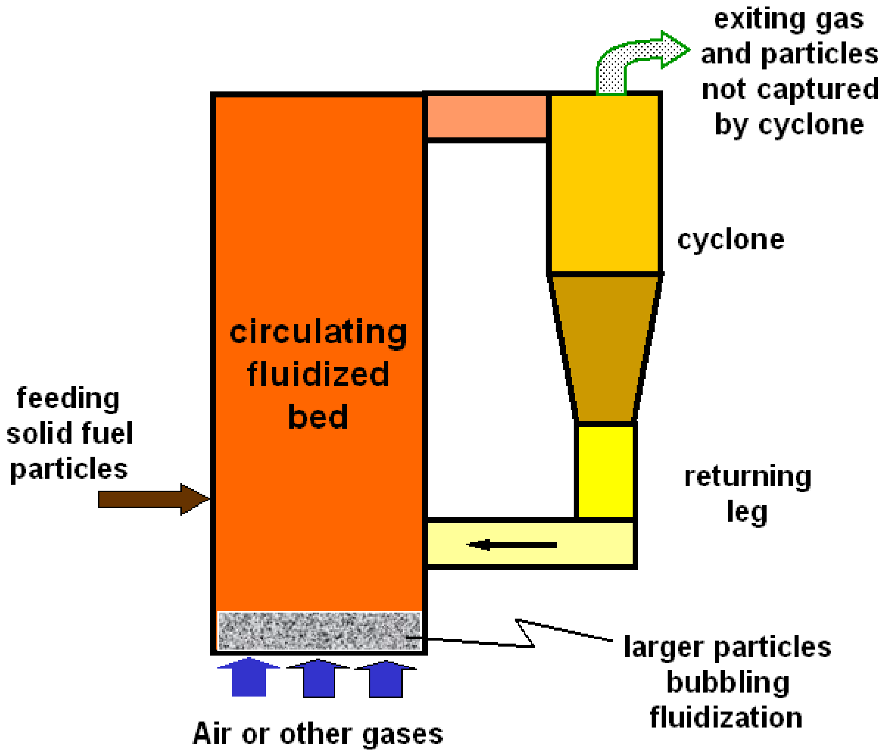
First stage

A: Zona de secagem
B: Zona de pirólise
C: Zona de redução
D: Zona de combustão

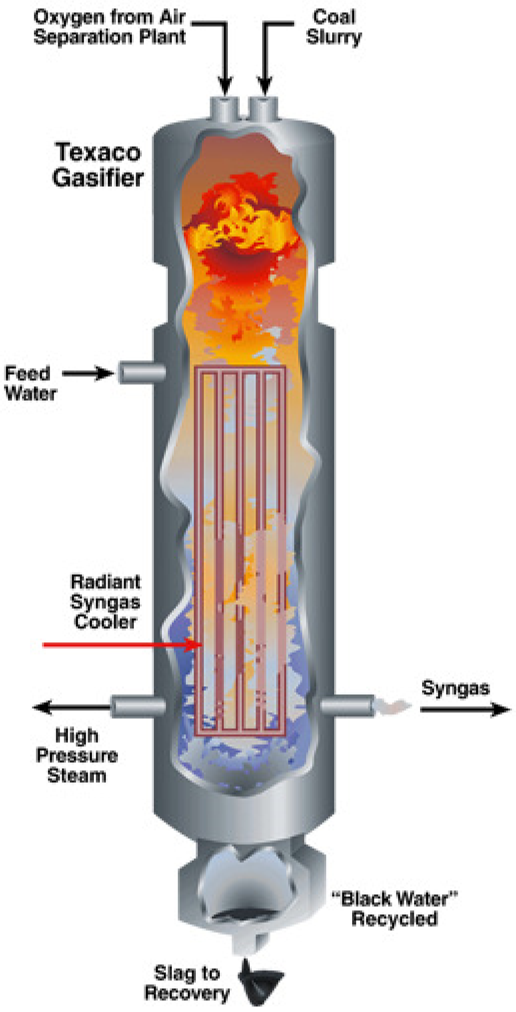
Saída do gás
produzido

Circulating fluidized bed gasifier

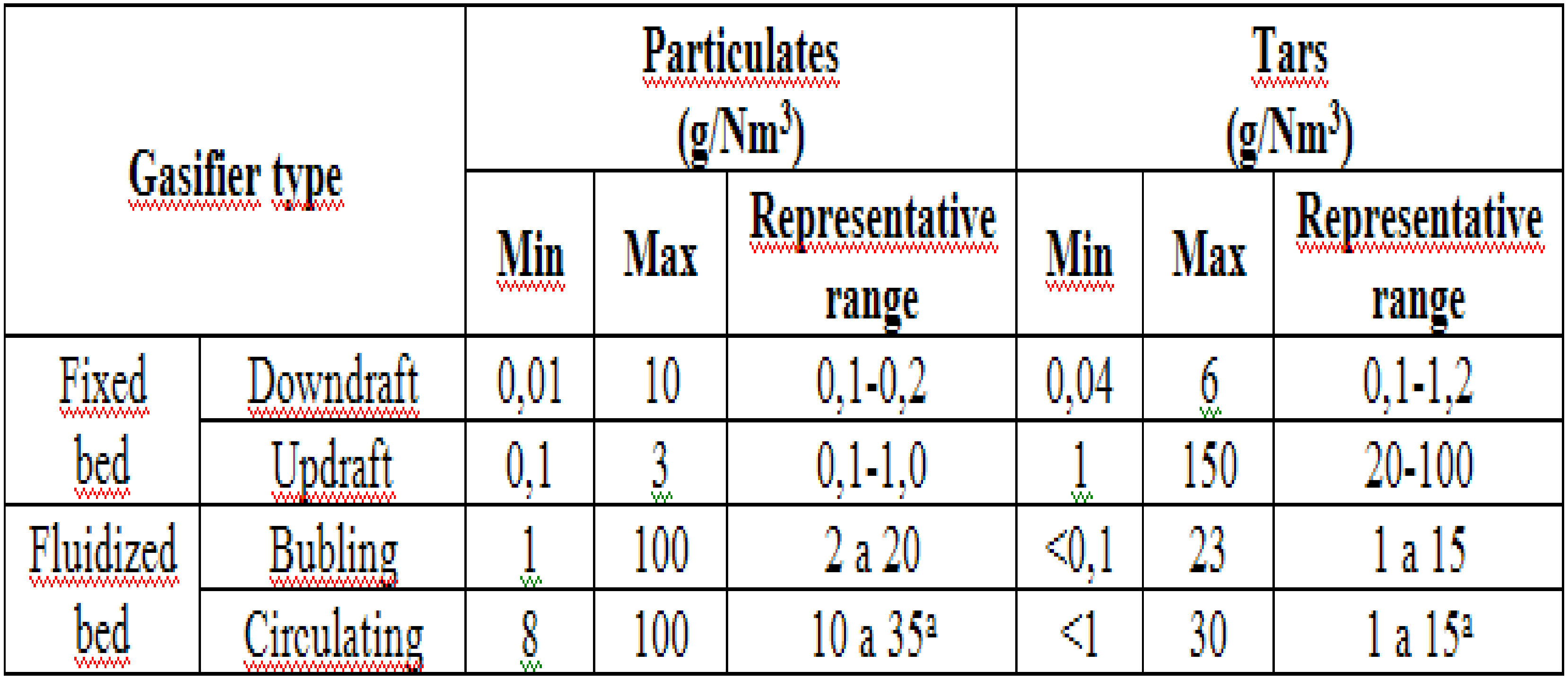




Entrained flow gasifier



Texaco Entrained Flow Gasifier



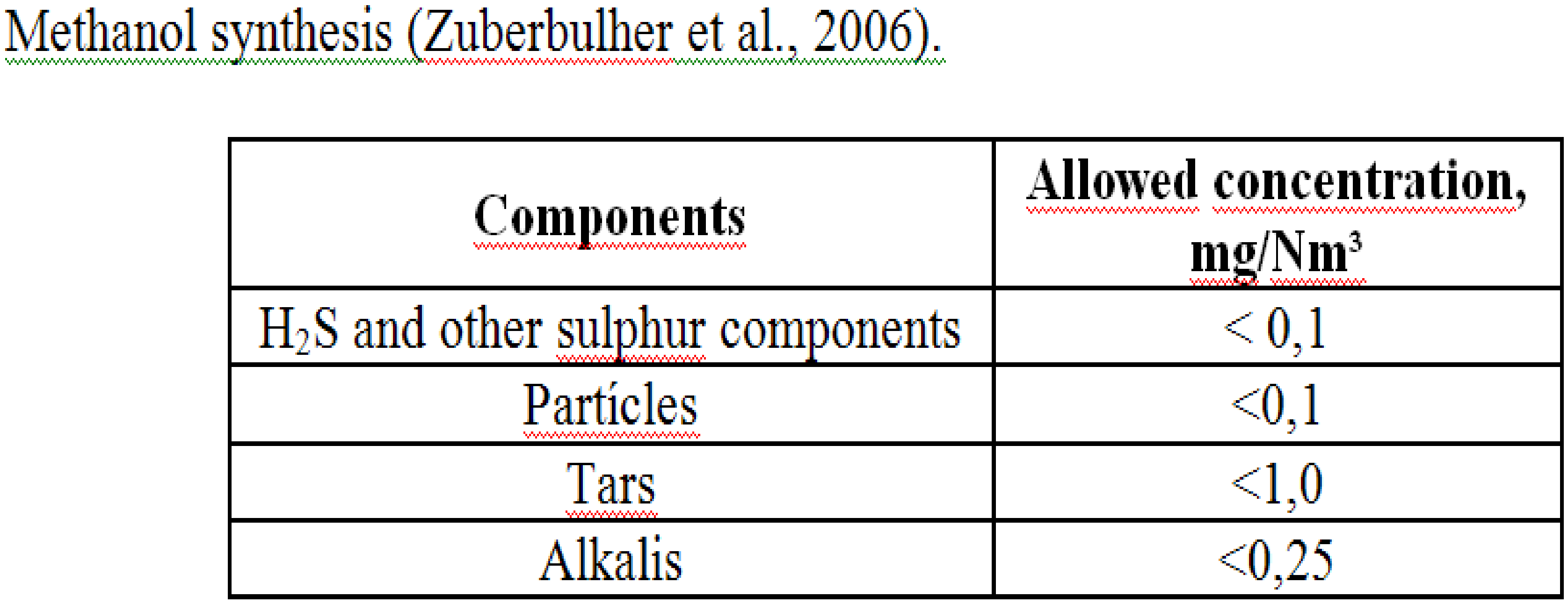
Gasifier type		Particulates (g/Nm^3)			Tars (g/Nm^3)		
		Min	Max	Representative range	Min	Max	Representative range
Fixed bed	Downdraft	0,01	10	0,1-0,2	0,04	6	0,1-1,2
	Updraft	0,1	3	0,1-1,0	1	150	20-100
Fluidized bed	Bubling	1	100	2 a 20	<0,1	23	1 a 15
	Circulating	8	100	10 a 35[a]	<1	30	1 a 15[a]

Syngas quality requirements PRIME MOVERS

Syngas quality requirements for it utilization as fuel for different prime movers (Kaltschmitt e Hartmann, e * NREL, 2001).

Impurities	Units	Internal combustion engine	Gas turbine	Fuel Cells
Particules	mg/Nm^3	< 50	< 30	-
	µm	< 3	< 5	-
Tars	mg/Nm^3	< 100	-	< 1
Álcalis	mg/Nm^3	-	<0,25	-
NH_3	mg/Nm^3	< 55	-	< 0,1
H_2S**	mg/Nm^3	< 1150	-	< 1
HCl*	ppm	-	-	<1
SiO_2*	mg/Nm^3	-	-	<1

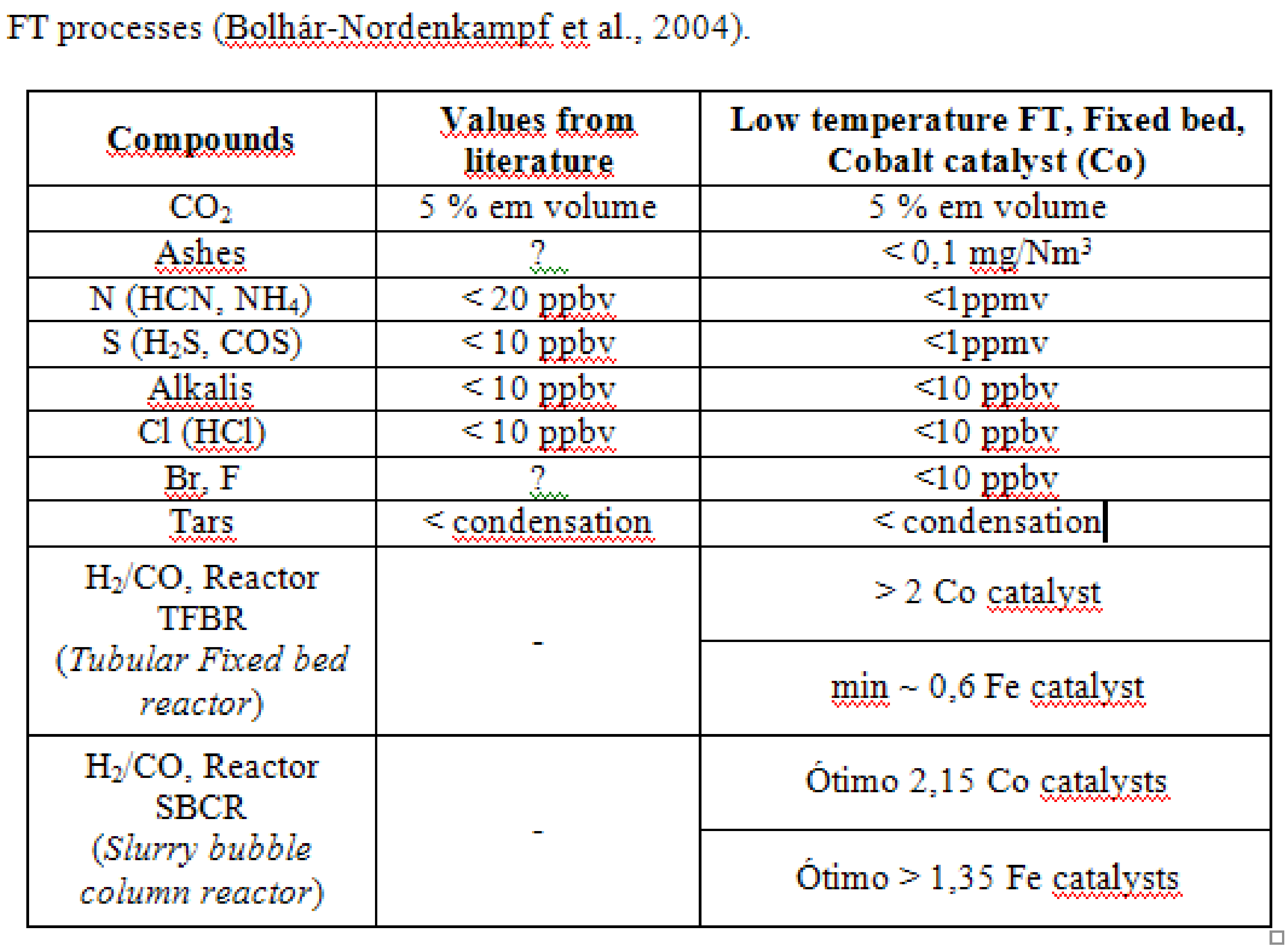
Syngas quality requirements
METHANOL SYNTHESIS



Methanol synthesis (Zuberbulher et al., 2006).

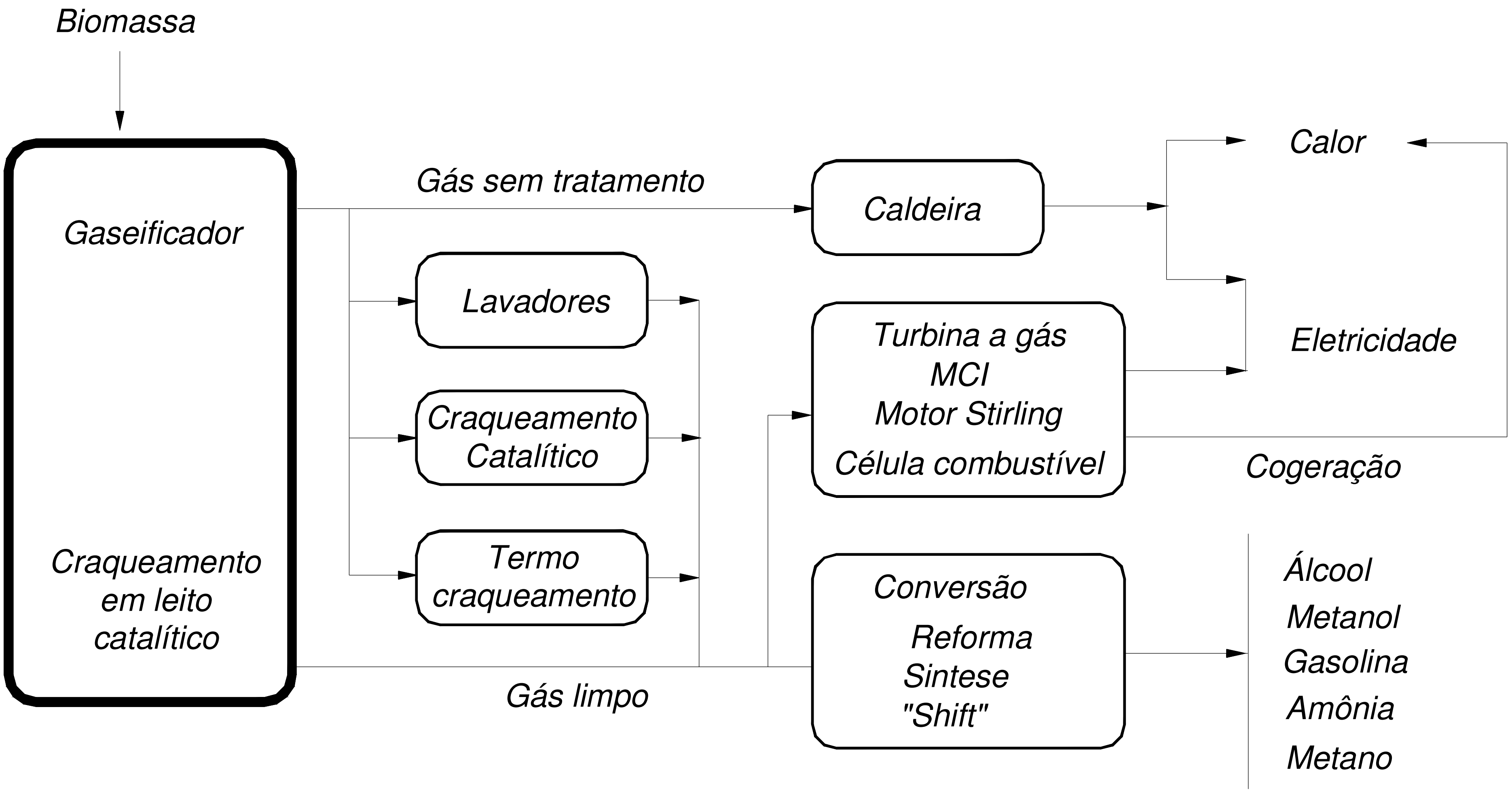
Components	**Allowed concentration, mg/Nm^3**
H_2S and other sulphur components	< 0,1
Partícles	<0,1
Tars	<1,0
Alkalis	<0,25

