Rapport SGC 193

International Seminar on Gasification 2008

Editor: Jörgen Held

Rapport SGC 193 •1102-7371 • ISRN SGC-R-193-SE

Svenskt Gastekniskt Center AB

October 24, 2008

PREFACE

This report is a compilation of the presentations given at the international seminar on gasification held in October 9-10, 2008 in Malmö, Sweden.

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SGC co-ordinates the technological development within the field of energy gases and promotes a widespread and efficient usage of energy gases, with the least possible environmental impact.

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Following sponsors made it possible to arrange the international seminar and publish this report:

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SWEDISH GAS CENTRE

Jörgen Held
Managing Director

SUMMARY

9-10 of October 2008 Swedish Gas Centre (SGC) arranged an international seminar on gasification in Malmö, Sweden. In total 20 international and national experts were invited to give presentations. The seminar was chaired by Staffan Karlsson, SGC.
The seminar was divided into three parts

- Production technologies
- Applications
    - Gas turbines and gas engines
    - Biomethane as vehicle fuel
    - Syngas in industrial processes
- Strategy, policy and vision

BACKGROUND
Production of synthetic fuels through gasification of biomass is expected to develop rapidly due to political ambitions related to the strong fossil fuel dependency, especially within the transportation sector, security of supply issues and the growing environmental concern.

Techniques that offer a possibility to produce high quality fuels in an efficient and sustainable way are of great importance. In this context gasification is expected to play a central part.

TECHNOLOGY STATUS - PRODUCTION
Gasification of biomass has been successfully demonstrated in different projects during the years and several activities are on-going. Below are some R&D activities and related plants concerning biomass gasification described.

Indirect gasification:
The indirect gasification concept has been further developed in recent years and there are now pilot and demonstration plants as well as commercial plants in operation.
The R&D activities at the semi-industrial plant in Güssing, Austria have resulted in the first commercial plant, in Oberwart. The design data is 8.5 MW_{th} and 2.7 MW_e which gives an electric efficiency of 32 % and the possibility to produce biomethane. In this scale conventional CHP production based on combustion of solid biomass and the steam cycle would result in a poor electric efficiency.

Metso Power has complemented the 12 MW_{th} CFB-boiler at Chalmers University of Technology, Gothenburg, Sweden with a 2 MW_{th} indirect gasifier. The gasifier is financed by Gothenburg Energy and built for R&D purposes.

Gothenburg Energy in collaboration with E.ON Sweden will in a first stage build a 20 MW plant for biomethane production (as vehicle fuel and for grid injection) in Gothenburg based on the indirect gasification technology. The plant is expected to be in operation in 2012. The next stage involves an 80 MW plant with a planned start of operation in 2015.

Indirect gasification of biomass results in a product gas free of nitrogen and hence suitable for production of biomethane. The concept has been proven at the Güssing plant using a slip-stream but still we are awaiting the first commercial plant that produce biomethane suitable as vehicle fuel or for grid injection.

Air-blown gasification
Several demonstration projects are related to air-blown gasification and CHP production. The two-stage Viking gasifier developed at Technical University of Denmark produces a gas with low tar content (<5 mg/Nm^3) suitable for combined heat and power production where a gas engine is used for the electricity production. The 70 kW$_{th}$ pilot plant has an electric efficiency of 25 %. With a scale-up to 0.2-2 MW$_e$ and improved internal heat recovery an electric efficiency of >37 % is expected.

In Skive, Denmark, biomass gasification in a 20 MW$_{th}$ gasifier based on technology developed at GTI, USA and commercialized by Carbona, Finland is demonstrated. The total investment cost is 30 million Euro. Expected pay-back time is approx. 10 years. The project is delayed and the official opening is planned to April 2009. The delay reflects the inherent uncertainty related to large-scale demonstration of new technology.

There are several other demonstrations related to biomass gasification and gas cleaning on their way and the field of gasification seems to experience a renaissance.

TECHNOLOGY STATUS - APPLICATIONS
Gasfied biomass has been demonstrated in many applications and some of them are now well proven and commercially available.

CHP production - Gas engines
Gas engines utilizing gasified biomass are commercially available. GE Jenbacher has installed gas engines in many biomass gasification plants in Europe (e.g. Harboore and Skive in Denmark, Güssing, Austria, Spiez, Switzerland and Kokemäki, Finland). The accumulated hours of operation for the gas engines well exceed 100,000 hours. The plants with installed gas engines span over different gasification technologies (e.g. fixed bed – updraft, fixed bed – down draft and indirect gasification) and different gas compositions with lower heating values ranging from 5.4 MJ/Nm^3 to 10.5 MJ/Nm^3. High CO content in the gas results in high CO emissions from the gas engine which calls for exhaust gas after-treatment. To avoid problems related to tars, particles, corrosive substances, water etcetera gas cleaning is crucial and a key technology.

