9th Annual International Fuel Cell & Hydrogen Conference

BIOMASS FUELS FOR SOFC

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CONTENTS

LNEG

- As development takes place, society takes more advantage of the energy supply, demand tends to increase, and this has a direct impact on the environment
  - how to compromise?
    - **Security of energy supply**
    - **Economic development**
    - **Less environmental impact**

Limited fossil fuel reserves
Rising energy demand
Rising CO_2 emissions

The FUTURE… towards the concept of "zero emissions" for a better use of the energy resources

New paths and approaches are needed… *to meet the challenges* [1]

- These should take into account aspects that impact on the chain between science and deployment, market development and dissemination

- **A new mechanism has to be put in place with correct strategies in which all interested parties and stakeholders have to participate**

- **Technology transfer is a very important step to consider on the technology roadmap**

  - **Cooperation between countries could be useful to promote the up-take of cleaner technologies**

Demonstration of new concepts
Assessing Industrialisation Issues for penetration

Prospects for Hydrogen and Fuel Cells [2]

Quoting a statement in IEA publication...

Technology robustness

"Stationary SOFC and MCFC – mostly fuelled by natural gas – can contribute to meeting the demand for distributed combined heat and power with some 200-300 Gigawatt, equal to 2-3% of global generating capacity in 2050.

Challenges
- Security of supply
- Global Warming
- Economic Efficiency

Recommendations
- Cost effective production of Hydrogen meeting environmental/quality standards
- New materials and concepts to reduce Fuel Cell cost & durability
- More basic research and better link with applied science communities on:
    - photo-electrolysis
    - high temperature water splitting
    - biological production of hydrogen
    - new materials for H_2 storage and fuel cells
    - nanotechnologies

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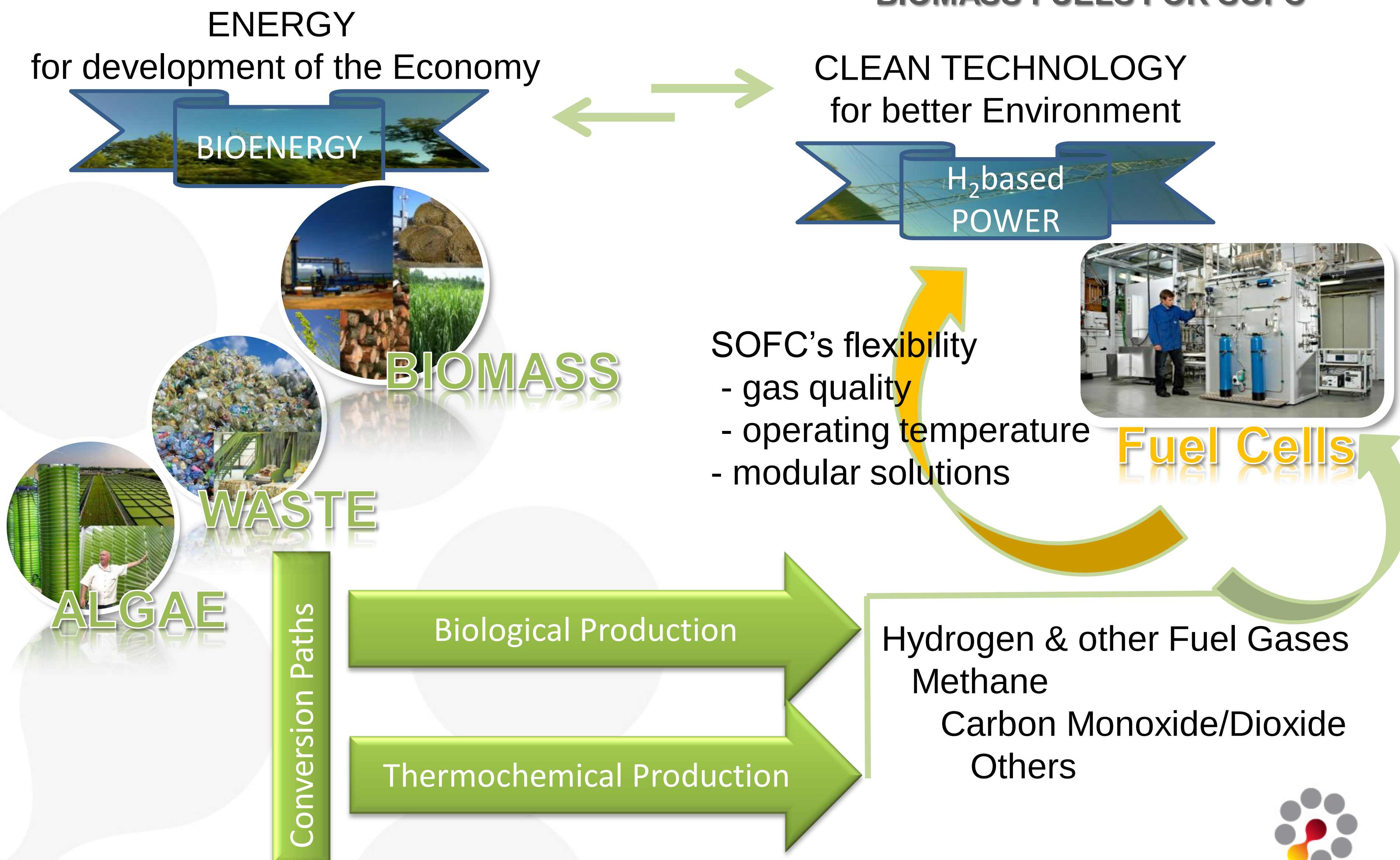