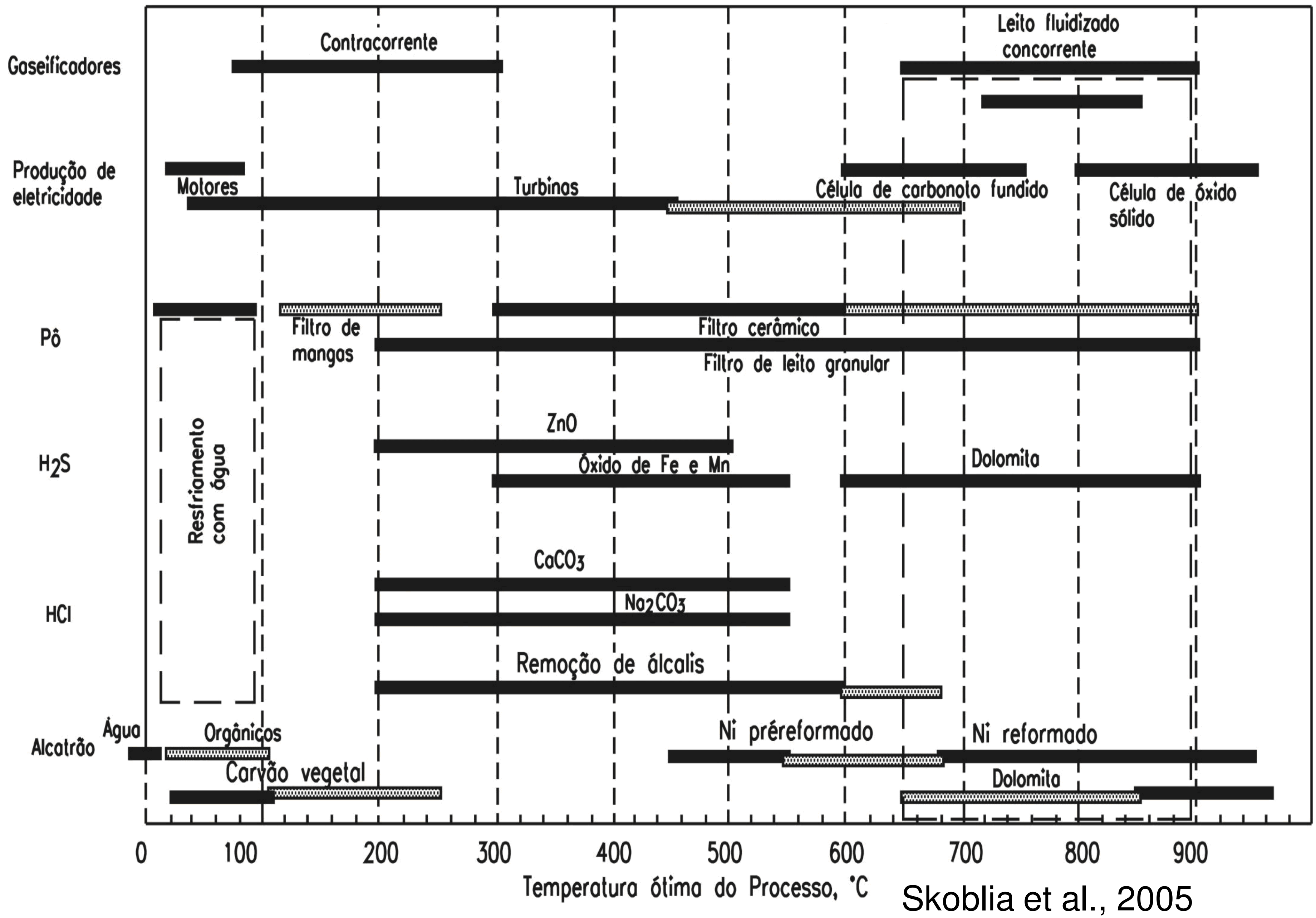
Syngas quality requirements FT synthesis



FT processes (Bolhár-Nordenkampf et al., 2004).

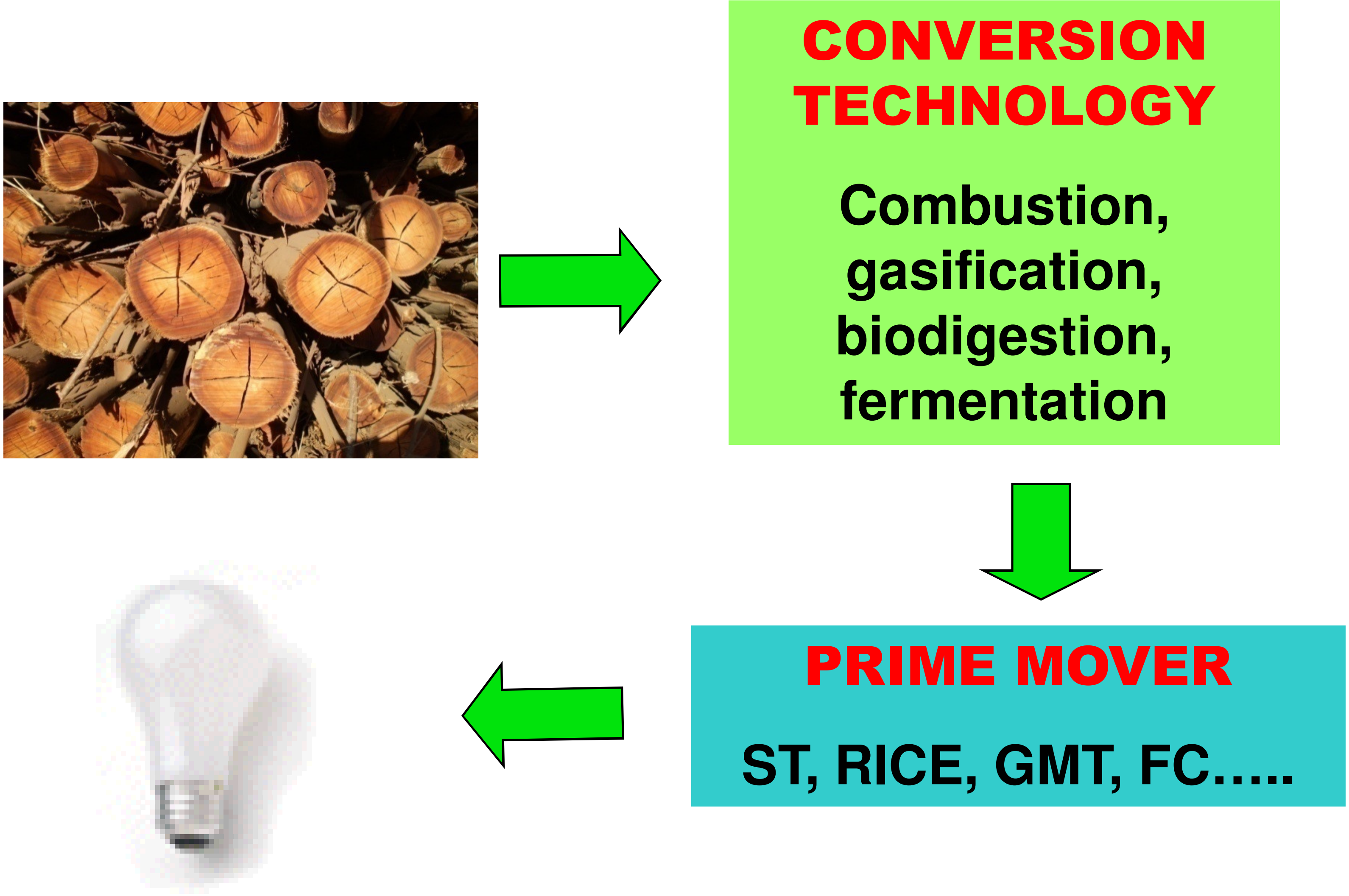
Compounds	**Values from literature**	**Low temperature FT, Fixed bed, Cobalt catalyst (Co)**
CO_2	5 % em volume	5 % em volume
Ashes	?	< 0,1 mg/Nm³
N (HCN, NH_4)	< 20 ppbv	<1ppmv
S (H_2S, COS)	< 10 ppbv	<1ppmv
Alkalis	< 10 ppbv	<10 ppbv
Cl (HCl)	< 10 ppbv	<10 ppbv
Br, F	?	<10 ppbv
Tars	< condensation	< condensation
H_2/CO, Reactor TFBR (*Tubular Fixed bed reactor*)	-	> 2 Co catalyst
		min ~ 0,6 Fe catalyst
H_2/CO, Reactor SBCR (*Slurry bubble column reactor*)	-	Ótimo 2,15 Co catalysts
		Ótimo > 1,35 Fe catalysts


Biomassa
Gaseificador
Craqueamento em leito catalítico
Gás sem tratamento
Lavadores
Craqueamento Catalítico
Termo craqueamento
Gás limpo
Caldeira
Turbina a gás
MCI
Motor Stirling
Célula combustível
Conversão
Reforma
Sintese
"Shift"
Calor
Eletricidade
Cogeração
Álcool
Metanol
Gasolina
Amônia
Metano



Skoblia et al., 2005

Small scale electricity generation using biomass



CONVERSION TECHNOLOGY

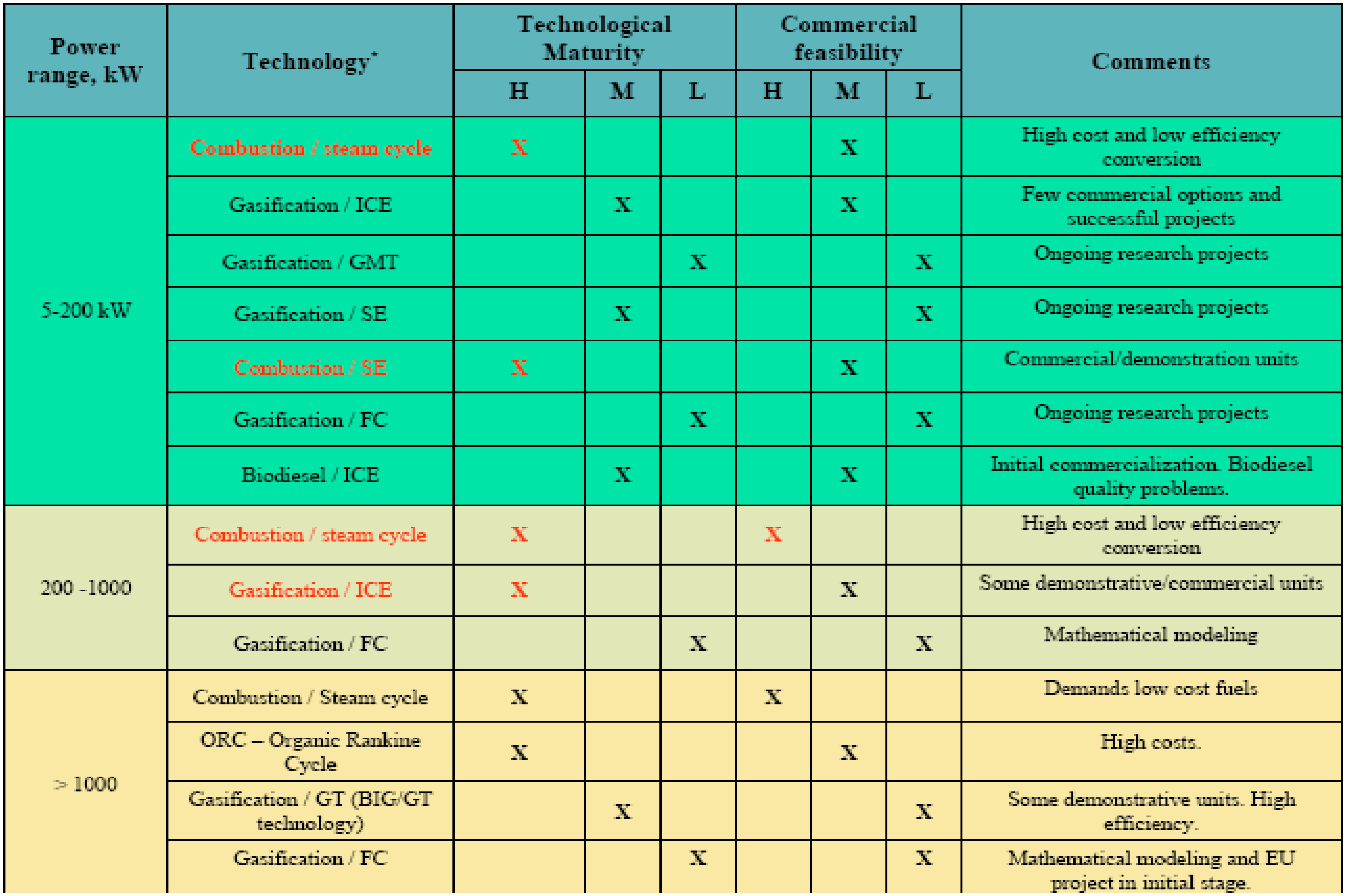
Combustion, gasification, biodigestion, fermentation

PRIME MOVER

ST, RICE, GMT, FC…..

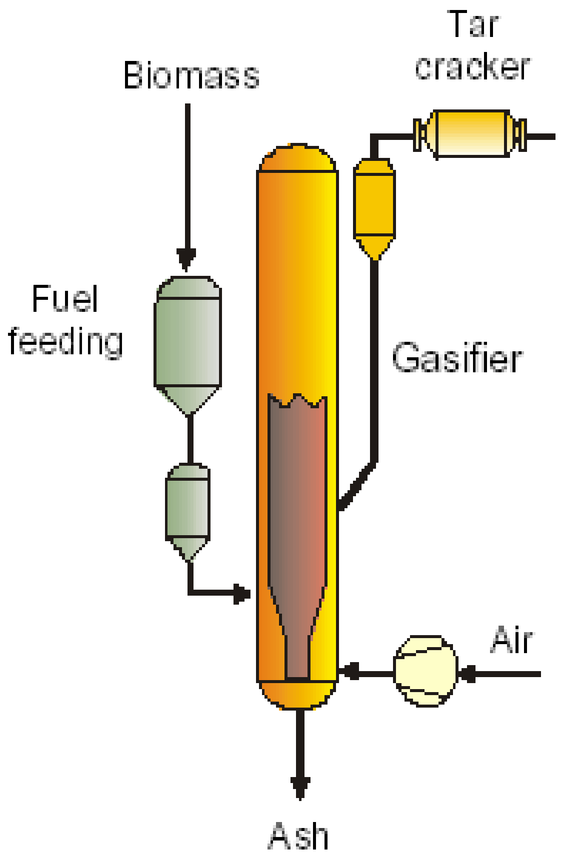
TECHNOLOGICAL AND COMERCIAL MATURITY

Estado da arte das tecnologias disponíveis para a geração de eletricidade para diferentes faixas de potência.



Power range, kW	Technology*	Technological Maturity			Commercial feasibility			Comments
		H	M	L	H	M	L	
5-200 kW	Combustion / steam cycle	X				X		High cost and low efficiency conversion
	Gasification / ICE		X			X		Few commercial options and successful projects
	Gasification / GMT			X			X	Ongoing research projects
	Gasification / SE		X				X	Ongoing research projects
	Combustion / SE	X				X		Commercial/demonstration units
	Gasification / FC			X			X	Ongoing research projects
	Biodiesel / ICE		X			X		Initial commercialization. Biodiesel quality problems.
200 -1000	Combustion / steam cycle	X			X			High cost and low efficiency conversion
	Gasification / ICE	X				X		Some demonstrative/commercial units
	Gasification / FC			X			X	Mathematical modeling
> 1000	Combustion / Steam cycle	X			X			Demands low cost fuels
	ORC – Organic Rankine Cycle	X				X		High costs.
	Gasification / GT (BIG/GT technology)		X				X	Some demonstrative units. High efficiency.
	Gasification / FC			X			X	Mathematical modeling and EU project in initial stage.

Biomass gasification based technologies



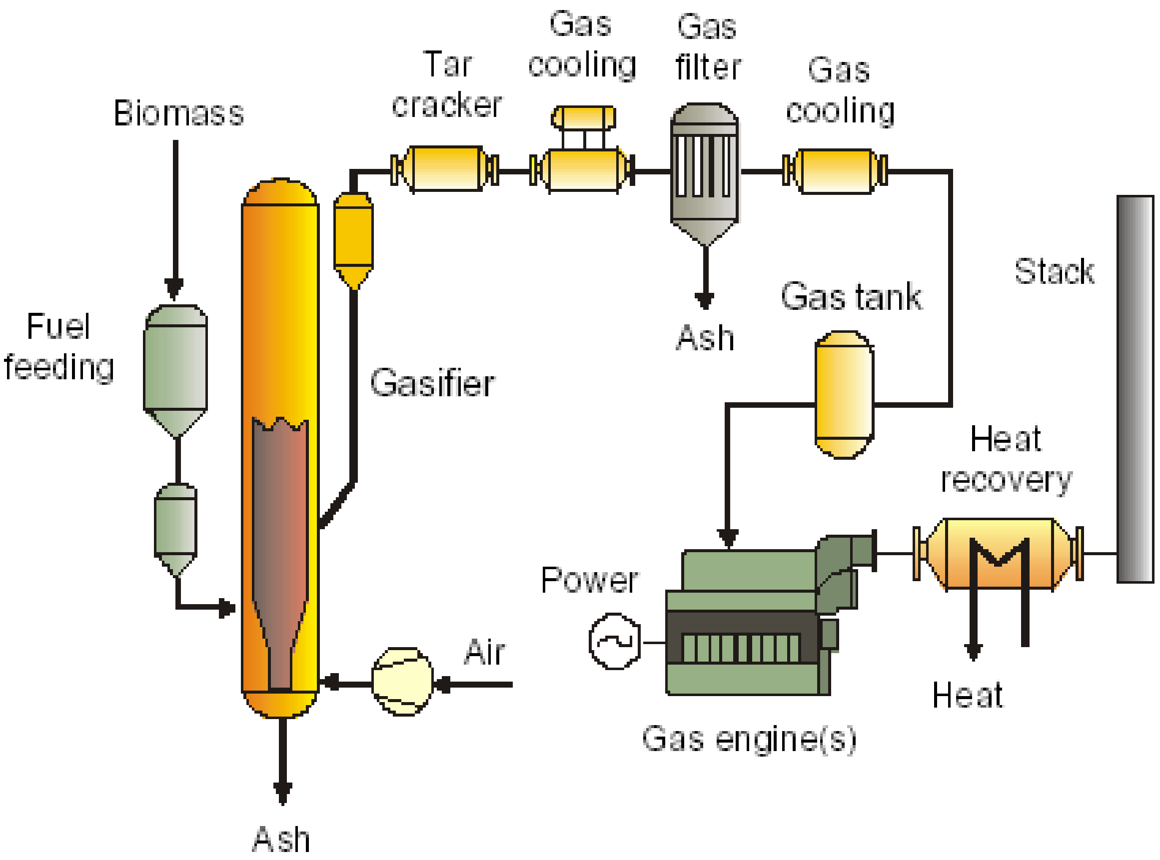
INTERNAL COMBUSTION ENGINES

GAS MICROTURBINES

STIRLING ENGINES

FUEL CELLS

GASIFICATION + ICE



Derating (20-30%)
Timing
Gas cleaning
Compression ratio

Succesfully projects in biomass gasification

- \- **Open top gasifier of the Indian Institute of Science**. Efficiency 80%. Gas LHV 4,7 MJ/Nm3 and tar /particulate content 50 / 80 mg/Nm3.