CHP production - Gas turbines
Gas turbines are associated with low maintenance, high availability and reliability, low emissions (compared to gas engines) and high power density. On the downside gas turbines in single cycle have a low electric efficiency compared to gas engines and unfavourable part-load characteristic (single-shaft turbines).

The applicability of standard gas turbines covers high heating value gases such as natural gas, up-graded biogas (anaerobic digestion) and biomethane through gasification and methanation. For gases with lower heating value, typically landfill gas, non-upgraded biogas or producer gas from air-blown gasifiers the turbines normally have to be adjusted.

Biomethane as vehicle fuel

Vehicles powered by compressed or liquefied methane (natural gas and biogas) increase rapidly and in the world there are now more than 9 million vehicles powered with methane. In Iran, where there in principal were no vehicles powered by methane 5 years ago, gas powered vehicles now constitute 75 % of the total number of cars, trucks and buses. In Sweden upgraded biogas (approx. 97 % methane) has surpassed natural gas as vehicle fuel. The potential to produce biomethane through gasification and methanation of biomass is huge especially in countries with vast forest resources.

The high conversion efficiency of 60-70 % (from wood chips to biomethane) makes gasification and methanation a promising route towards the production of a renewable vehicle fuel.

Gasified biomass in industrial processes

Hydrocarbons are the main constituent in many products, e.g. paint, plastic products, coatings, cable insulation, flooring etcetera. The petrochemical industry heavily relies on fossil resources such as oil and natural gas but renewable options are of great interest. This can be achieved in different ways. One way is to produce biomethane with a quality suitable for grid injection. In this way renewable biomethane enters together with natural gas into the petrochemical processes. Another way is to place a biomass gasification plant at the petrochemical site and produce syngas (CO and H_2) which is used as raw material in petrochemical processes. The gas cleaning is of vital importance in order to avoid catalyst poisoning and deactivation further downstream.

In metallurgical processes the use of gases is widely spread. Much of the gas comes from internal processes (e.g. coke oven gas and blast furnace gas). It may be possible to partly replace the use of coke, coal and oil with gas. The use of gas from external supply is influenced by the local situation and requirements (i.e. heat value and impurities) for the actual application.

During the seminar different productions technologies related to biomass gasification and applications as well as strategy and policy issues were presented by international and national experts.

The presentations give an excellent overview of the current status and what to be expected in terms of development, industrial needs and fuel requirements in different applications.

NOMENCLATURE

CFB Circulating Fluidised Bed
CHP Combined Heat and Power
RME Raps Methyl Ester
R&D Research and Development

Malmö, October 24, 2008

Jörgen Held
Managing Director Swedish Gas Centre

CONTENT

Gasification

- production technologies and applications

SEMINAR PROGRAMME LOCATION REGISTRATION CONTACT





Final programme

OCTOBER 9, PRODUCTION TECHNOLOGIES

12:00 - 12:45 **LUNCH**
12:50 Welcome, **Jörgen Held**, Director Swedish Gas Centre

13:00 – 14.30
Hermann Hofbauer, TU Vienna. *Biomass Steam Gasification: Industrial Experience and Future Prospects.* (presentation given by Barbara Rehling, TU Vienna)
Vann Bush, Gas Technology Institute, USA. *Biomass Gasification - Experience and Current Projects.*
Ulrik Henriksen, Technical University of Denmark. *Up-Scaling and Commercialization of the Two-Stage Gasifier.*

14:30 - 15.00 **COFFEE BREAK**

15:00 – 16.15
Pekka Saarivirta, Metso Power. *Development and Experience of Biomass Gasification.*
Christian Aichernig, Repotec. *Biomass CHP Plant Güssing: Results from 5 European Research Projects.*
Matti Nieminen, VTT Finland. *Gasification of Biomass and Waste Derived Fuels for Industrial Applications.*

16.15 - 16.45 **COFFEE BREAK**

16.45 – 18.00
Ingemar Gunnarsson, Gothenburg Energy. *The GoBiGas-Project is on Track.*
Sven Aaen, AAEN A/S. *Experience with Gasification of Biomass in the 28 MW CHP Plant in Skive, Denmark.*
Göran Tillberg, E.ON Sweden AB. *Towards Commercialisation of Biomass Gasification.*

19:00 **DINNER**
-23:00 Mingle and Networking

OCTOBER 10, APPLICATIONS

08:45 – 10.00 CHP, Gas Turbines and Gas Engines
Dieter Bohn, IDG Aachen. *Use of Biomass in Gas Turbines - Requirements and Challenges*
Thomas Stenhede, Wärtsilä. *Wärtsilä Green Solutions - Running Large Engines on Alternative Fuels*
Martin Schneider, GE Jenbacher. *Utilization of Special Gas in Gas Engines - Experiences and Requirements.*