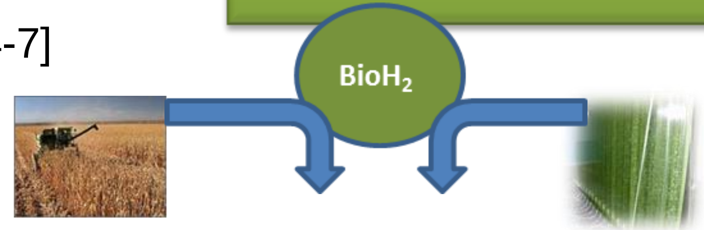
Biological Biomass Fuels Production

Processes [3]

- direct biophotolysis
- indirect biophotolysis
- photo-fermentations
- dark-fermentation

Further research is needed
- to improve H_2 production yields
- bio-reactor design & scale-up
- fuel gas cleaning
- issues for industrialisation

Biohydrogen ($BioH_2$) by direct biophotolysis [4-7] and dark fermentation
- ongoing research at LNEG



Anaerobic bacterial growth on carbohydrate-rich substrates

Feedstock: biomass waste, lignocellulose agricultural byproducts, microalgae
Microorganisms: include species of *Clostridium* and *Enterobacter*
Fuel Gas: H_2/CO_2
Organic acids: substrate for additional energy generation

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Biomass Gasification

Technologies
- fixed bed gasifiers
- fluidised bed gasifiers
- entrained flow gasifiers

Expected Gas composition
- H_2
- CO, CO_2, hydrocarbons
- H_2O
- N_2 (if air is used)
- tars
- particulates
- other contaminants

Interactions with FC are at the level of the anode

ISSUES [8,9]

Different technologies lead to different gas compositions
- what is the best option?

Different gases/contaminants have different impacts on the anode
- What is the best selection for anode materials?

Hydrogen rich gas+CO+CH_4+H_2O
N_2 presence depends on gasification medium

Focus on the gasification method and gas cleaning

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Fluidized bed gasification

- Allows the use of lower gasification temperatures, due to the high mass and heat transfer, which is an advantage when the materials to be gasified have low melting points
  - the use of lower gasification temperatures may favour the release of higher tar contents, but low cost minerals may be added to the gasification bed to promote tar destruction

- Can guarantee high efficiency, fuel flexibility and lower formation of potential pollutants compounds

- Feedstock composition influences fuel gas composition, which leads to the need to ensure proper gas cleaning prior to the fuel cell

- Feedstock particle size has an influence on the efficiency of the process

Fluidised Bed Gasification Installation at LNEG [10,11]

Main characteristics of the installation

- FB gasifier
  with a square cross sectional area, each side being 0.2 m long and the height 3.7m
- Bed inert material
  sand
- Gasification medium
  air/steam; oxygen/steam
- Gasification Temperature
  800ºC – 900ºC
- Catalytic hot gas cleaning system