- **- Comercial chinese rice husk gasifier**, Specific fuel consumption 3,75 – 4,0 kg /kWh, reprted data in the range 2,0 – 2,5 kg/kWh.

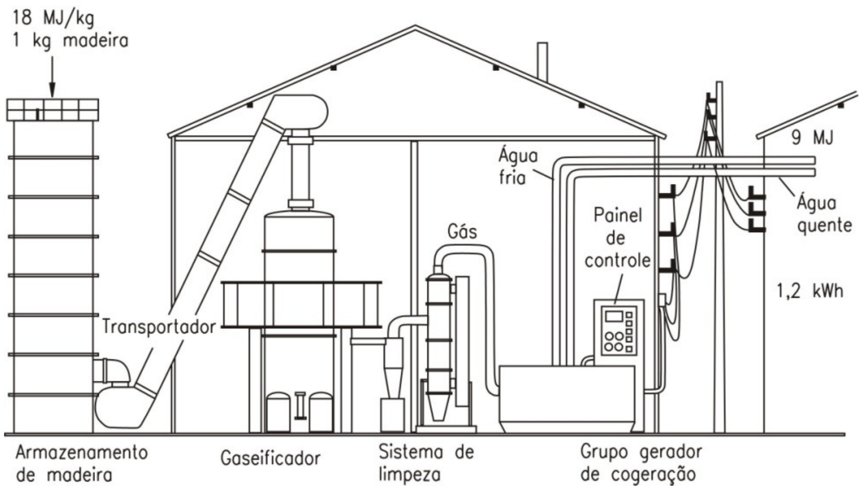
GASEIFICADOR XYLOWATT

Power gasifiers

Xylowatt, Bulle

200 kWe
Just installed

GASIFIER/ENGINE SET FROM XYLOWATT



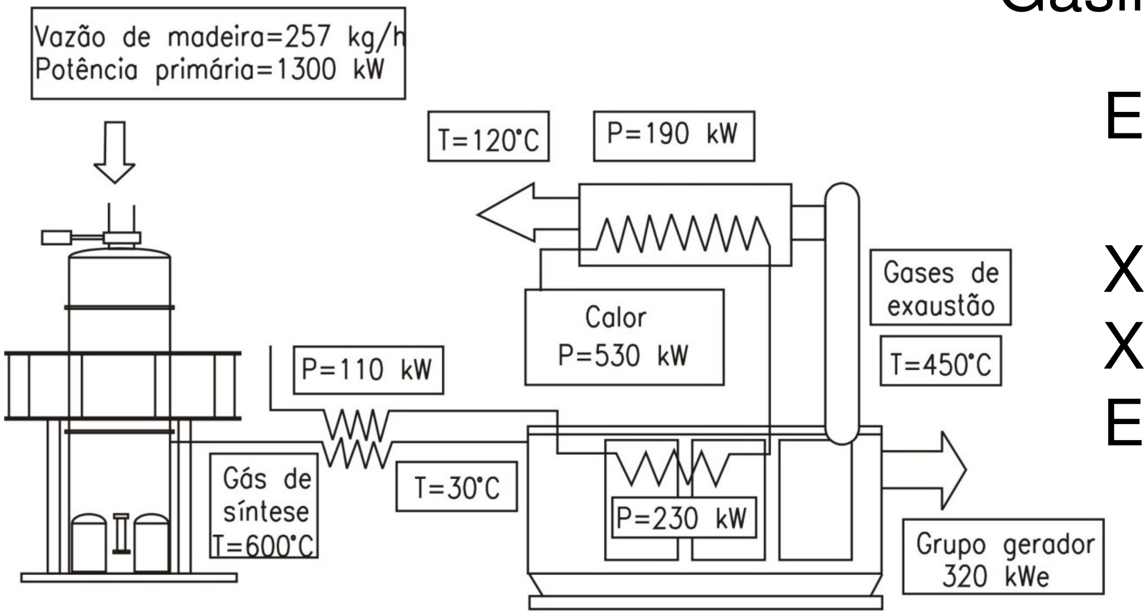
Gas LCV – 5,2 MJ/m3

CO – 25 %
H2 -14 %
CH4 -2 %

Gasifier efficiency – 70-80 %

Electric Power

XW 300- 300-350 kWe
XW 900 – 900-1050 kWe
Electric efficiency – 25 %



Source: Laborelec, 2004

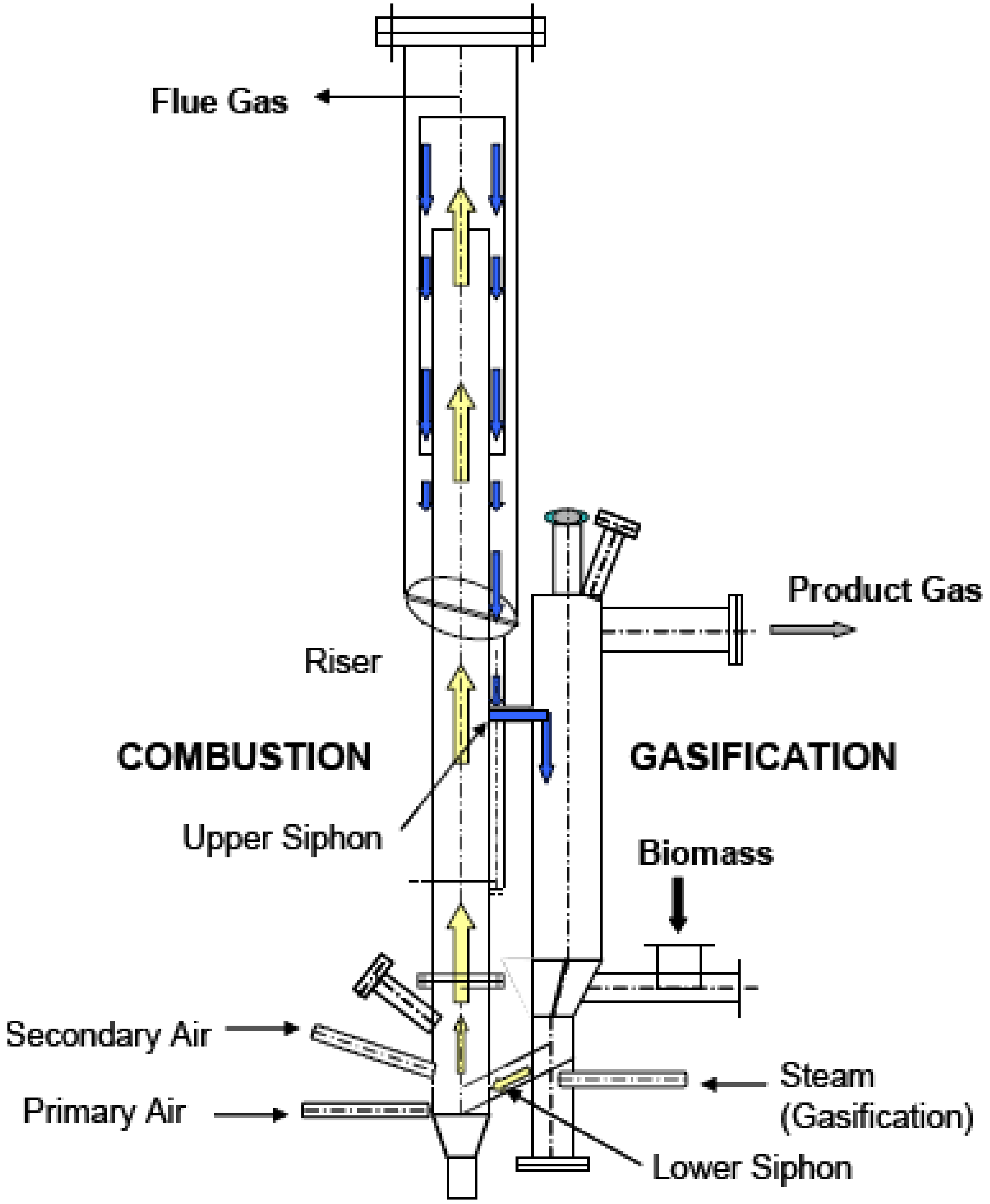
Succesfully projects in biomass gasification

- **ENAMORA Gasifier** installed in Móra d´Ebre, Tarragona, Spain. Developed by the Instituto Catalán de Energía. Coupled to an 750 kWe engine with a system efficiency of 21-22 %.

- **Gasificación in Gussing, Austria**. Composed by a two zone indirectly heated gasifier and a gas ICE Jenbacher J620 GS. The gas LHV is 12,00 MJ/Nm3 and the system electrical efficiency 30 %.

- \- **Biomax 15.** Gasifier/ICE set of 10-25 kWe developed by Community Power Corporation (CPC) and the National Renewable Energy Laboratory-NREL. Biomass specific consumption 1,5 kg/kWh and specific investment 1200,00 $/kWh.

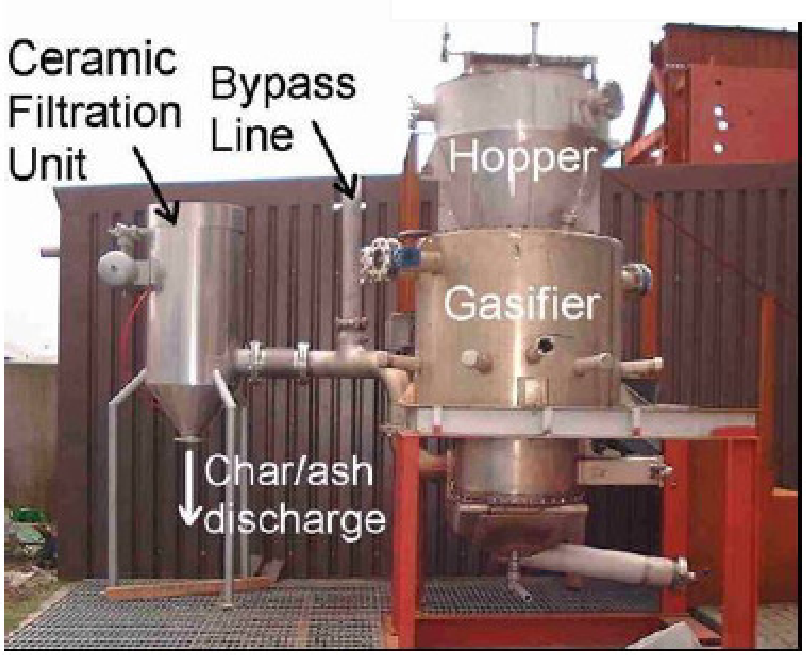
GASEIFICADOR ENAMORA



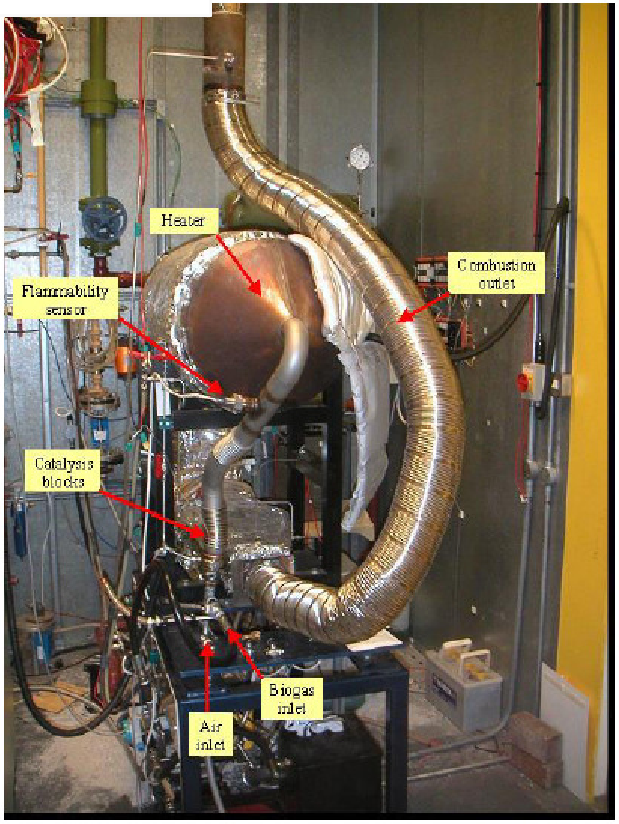
: *FICFB gasification reactor /Hofbauer 2001/*

BIOMAX 15

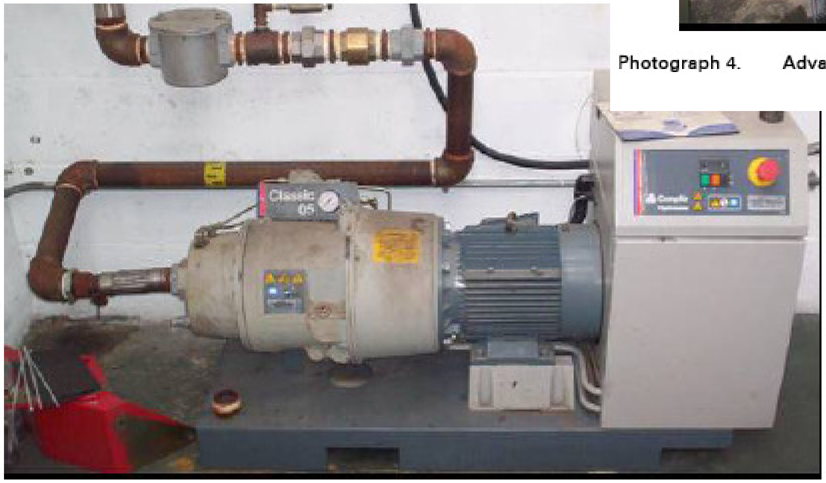
GASIFIER / GMT



Photograph 1. Gasifier and Test filtration unit without feed conveyor addition of char/ash bin)

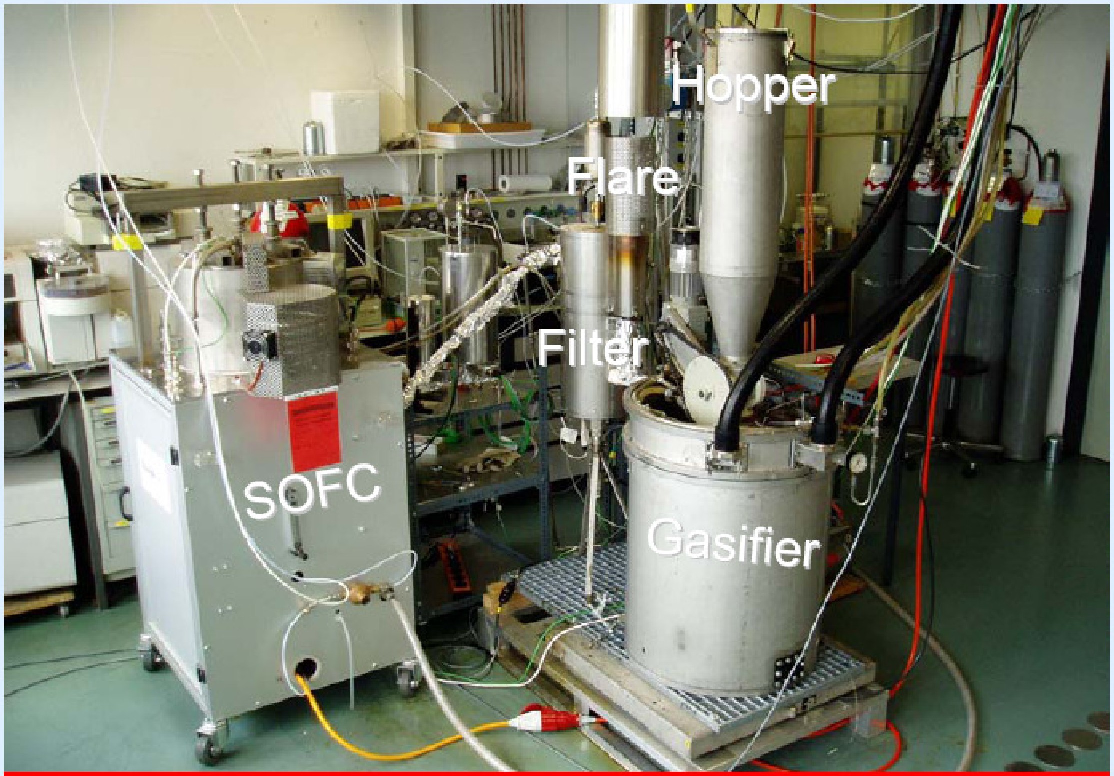


Photograph 4. Advantica Catalytic test rig



Photograph 3. Gas compressor model HV07

GASIFIER / SOFC



Tested successfully for more than 100 hours

Source: F. P. Nagel, M. Künstle, S. Biollaz, "Link-Up of a Solid Oxide Fuel Cell with a Wood Gasi-fier", Proceedings of 14th European Biomass Conference, pp. 746-748, Paris, France, 17th-21st October 2005

Experimental setup

- ☐ Lab scale up-draft gasifier
- ☐ Ceramic particle filter
- ☐ Jet stream pump
- ☐ 60W- SOFC short stack

Results

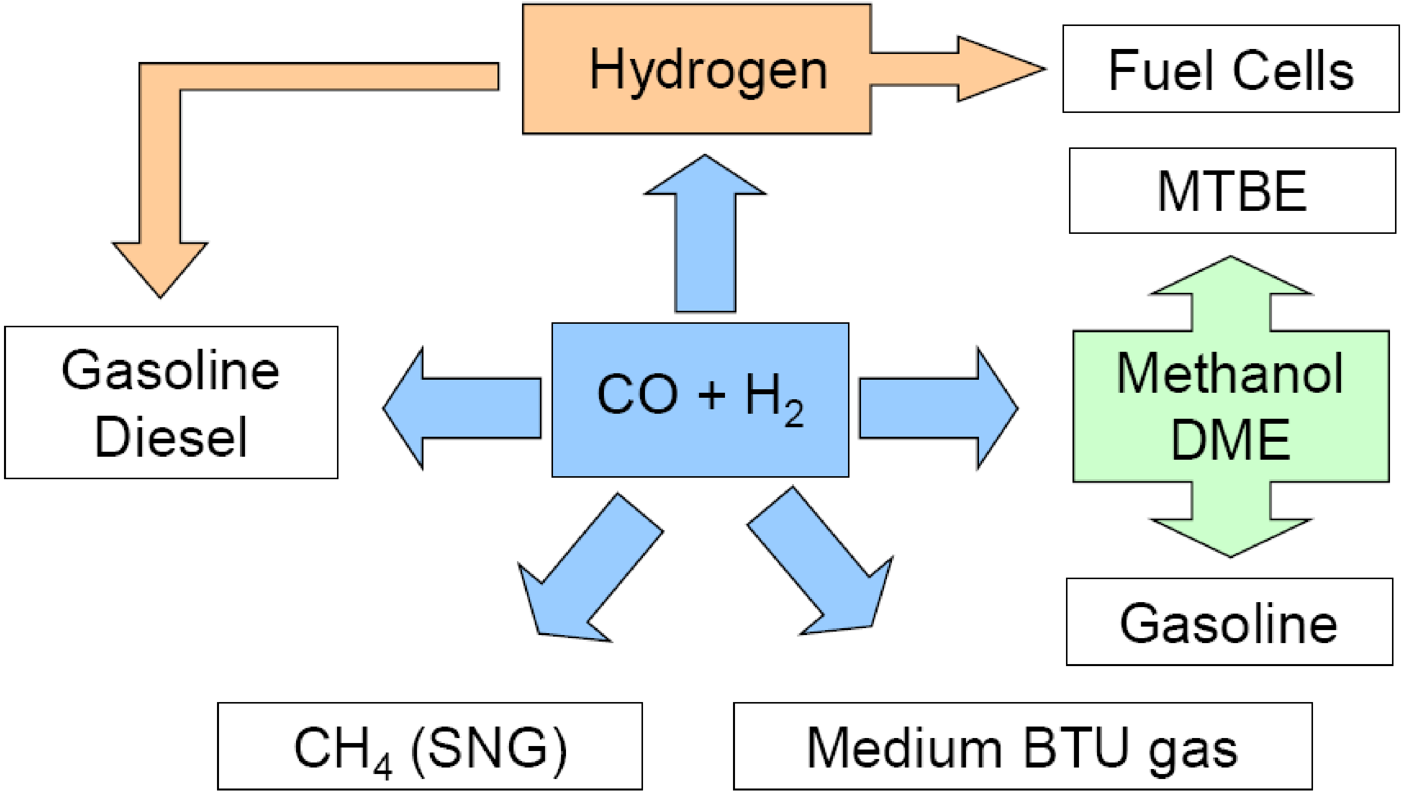
- ☐ Non-stop experiments up to 16 h
- ☐ Gas analysis of producer gas with up to 150 g/m_n^3 tar load
- ☐ Normal deactivation

SYNGAS

Mixture of gases composed mainly by H_2 e CO, obtained from natural or previously pyrolyzed biomass, and with a potential application for the synthesis of different chemical compounds.

In the case of the BTL technology the main interest in the production of chemicals with similar properties as fossil transport fuels.

Fuel options of syngas and hydrogen



Hydrogen

Fuel Cells

MTBE

Gasoline
Diesel

CO + H_2

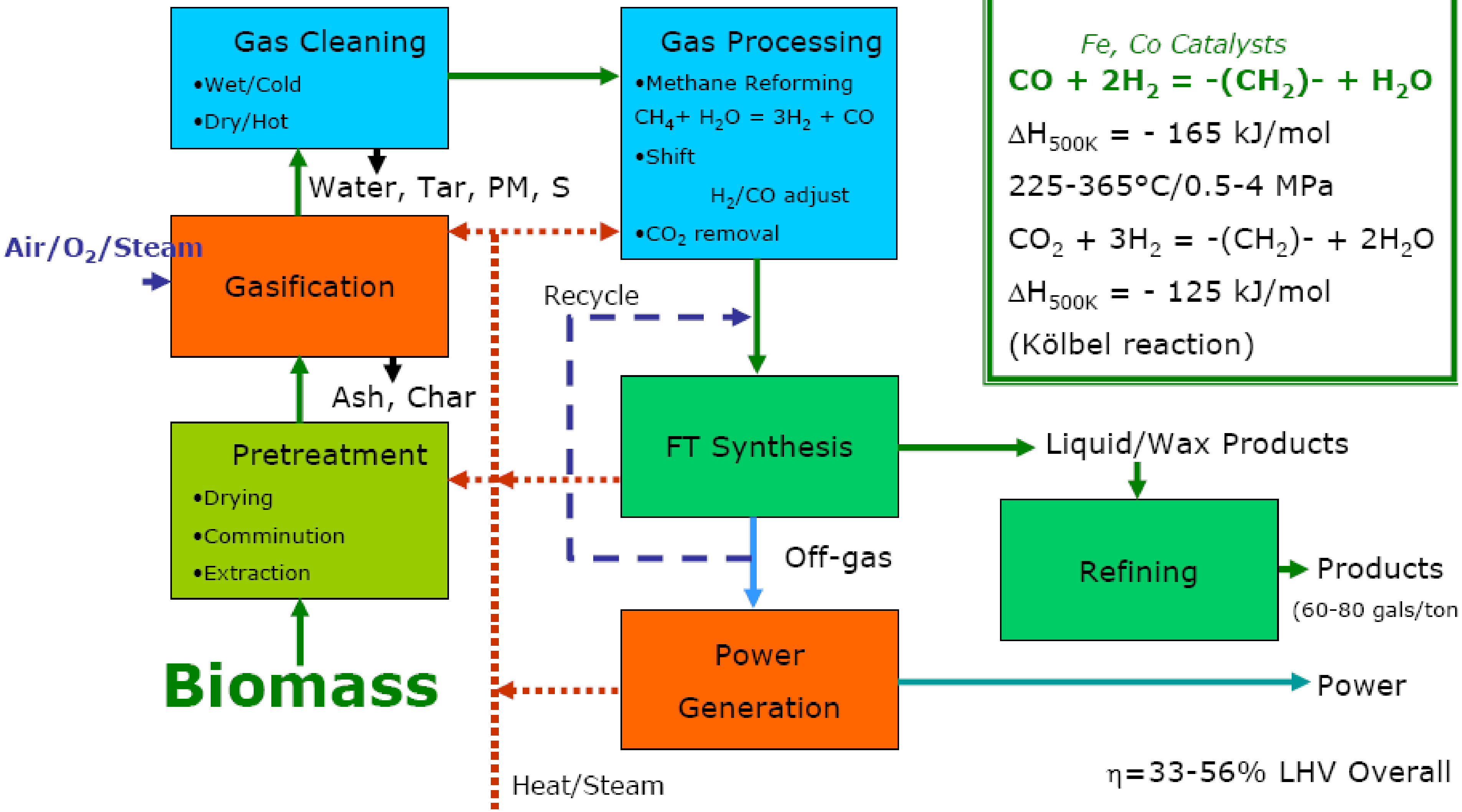
Methanol
DME

Gasoline

CH_4 (SNG)

Medium BTU gas

BTL: Biomass To Liquids



Gas Cleaning
- Wet/Cold
- Dry/Hot

Water, Tar, PM, S

Gas Processing
- Methane Reforming

$CH_4 + H_2O = 3H_2 + CO$
- Shift

H_2/CO adjust
- CO_2 removal

Air/O_2/Steam

Gasification

Ash, Char

Recycle

Pretreatment
- Drying
- Comminution
- Extraction

Biomass

FT Synthesis

Off-gas

Liquid/Wax Products

Refining

Products (60-80 gals/ton

Power Generation

Power

Heat/Steam

η=33-56% LHV Overall

Fischer-Tropsch Synthesis

Fe, Co Catalysts

$$CO + 2H_2 = -(CH_2)- + H_2O$$

$\Delta H_{500K} = -165$ kJ/mol

225-365°C/0.5-4 MPa

$CO_2 + 3H_2 = -(CH_2)- + 2H_2O$

$\Delta H_{500K} = -125$ kJ/mol

(Kölbel reaction)

Requirements of the gasification for synthesis gas (I)

- Procesing capacities higher than 5.10^6 toneladas of biomass per year.

- Low content of impurities in the gas.

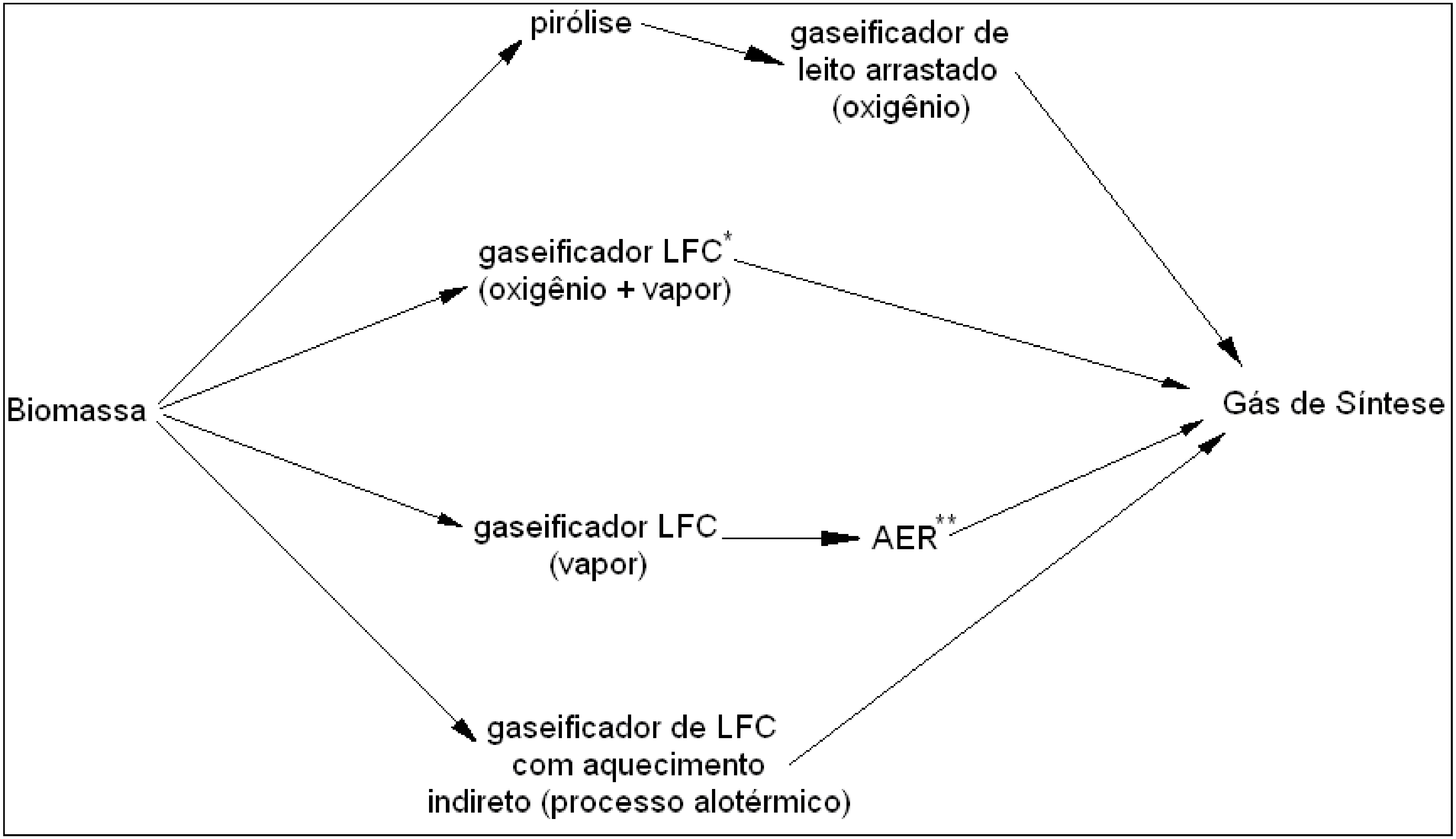
- High content of H_2 and CO (High H_2 content)

Requirements of the gasification for synthesis gas (II)

- Oxygen must be used as gasification gas to avoid N_2 in the synthesis gas.

- Steam injection for reforming and for temperature reduction.

Technological options of gasification for synthesis gas production



Biomassa

pirólise

gaseificador de
leito arrastado
(oxigênio)

gaseificador LFC*
(oxigênio + vapor)

gaseificador LFC
(vapor)

AER**

gaseificador de LFC
com aquecimento
indireto (processo alotérmico)

Gás de Síntese

* LFC - Leito Fluidizado Circulante

** AER - Reforma Melhorada por Adsorção

Gasifiers potentially usefull for SYNGAS I

- **Renugas (IGT): Bubbling fluidized bed, steam + O_2.**

- **Carbo V (pyrolysis + gaseification): Bubbling fluidized bed, O_2.**

- **HTW (High Temperature Winkler): O_2 + steam.**

- **DMT: indirect heating (steam as heat carrier).**

Gasifiers potentially usefull for SYNGAS II

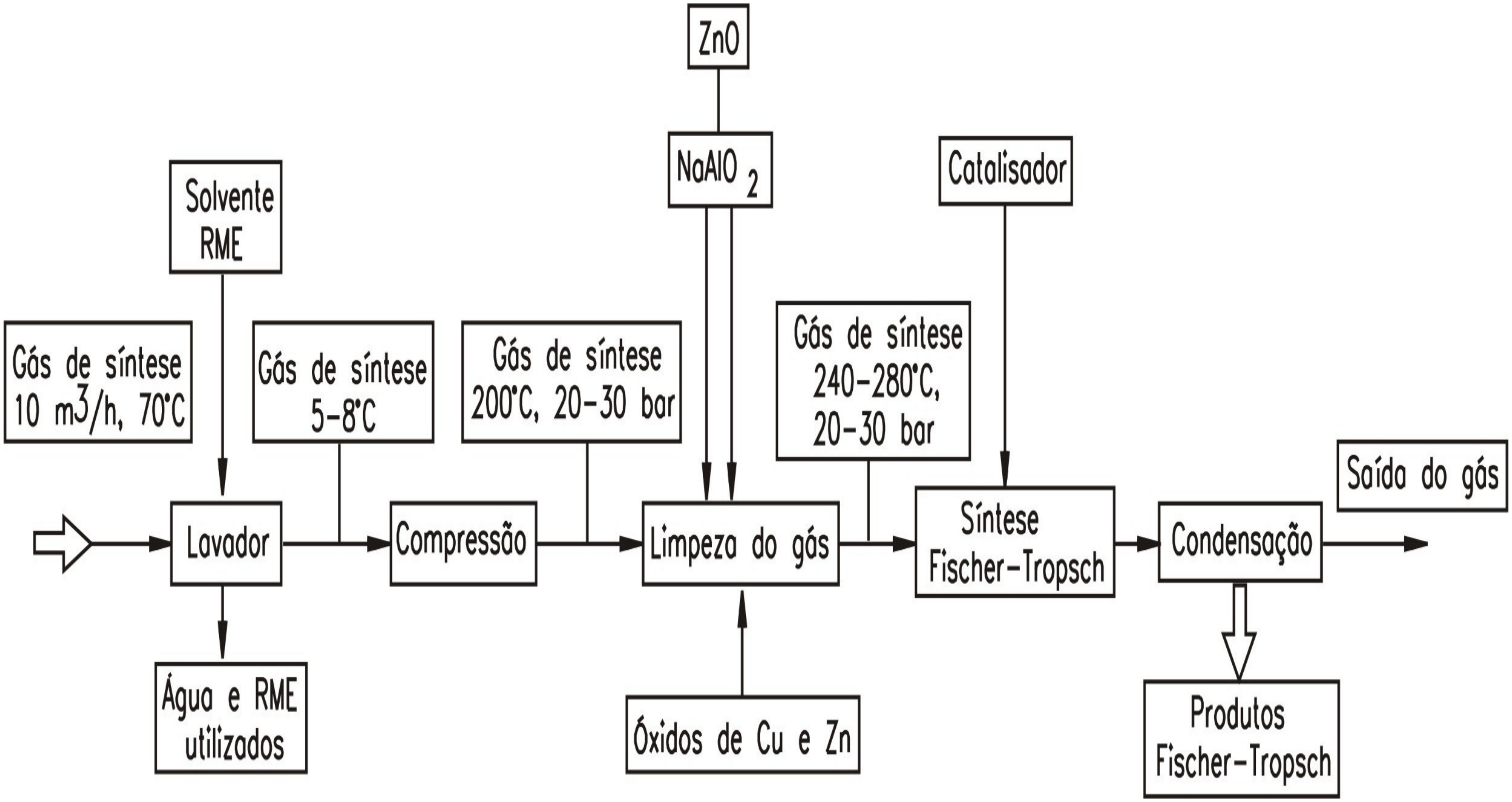
- Batelle/Ferco: Double indirect heated fluidized bed.

- FICFB (Fast Internally Fluidized Bed): Güssing Plant in Áustria.