Typical composition of fuel gas produced

H_2	30 – 45%
CO_2	15 – 20%
CO	15 – 20%
CH_4	5 – 10%
C_nH_m -	< 10%

Feedstocks

Various types of biomass - lignocellulosic wastes, urban wastes, olive bagasse

Mixtures of coal and wastes

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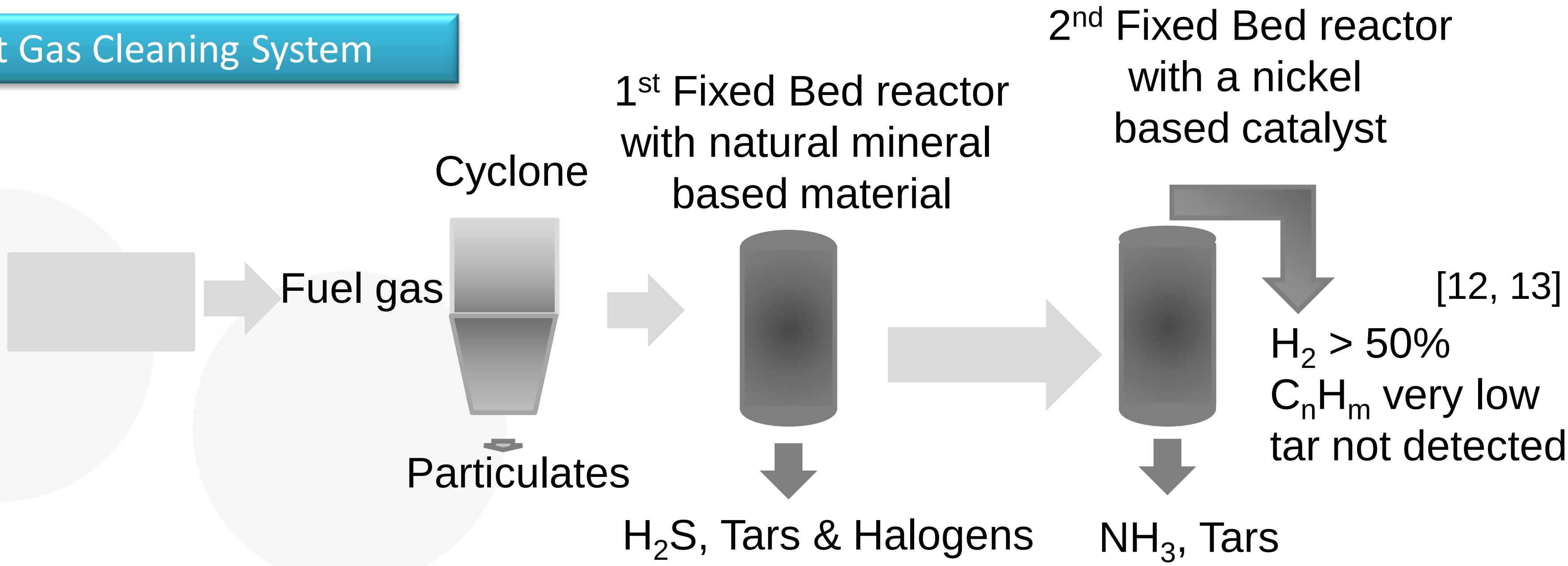
Hot Gas Cleaning System



LNEG configuration for hot syngas cleaning with two catalytic fixed bed reactors was found to be a suitable to deal with a wide range of feedstocks, including those with high contents of sulphur and halogens.

Sulphur and halogens gaseous compounds are destroyed in the fixed bed with dolomite, which would guarantee a longer life for the more specific catalyst for tar abatement used in the second reactor.

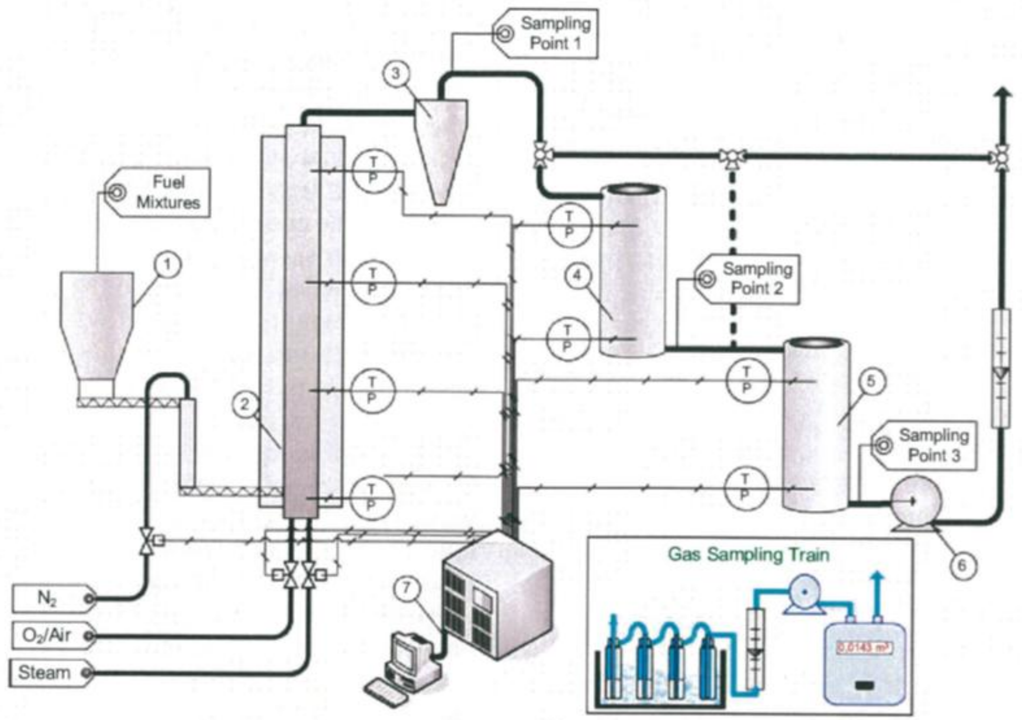
[10-13]

Information on materials used in the gas cleaning system and achievements

1st Fixed Bed
Calcinated Dolomite - Lime – CaO, Magnesium Oxide Carbonate $Mg_3O(CO_3)_2$ and Portlandite – $Ca(OH)_2$ *(detection by X-ray difraction analysis)*
- this step allowed about 80% tar reduction in the fuel gas

2nd Fixed Bed
Catalyst used - G-90 B 5 (supplied by C&CS) - 11% of Ni, 6–9% of CaO and 76–82% of Al_2O_3
- after this step no tar was detected in the fuel gas

Schematic diagram of the experimental set -up [12]



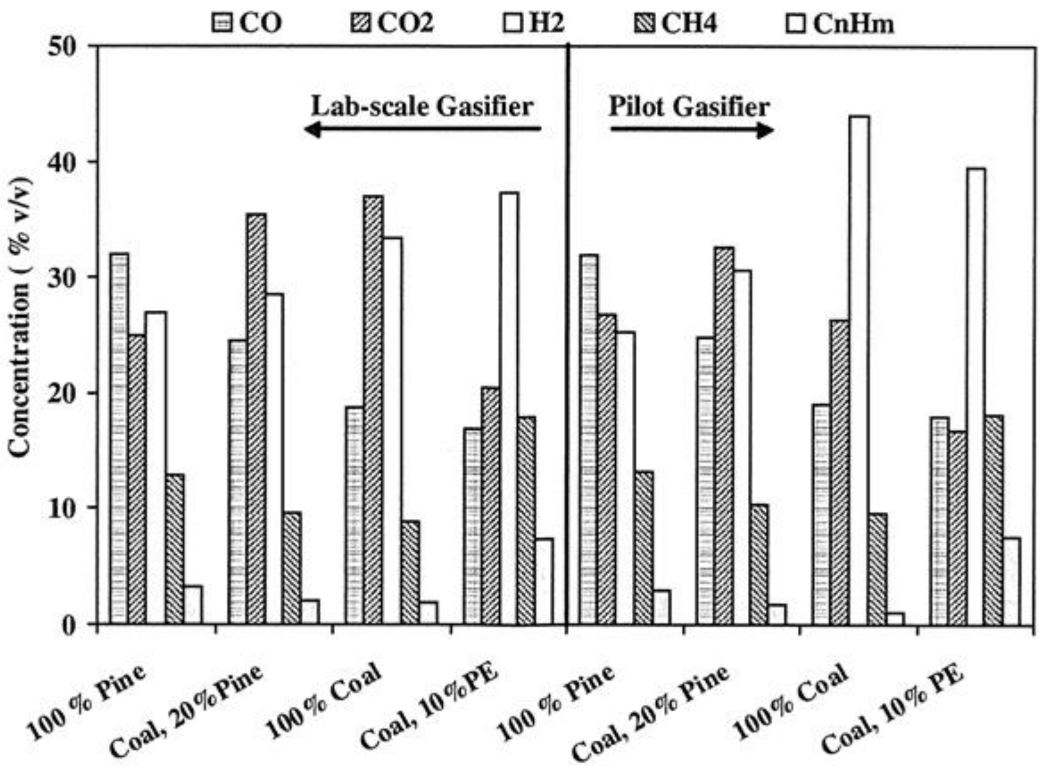
Legend:

1	Fuel Hopper	5	Secondary Catalytic Reactor
2	Fluidized Bed Reactor	6	Centrifugal Fan
3	Gas Cleaning Cyclone	7	Data Acquisition and Control
4	Dolomite Reactor		

Gas Quality

Experimental Results on tests performed with biomass [12]

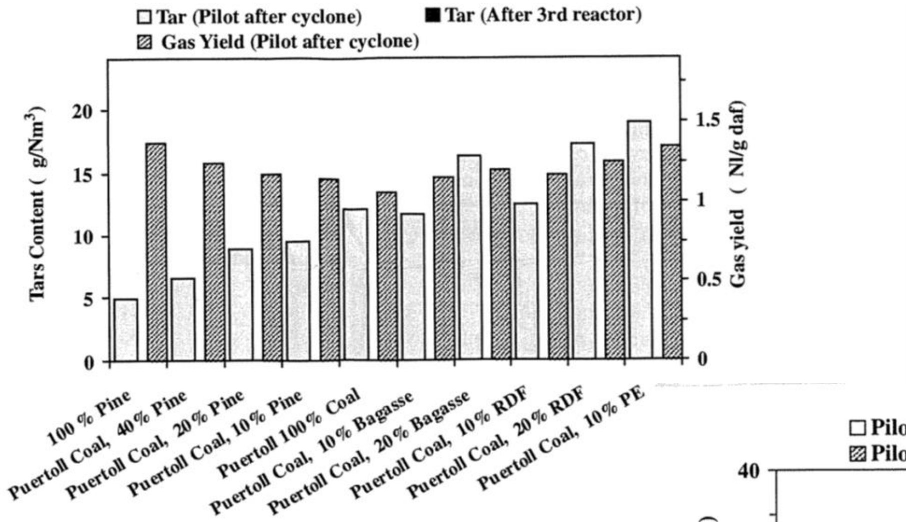
Inert free basis gas composition

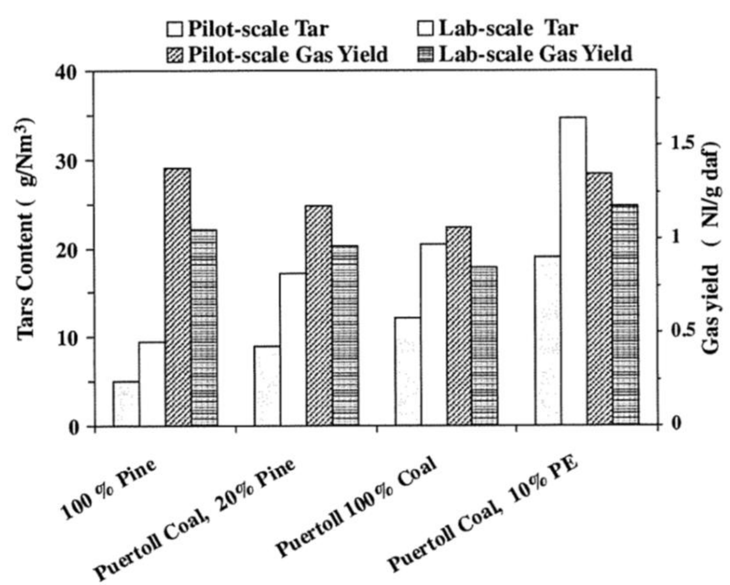


Experimental conditions

Temperature: 845 ºC
ER: 0.2
Steam/Feedstock ratio:0.85

Measuremets of tars' presence in the biomass gas fuel to feed SOFC [12]