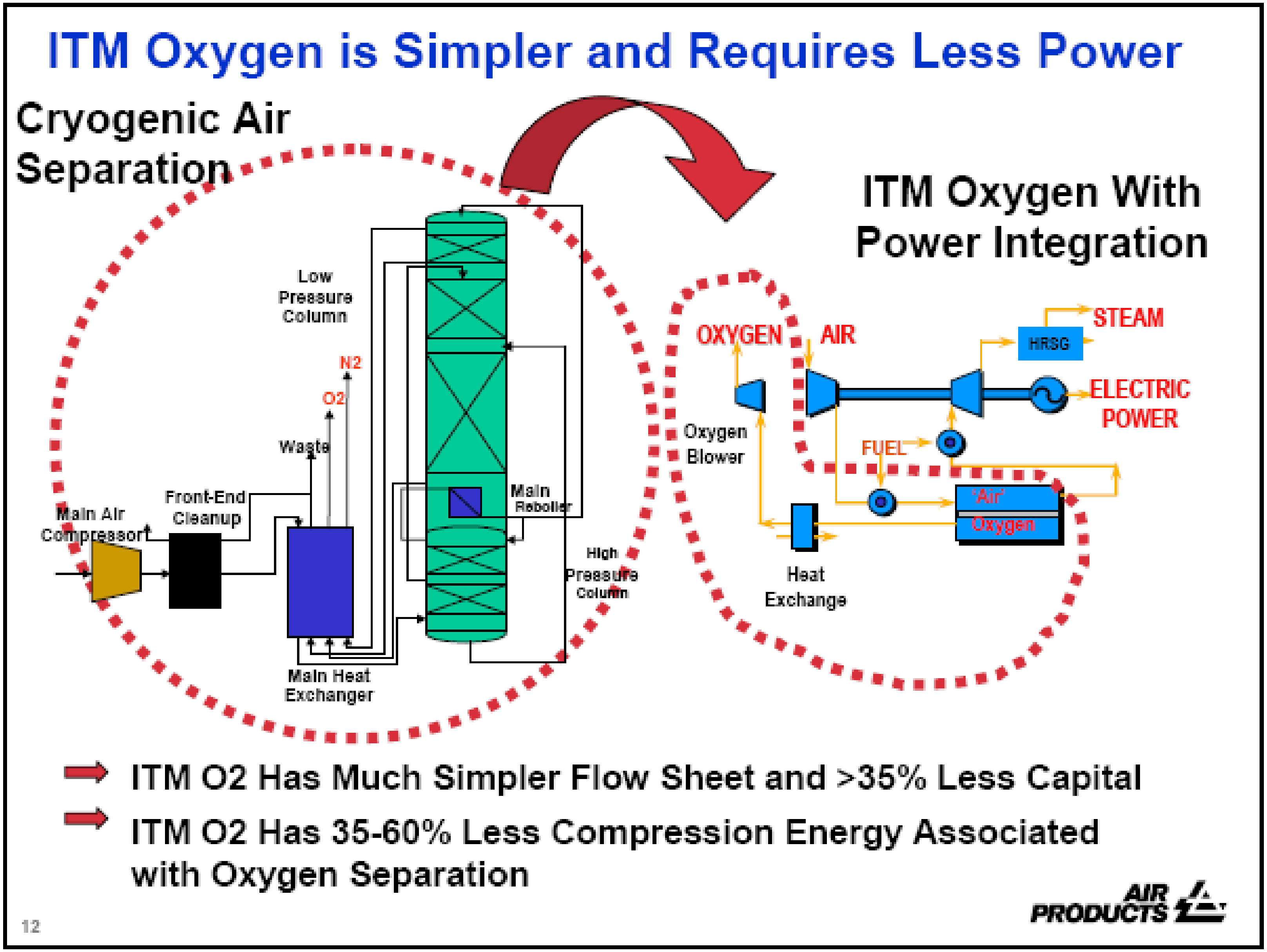
- AER Process AER: Steam gasification.

- Entrained flow gasifiers Shell, Siemens, Lurgi e Texaco.

The Gussing gasification plant in Austria



THE OXYGEN PROBLEM: COST



ITM Oxygen is Simpler and Requires Less Power

Cryogenic Air Separation

ITM Oxygen With Power Integration

- ITM O2 Has Much Simpler Flow Sheet and >35% Less Capital
- ITM O2 Has 35-60% Less Compression Energy Associated with Oxygen Separation

Research projects in gasification for synthesis gas

- **Delft** University - Holland: CFB hasification with steam and O_2.

- **ECN** (Energy Research Centre of Netherlands) - Holland:

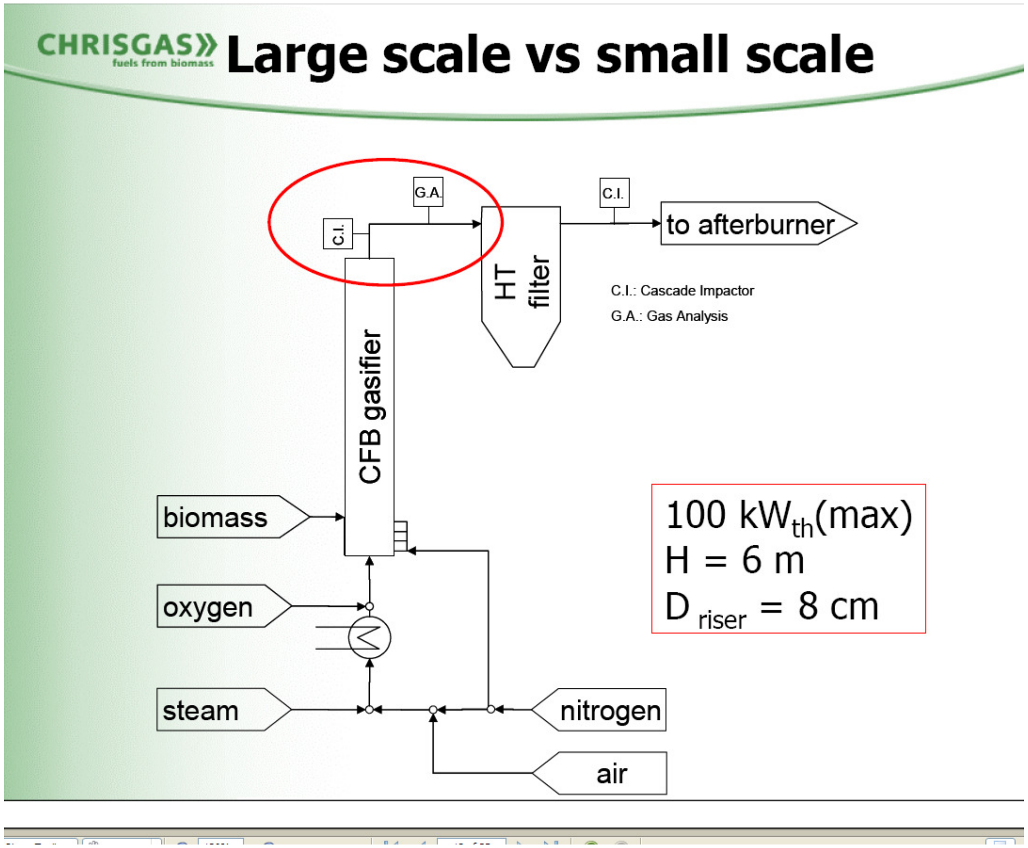
- **CIEMAT** (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) Spain: CFB gasifier using air in a first stage.

- **VTT** (Technical Research Centre of Finland): Pressurized BFB gasifier (O_2 + steam).

- **Chrisgas project**. EU Project.

- **IOWA STATE UNIVERSITY**

Delft University (Holland)



Large scale vs small scale

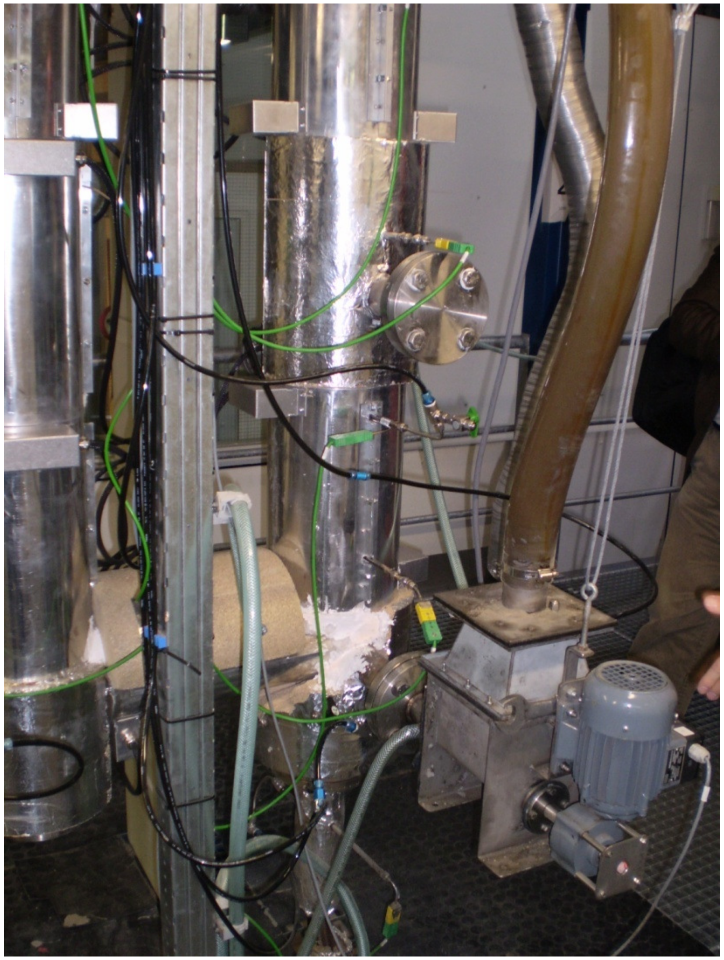
C.I.: Cascade Impactor

G.A.: Gas Analysis

100 kW_{th}(max)

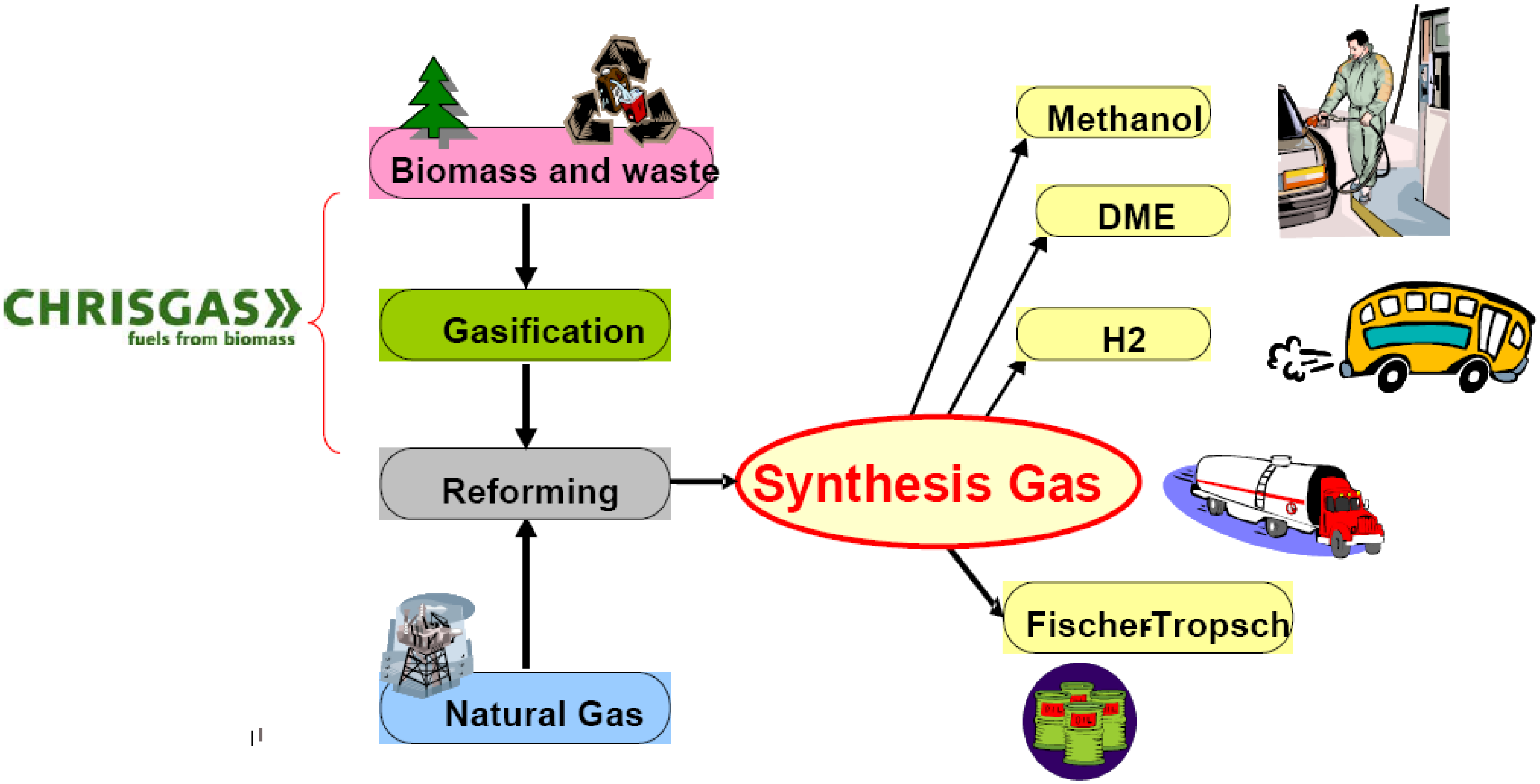
H = 6 m

D_{riser} = 8 cm



Varnamo (Sweden)

CHRISGAS:
Clean Hydrogen-rich Synthesis Gas



CHRISGAS»
fuels from biomass

Biomass and waste

Gasification

Reforming

Natural Gas

Synthesis Gas

Methanol

DME

H2

FischerTropsch

CHRISGAS Objectives

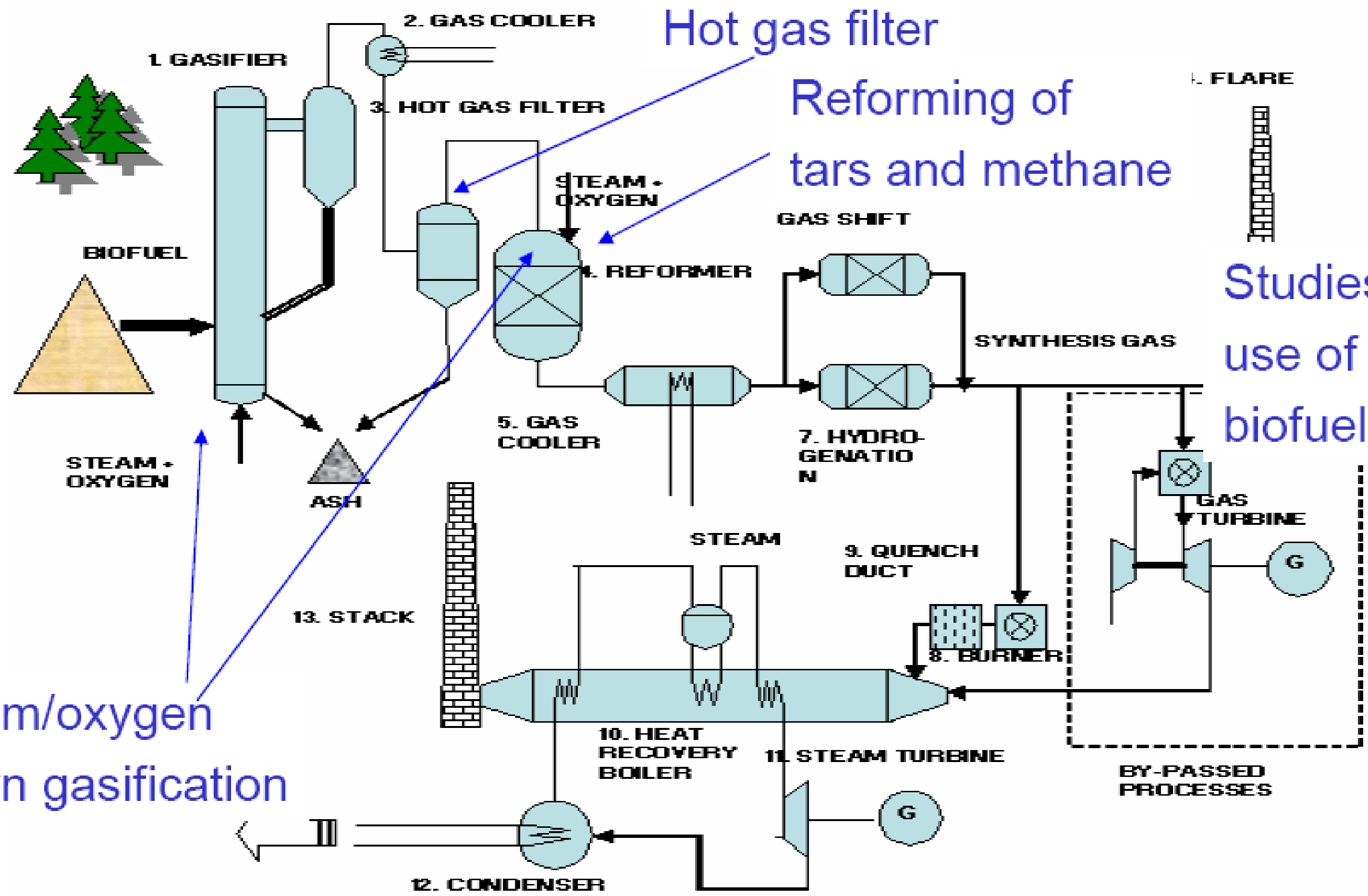
To demonstrate the production of a clean hydrogen-rich synthesis gas

(within a 5 year period at 18 MWth,3 500 Nm^3/hr H_2 equivalent)

based on:

- steam/oxygen-blown gasification of biomass
- hot gas cleaning (to remove particulates)
- steam reforming (of tar and light hydrocarbons,incl CH_4)

Värnamo Gasification Plant (after rebuild)