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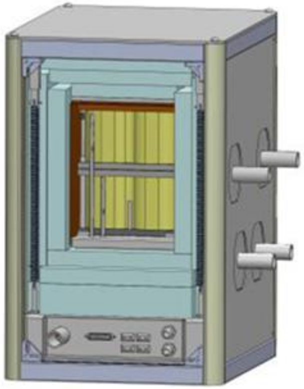

SOFC purchased by INETI to be installed at LNEG

SOFC with 2 modules of 1.1kW each (DIN IEC 62282-2)
Installed in a protective box thermally insulated.

The cells are installed with a complete auxiliary system for fuel gas and air admissions, with pre-heating conditions, cooling circuits, reforming reactor and exhaust. The umit also incorporates monitoring and control systems of flow rates and operating conditions like temperature and pressure, and safety systems.

Scope of the development

Portuguese RD&D project "Energy Technology and Innovation" of INETI approved for the period 2007 – 2011
Funding: Governmental programme – PIDDAC (Prog. 002; M. 005)
Aim: demonstration of the viability of "B-IGFC" with own developed technology

Collaboration set up with Jülich Research Centre – Staxera – EBZ

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Electrochemistry and Degradation Mechanisms

Testing infrastructure

Materials Selection and Coatings

Functional Catalyst and Electrodes

Corrosion Evaluation of Structural and Functional Materials in relevant environment

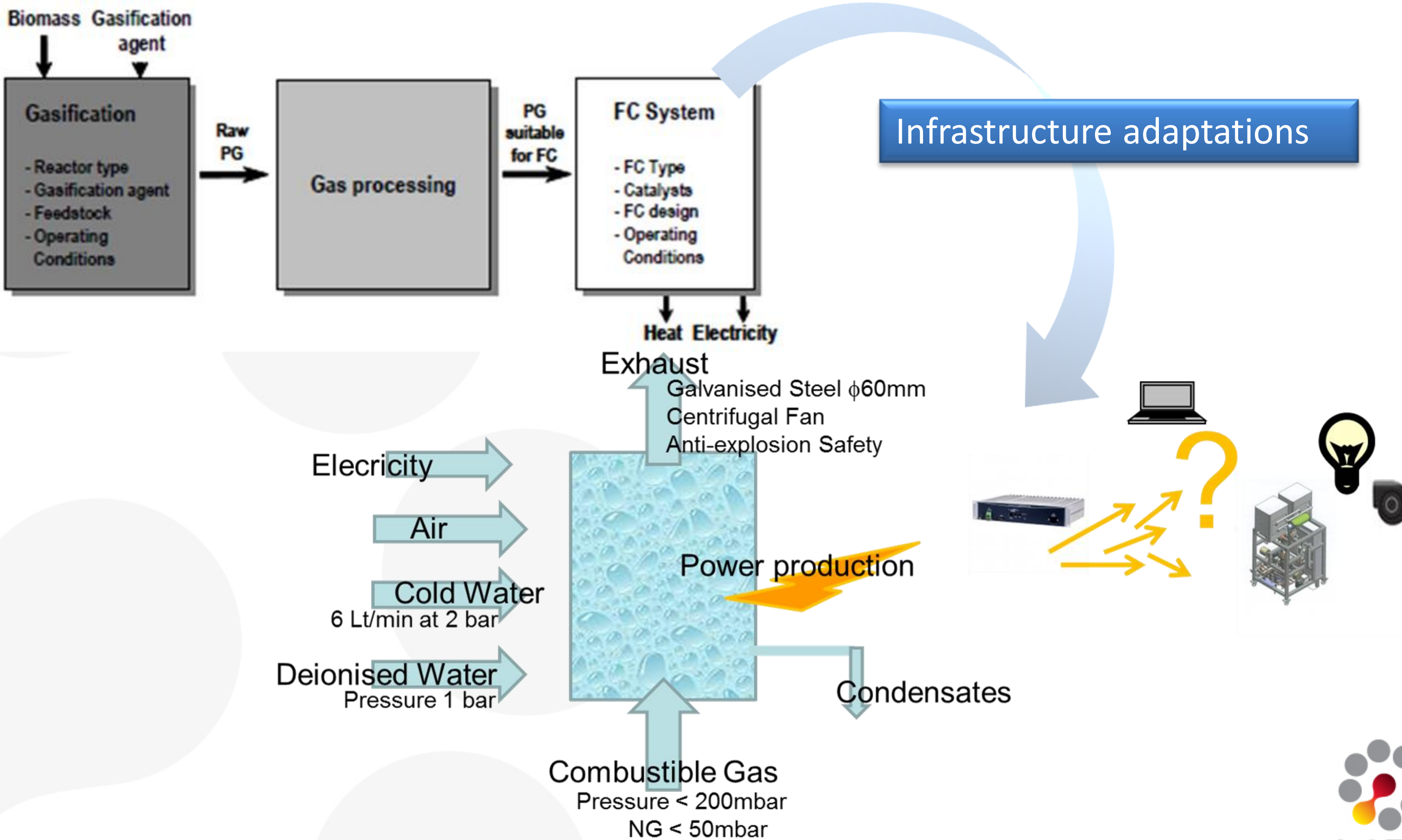
Assesment of Stability and Durability of Cell Components