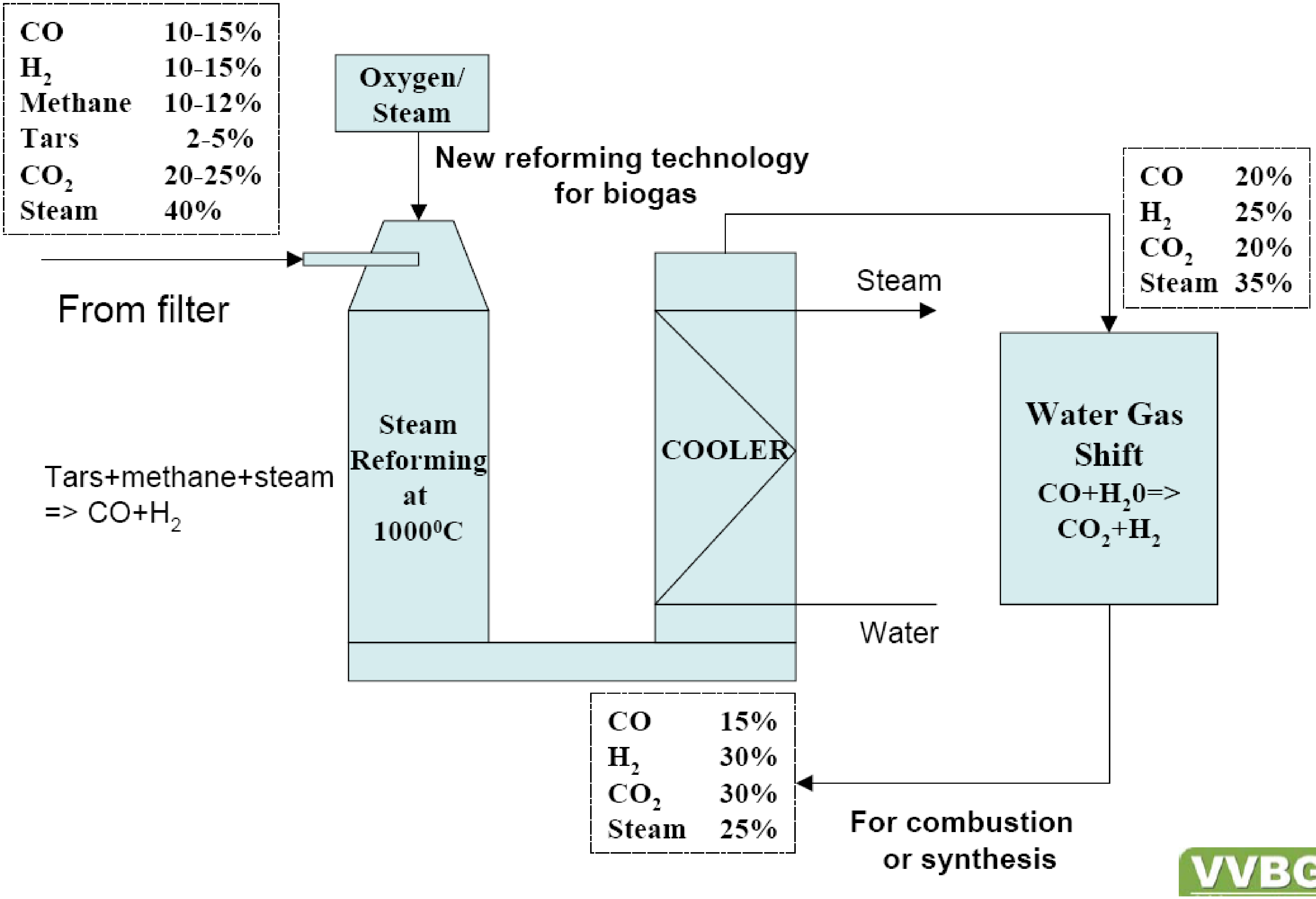
Hot gas filter

Reforming of tars and methane

Studies of future use of the gas for biofuel products

Steam/oxygen blown gasification

Gas Upgrading to Syngas



CO	10-15%
H_2	10-15%
Methane	10-12%
Tars	2-5%
CO_2	20-25%
Steam	40%

From filter

Oxygen/ Steam

New reforming technology for biogas

Steam Reforming at 1000°C

Tars+methane+steam => $CO+H_2$

COOLER

Steam

Water

CO	20%
H_2	25%
CO_2	20%
Steam	35%

Water Gas Shift

$CO+H_20 \Rightarrow CO_2+H_2$

CO	15%
H_2	30%
CO_2	30%
Steam	25%

For combustion or synthesis

VVBGC

VISITING VARNAMO

GASIFICATION RESEARCH

AT

NEST/IEM/UNIFEI

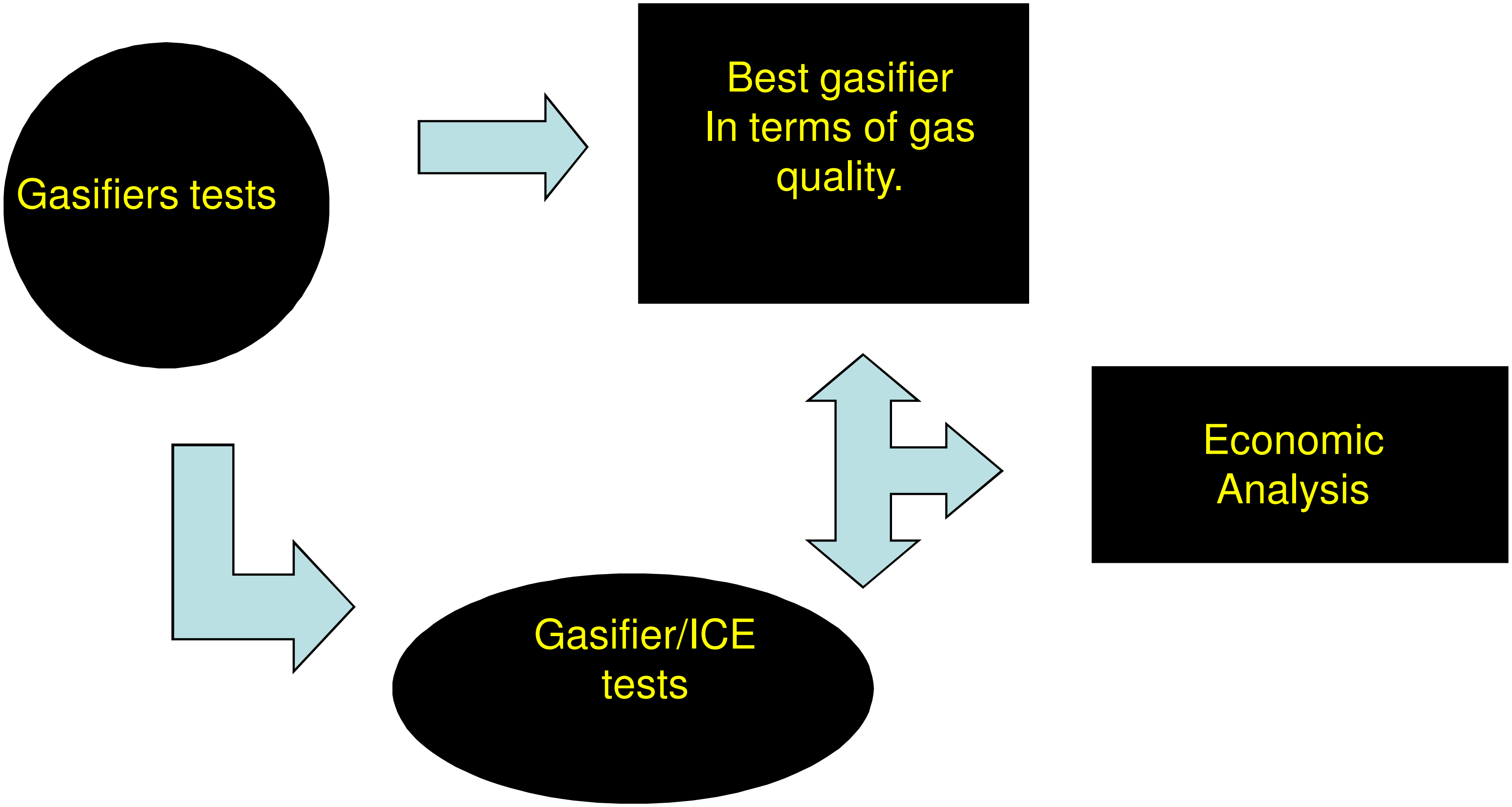
Present activities of NEST/IEM/UNIFEI in the field of biomass gasification

- Built-up and tests of a set comprising a two stage downdraft gasifier an and internal combustion engine.

- Design of a circulating fluidized bed gasifier for synthesis gas production (O_2 + Steam).

- LCA of the bio-H_2 and biomethanol production.

Research logic



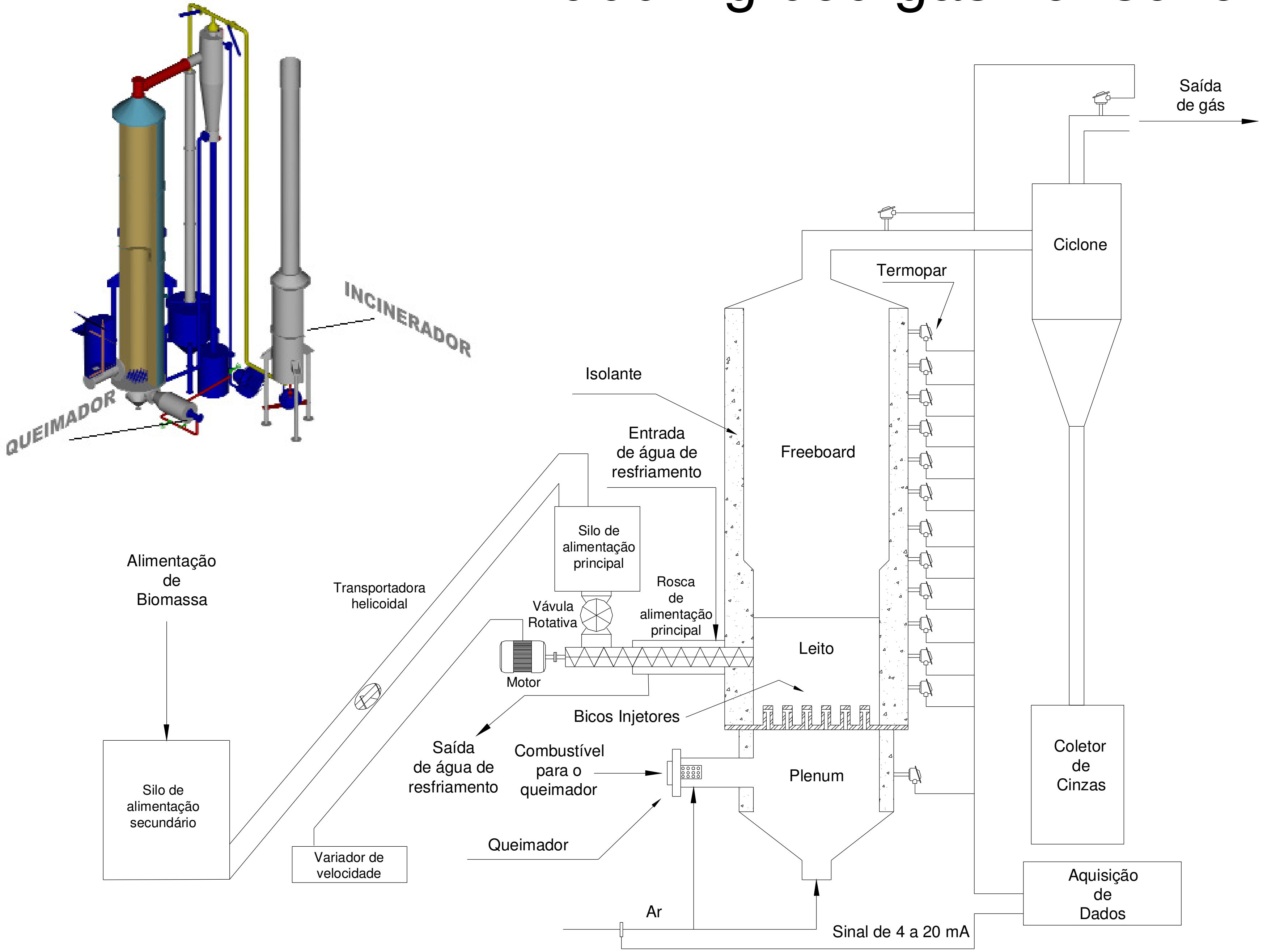
Gasifiers tests

Best gasifier
In terms of gas
quality.

Economic
Analysis

Gasifier/ICE
tests

Bubbling bed gasifier scheme



Saída de gás

Ciclone

Termopar

Isolante

Freeboard

Entrada de água de resfriamento

Silo de alimentação principal

Alimentação de Biomassa

Transportadora helicoidal

Vávula Rotativa

Rosca de alimentação principal

Leito

Motor

Bicos Injetores

Saída de água de resfriamento

Combustível para o queimador

Plenum

Coletor de Cinzas

Silo de alimentação secundário

Queimador

Variador de velocidade

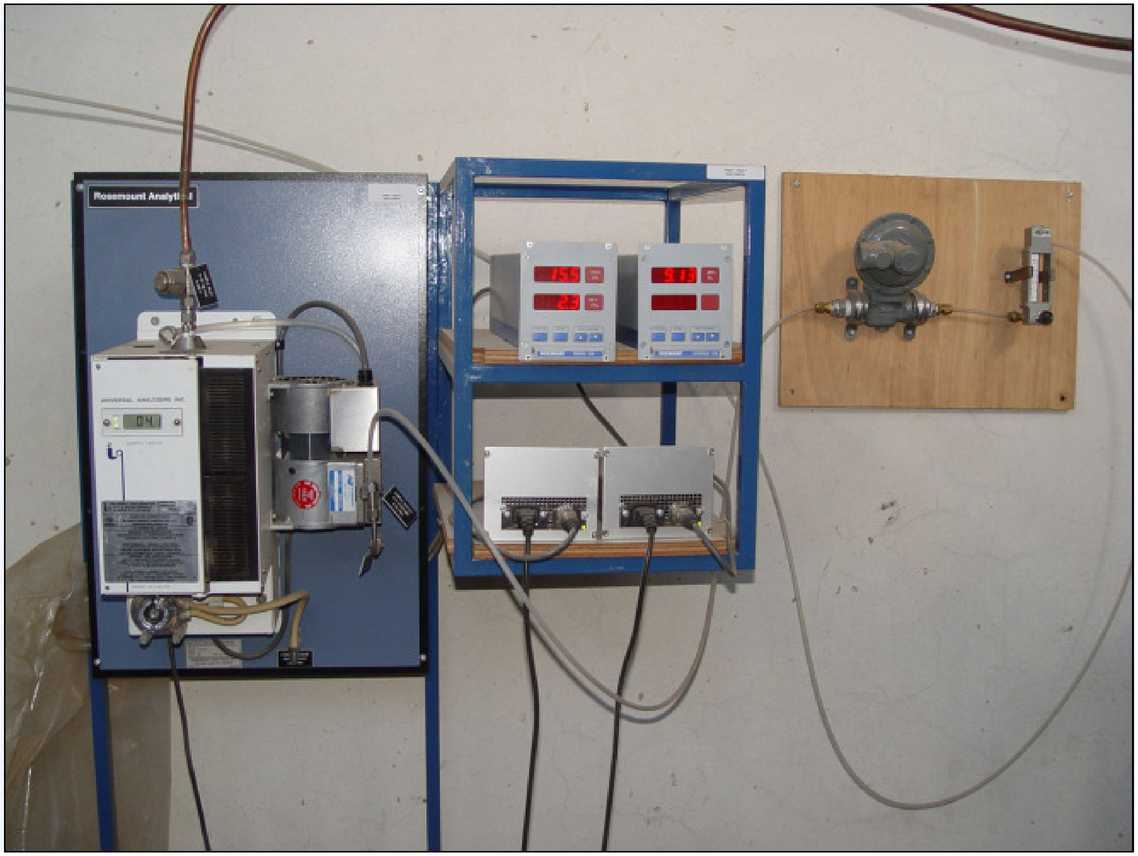
Aquisição de Dados

Ar

Sinal de 4 a 20 mA

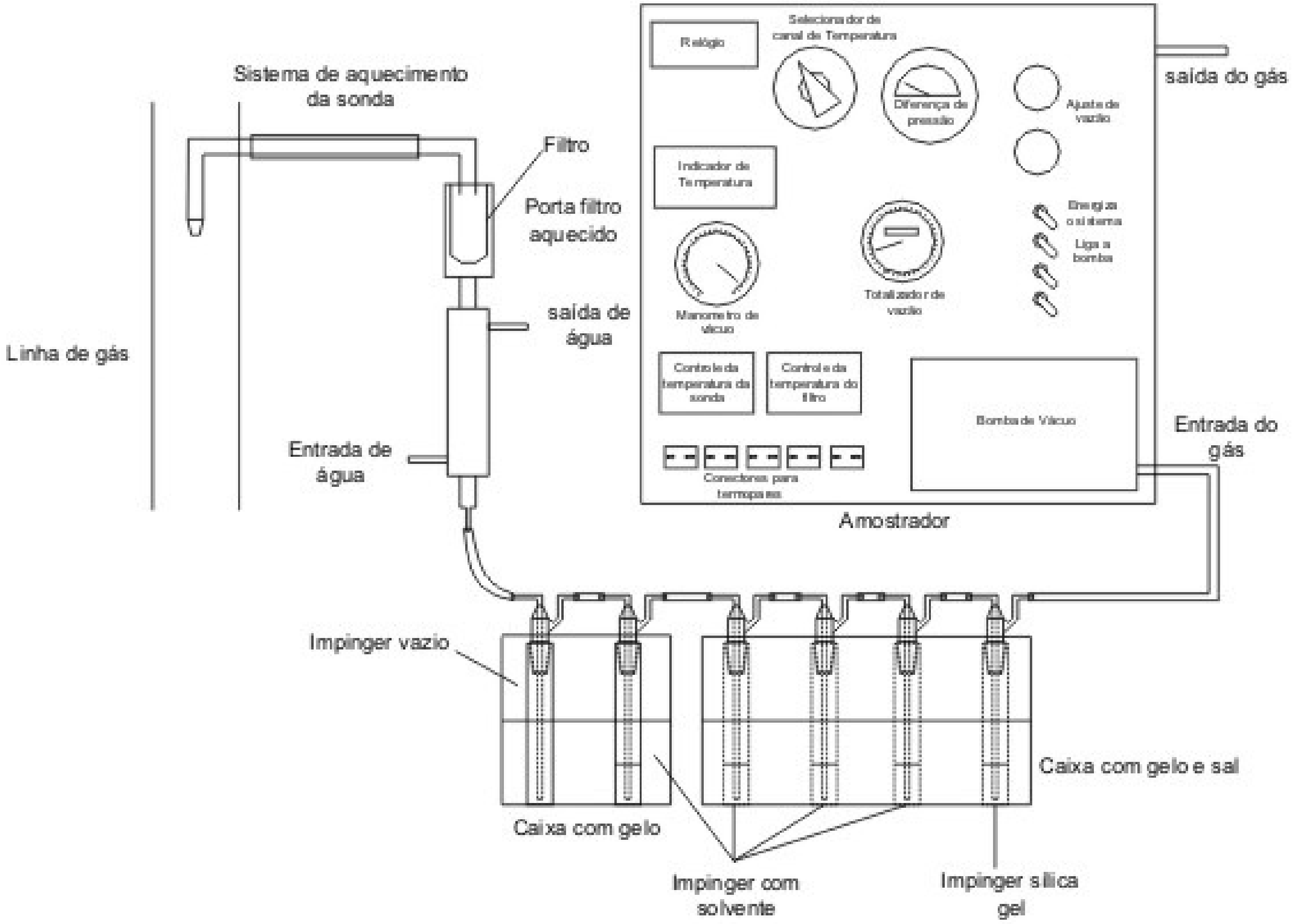
The gasifier in operation...

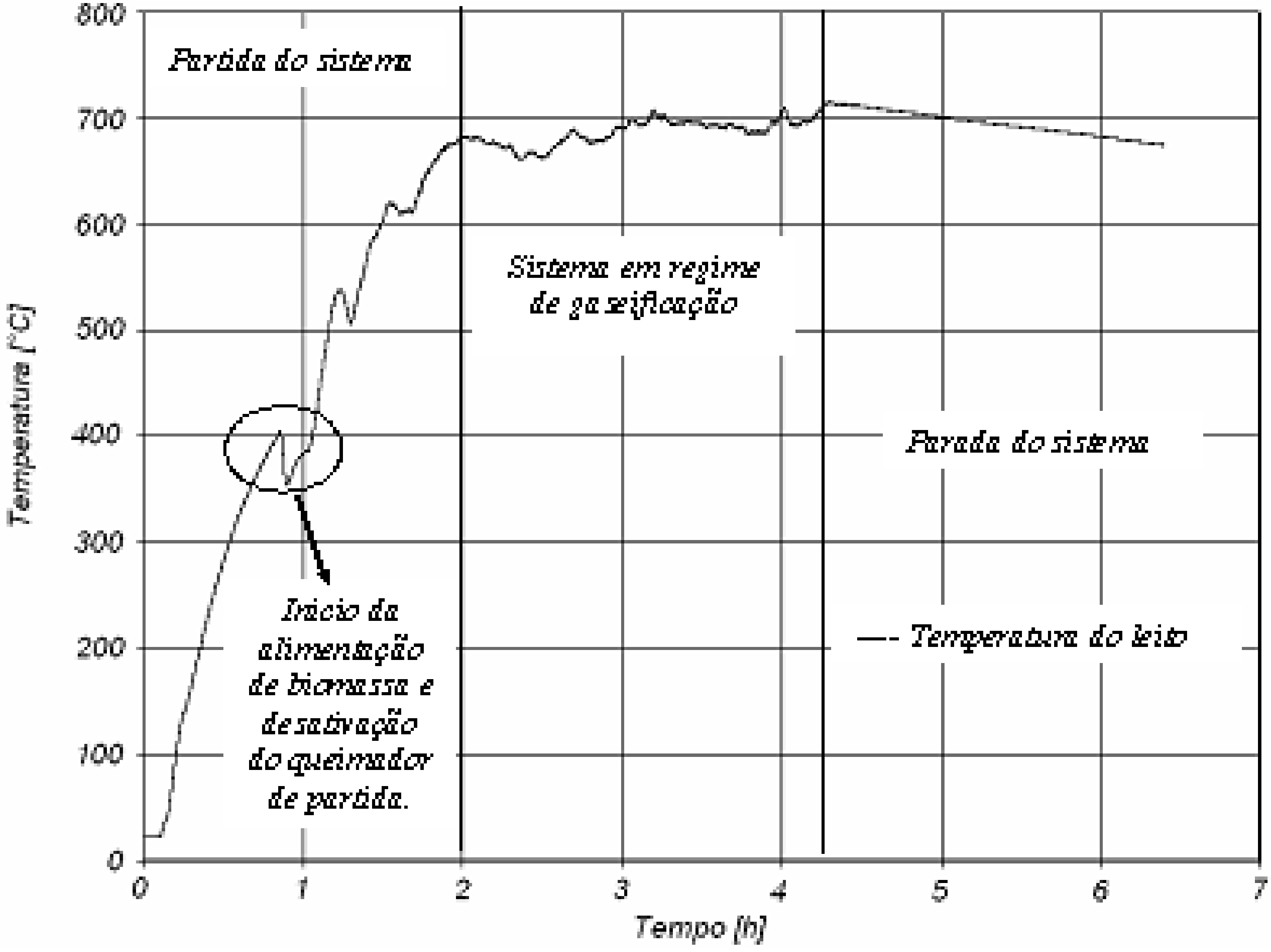
Continuous gas analyzers



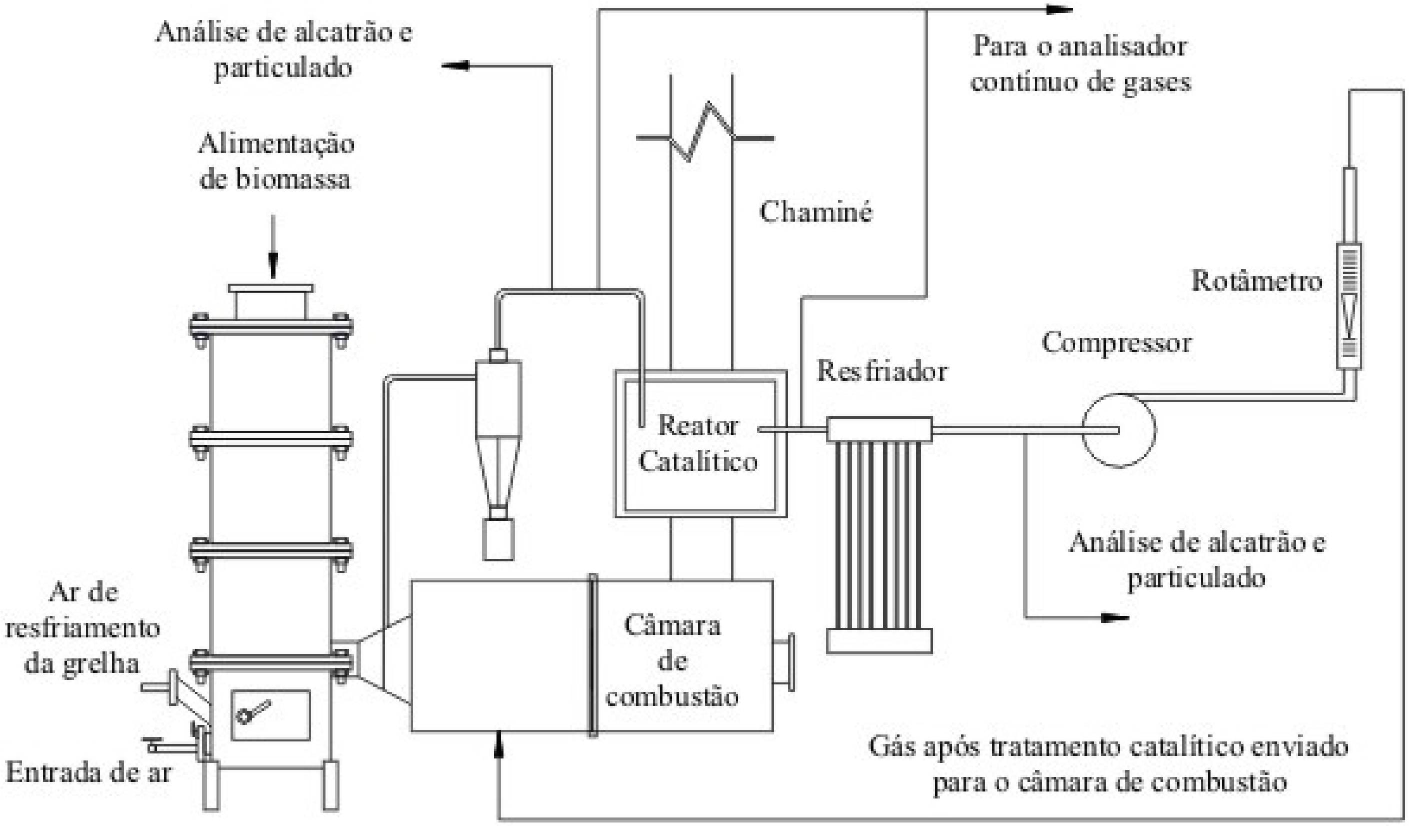
Tar and particulate content measurement

- Gravimetric analysis

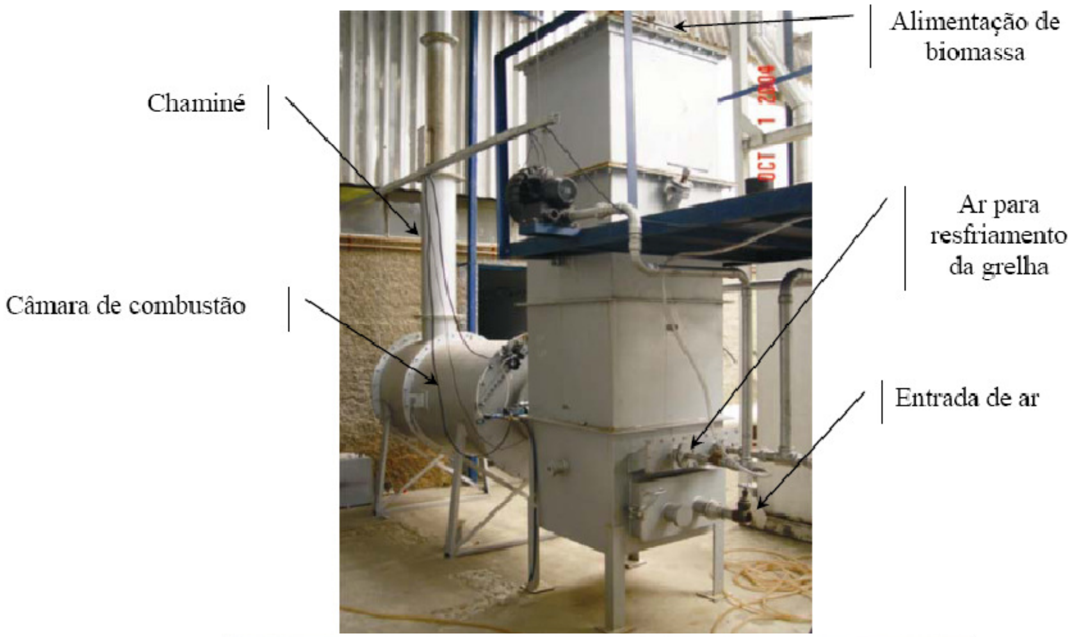



Partida do sistema
Sistema em regime de gaseificação
Parada do sistema
Início da alimentação de biomassa e desativação do queimador de partida.
— Temperatura do leito
Temperatura [°C]
0
100
200
300
400
500
600
700
800
Tempo [h]
0
1
2
3
4
5
6
7

Catalytic cleaning as a secondary method for tar conversion



System equipment



Catalytic cleaning results

Gas composition

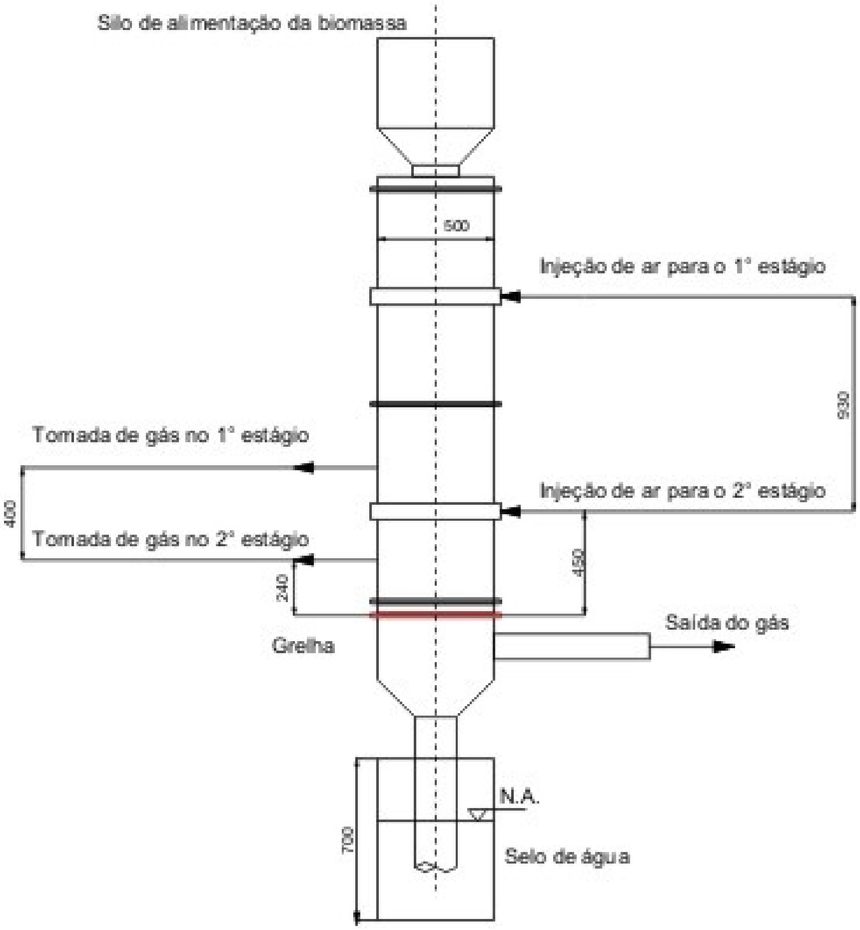
	CO	H_2	CH_4
Before CR	20	4	1,5
After CR	20	7	1,8

Tar content

Sampling point	Tar content (g/ Nm^3)	Particulate content [g/Nm^3]
Before CR	47,93	3,87
After CR	20,12	7,65

Downdraft two-stage gasification

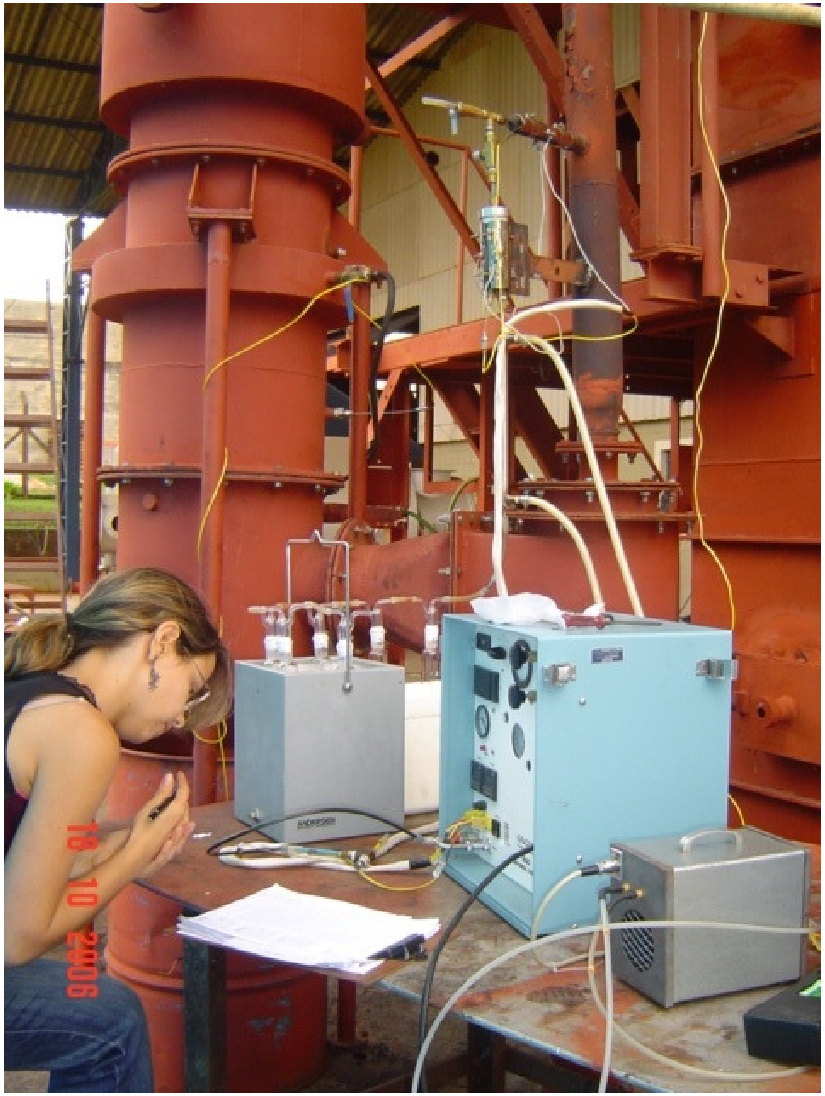
- Double stage gasification (Primary method for tar control)