Electrochemical Impedance Diagnostics

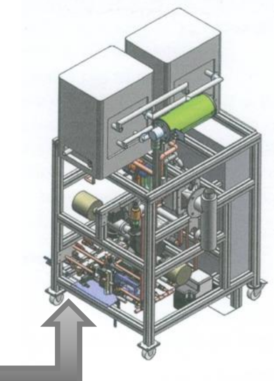
Post-mortem Analysis of Cell and Components

Fuel Cell Modeling

Fuel Cell Integration [14-18]



Plan of Work



Lab adaptations to install SOFC
SOFC Individual Tests with gas simulations
Adaptations to connect the gasification system to feed gas to SOFC
Experimental work with the fully connected B-IGFC system

- Optimization of operating conditions for the combined installation
- Cost/Benefit evaluation for the gas cleaning system
- Investigation of the correlation curve of biomass gas quality versus SOFC performance
- Evaluation of industry issues that determine commercialization of the combined system

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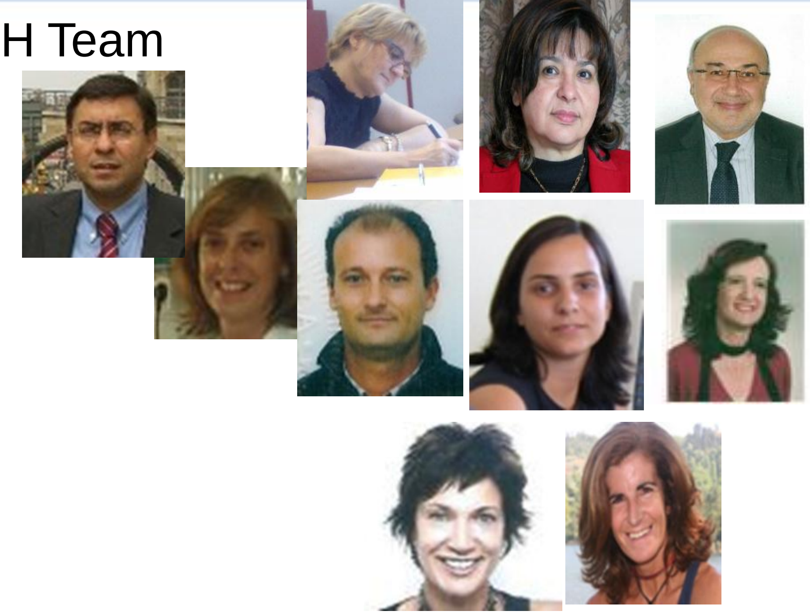
FC & H Team



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