18 10 2006

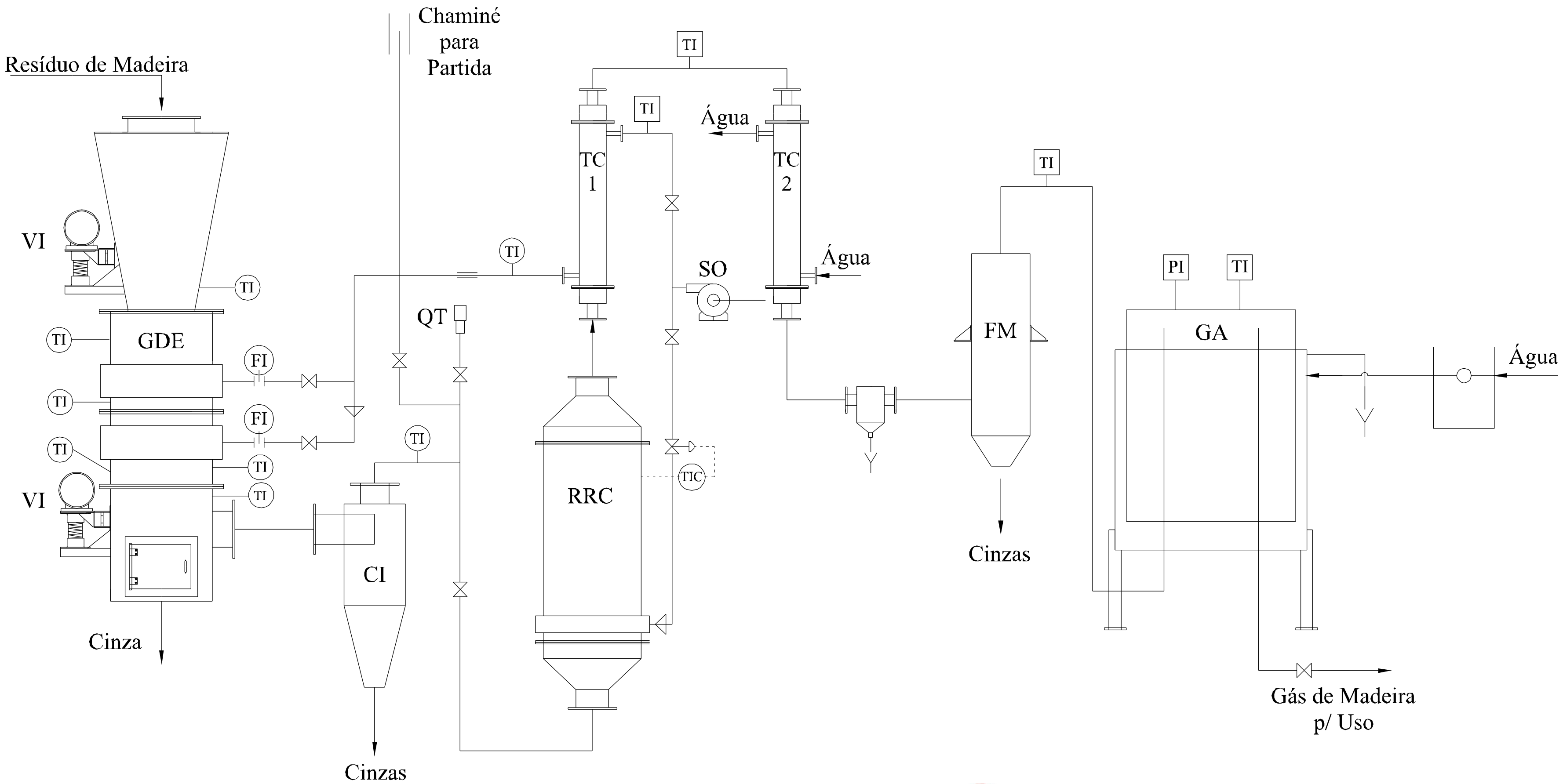

18 10 2006


17 10 2006

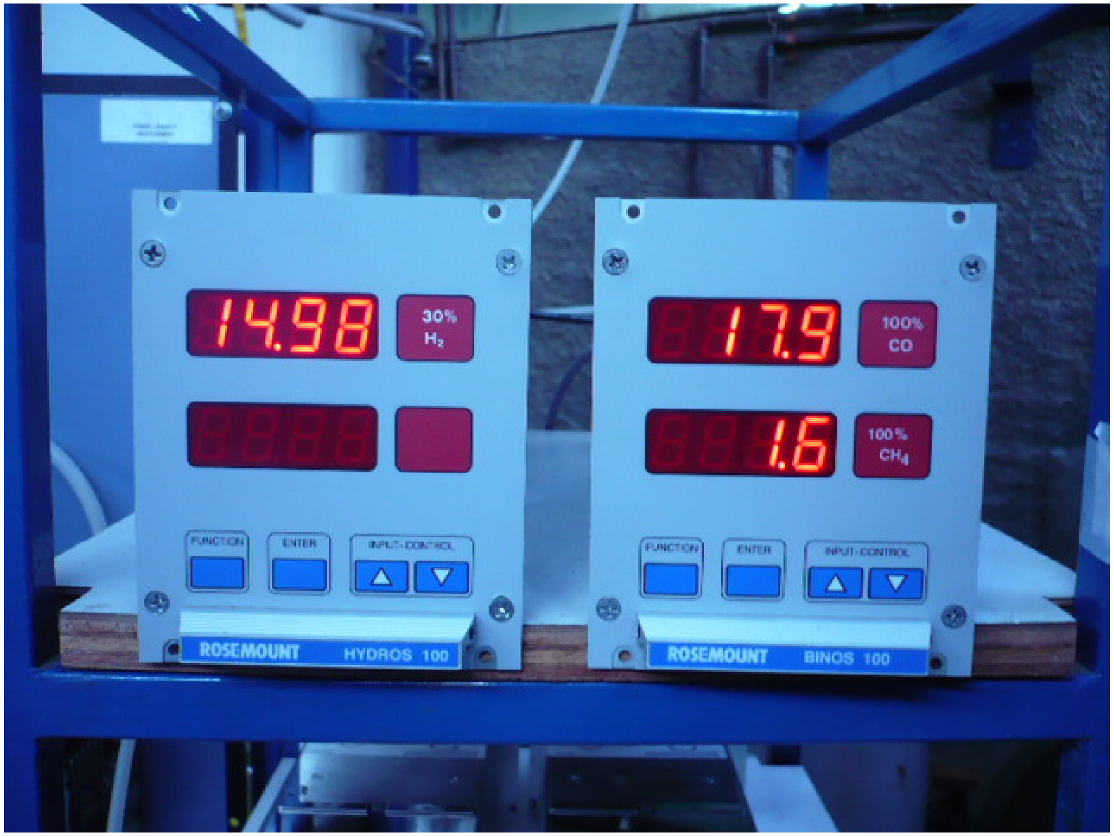

18 10 2006

Two stage fasifier at NESTNEST

Característica	Valor	Unidade
Thermal power	50	kW
Electric power	10	kW
Biomass consumption (dry basis)	10	kg/h
Biomass size	2 - 6	cm
Air factor	0,35	---



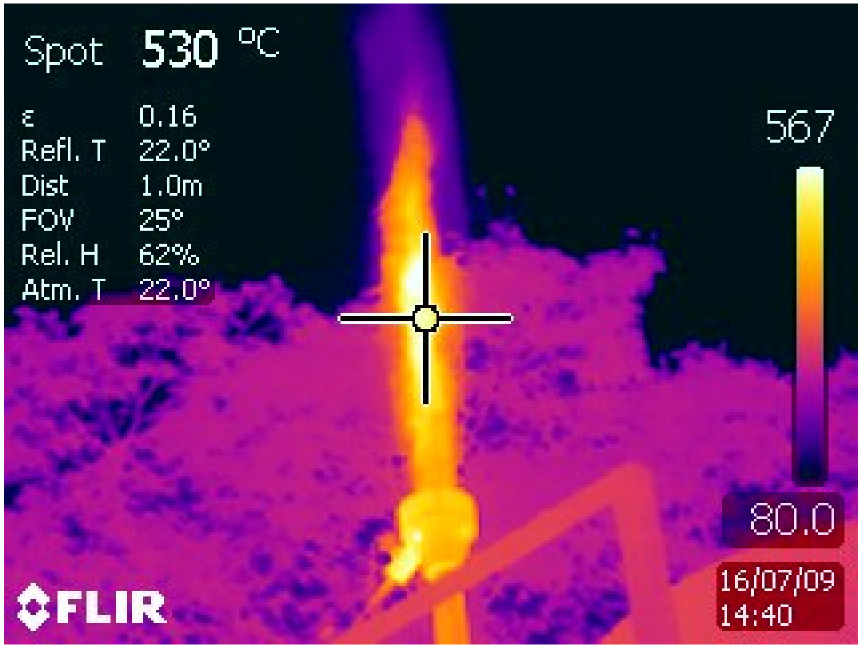
Instituto de Engenharia Mecânica (IEM)
Núcleo de Excelência em Geração Termelétrica e Distribuída (NEST)
Universidade Federal de Itajubá (UNIFEI)



Continuous analyzers: CO, CH4 (BINOS 100) and H2 (HYDROS 100).

Syngas combustion in the flare

Instituto de Engenharia Mecânica (IEM)
Núcleo de Excelência em Geração Termelétrica e Distribuída (NEST)
Universidade Federal de Itajubá (UNIFEI

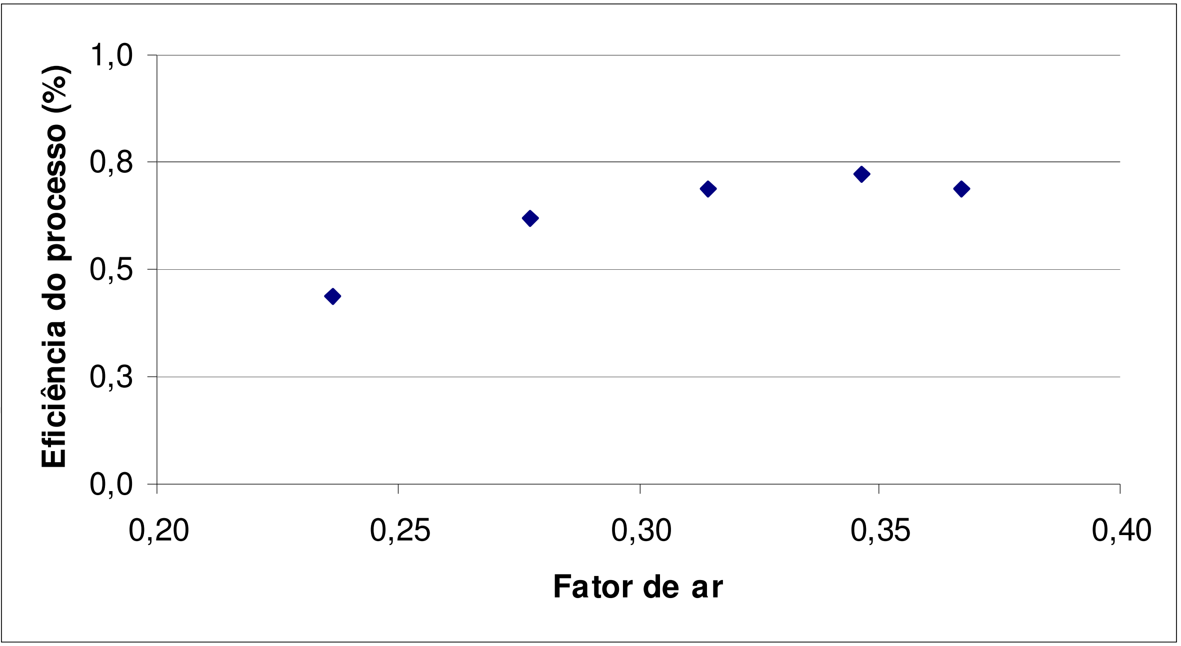

Spot 530 °C
ε 0.16
Refl. T 22.0°
Dist 1.0m
FOV 25°
Rel. H 62%
Atm. T 22.0°
567
80.0
16/07/09
14:40
FLIR

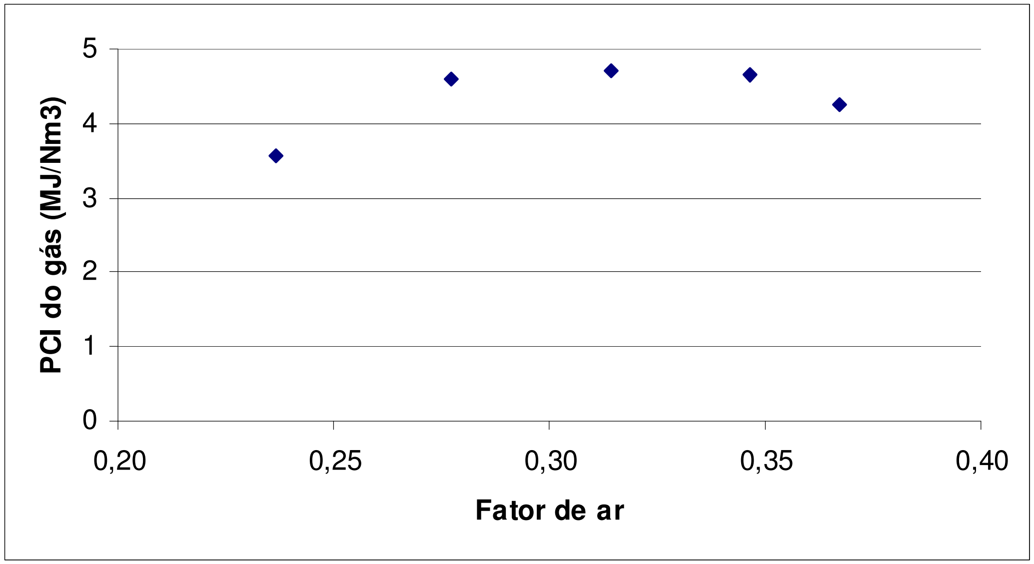

Spot 361> °C
ε 0.16
Refl. T 22.0°
Dist 1.0m
FOV 25°
Rel. H 62%
Atm. T 22.0°
361
18.5
16/07/09
17:12
FLIR

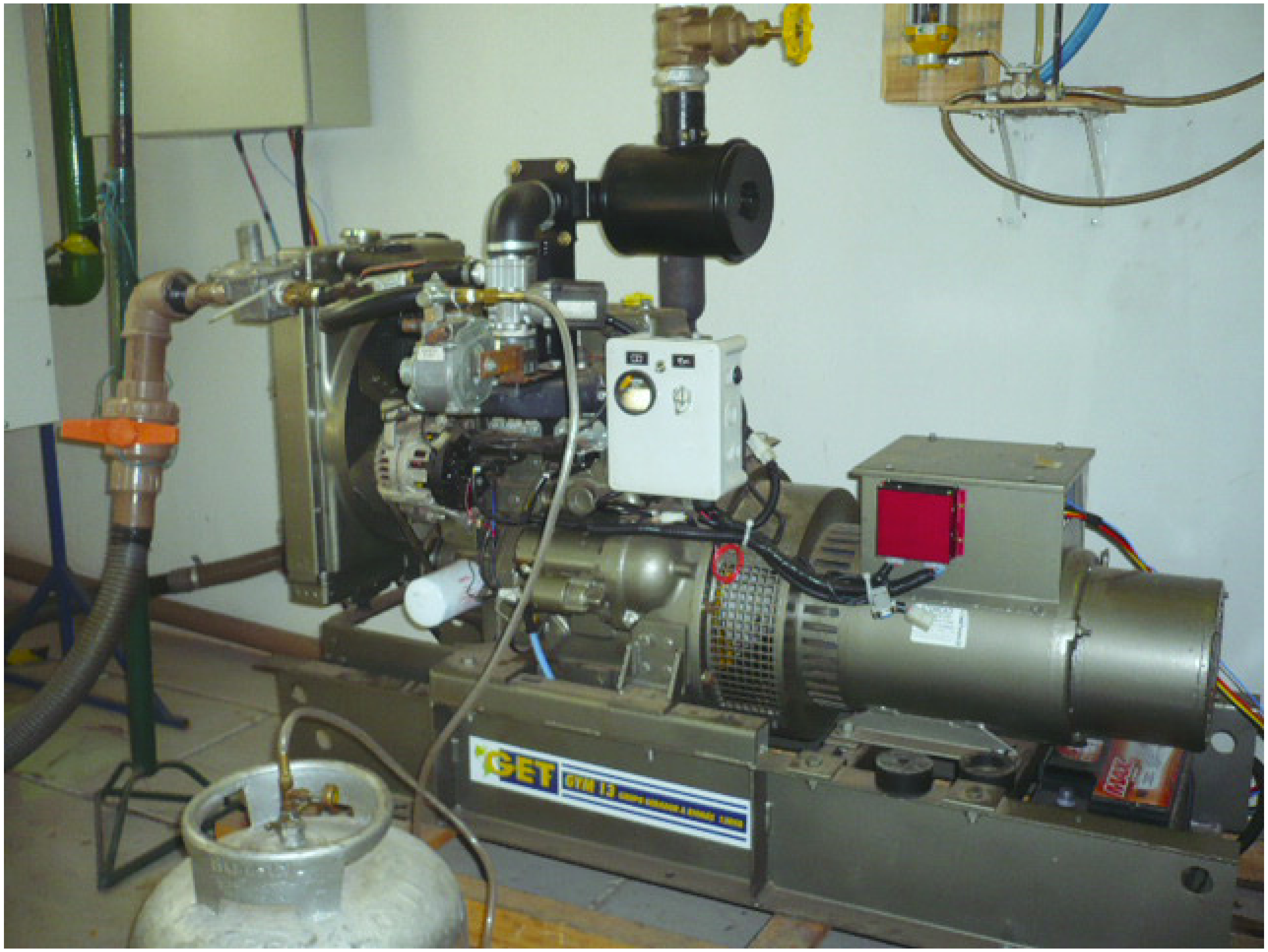
Test results

EFFICIENCY

GAS CALORIFIC VALUE

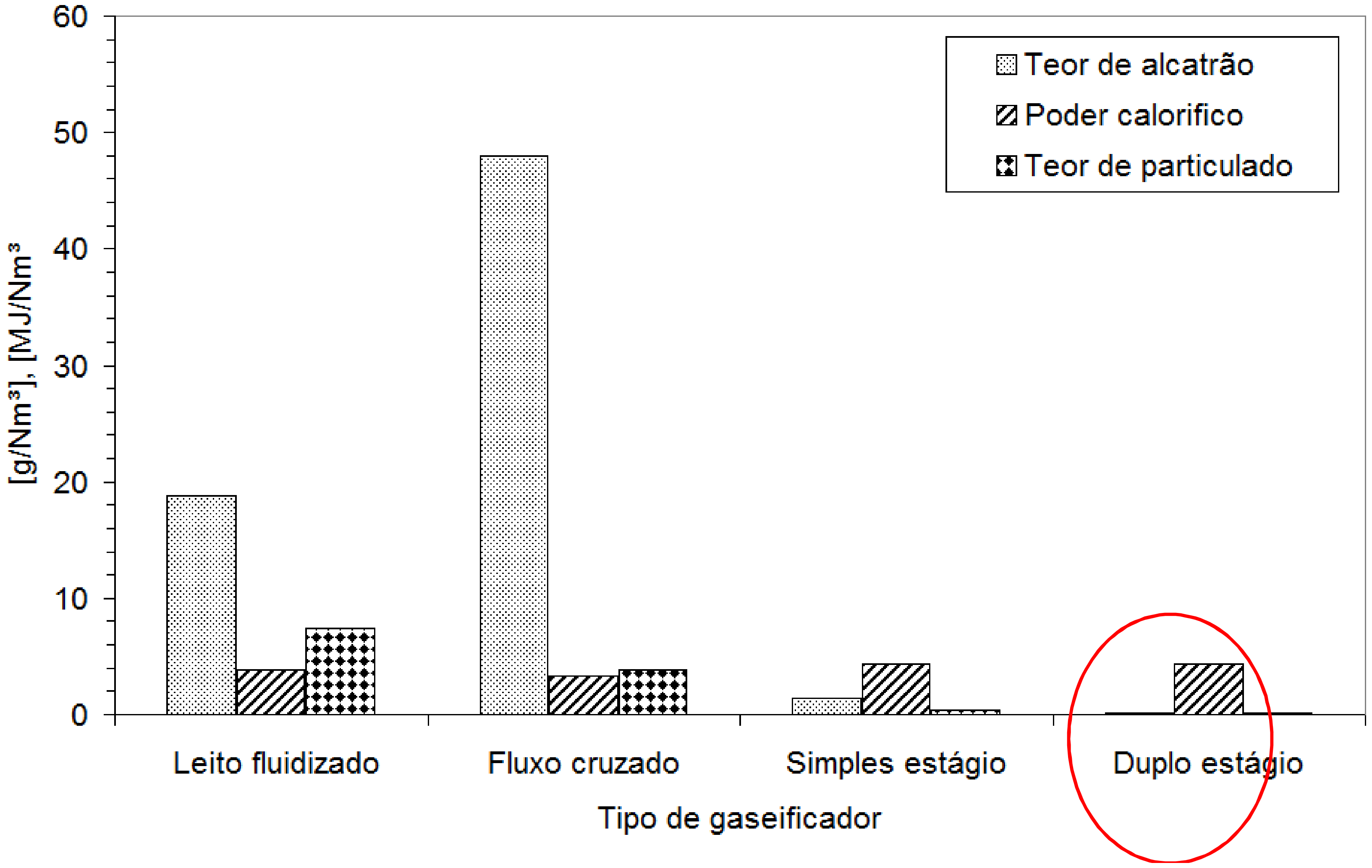






Instituto de Engenharia Mecânica (IEM)
Núcleo de Excelência em Geração Termelétrica e Distribuída (NEST)
Universidade Federal de Itajubá (UNIFEI

Tests results for the three evaluated gasifiers



Gasification at home

Thanks

Doubts, questions, suggestion and voluntaries for biomass gasification

electo@unifei.edu.br