10.00 – 10.20 **COFFEE BREAK**

10.20 – 12.00 Biomethane as Vehicle Fuel and in Industrial Processes
Peter Boisen, NGVA Europe. *The Future Role of Biomethane as a Vehicle Fuel*
Trevor Fletcher, Hardstaff Group. *Dual Fuel Technology and Experiences*
Lena Sundqvist Ökvist, MEFOS - Metallurgical Research Institute AB. *The Use of Gases in Metallurgical Processes - Applications and Requirements*
Lars Lind, Perstorp BioProducts. *Bio-Methane Based Production of Liquid Fuel Components*

12.00 – 13.00 **LUNCH**

13.00 – 15.00 Strategy, Policy and Vision
Anthi Charalambous, European Commission. *Overview of Biomass Gasification Projects Co-financed within the European Framework Programmes (Topic Energy)*
Harrie Knoef, Biomass Technology Group. *State of the Art of Biomass Gasification and the Needs for Creating Favourable Conditions.*
Mathieu Dumont, SenterNovem. *The Dutch Situation on Green gas.*
Henrik Kusar, Swedish Energy Agency. *A Swedish Strategy for Gaseous Fuels.*

Summary of the conference, Staffan Karlsson, Swedish Gas Centre

The seminar will be chaired by **Staffan Karlsson**, Swedish Gas Centre

WELCOME

to…

Jörgen Held
Managing director, Swedish Gas Centre

SGC Svenskt Gastekniskt Center AB

International Seminar on Gasification

9-10 October 2008
Hilton Hotel, Malmö

Organized by

SGC Svenskt Gastekniskt Center AB

Swedish Gas Centre

Supported by

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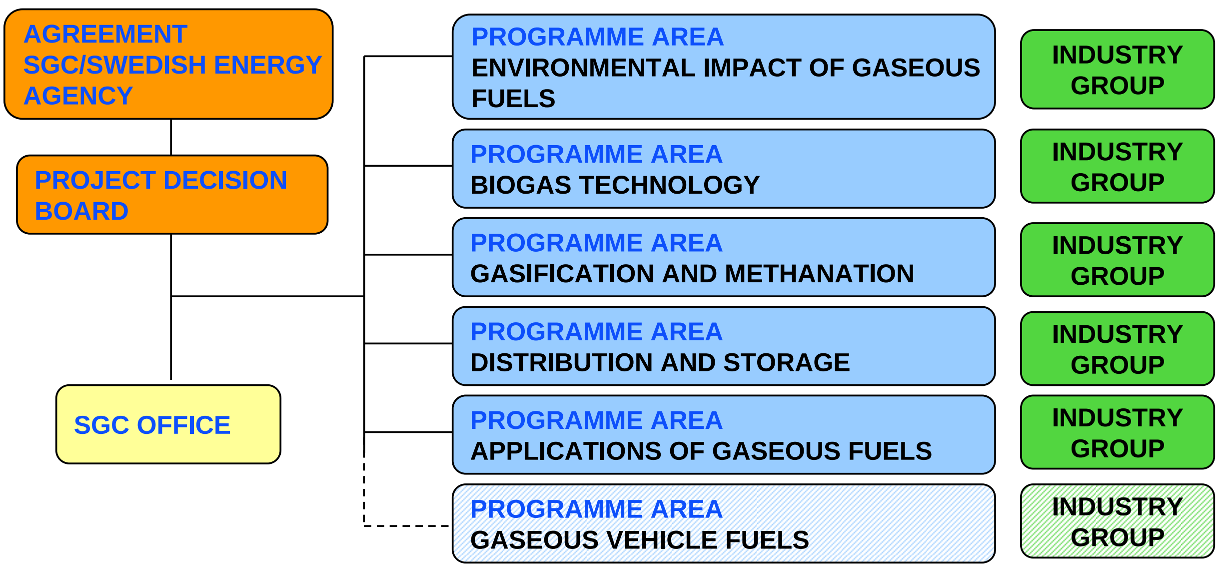
Swedish Gas Centre

SGC co-ordinates the technological development within the field of gas technolgy and promotes a widespread and efficient usage of energy gases.

Nr of employees:	6
Office:	Malmö, Sweden
Annual turnover:	approx 2.2 million euro
Website:	http://www.sgc.se

Swedish Gas Centre



Swedish Gas Centre

This seminar is part of the technology surveillance SGC performes within the field of gasification and methanation.

Our ambition is to offer a platform for exchange of information, results, experiences and networking on an international level.

WELCOME
once again!

Biomass Steam Gasification Industrial Experience and Future Prospects

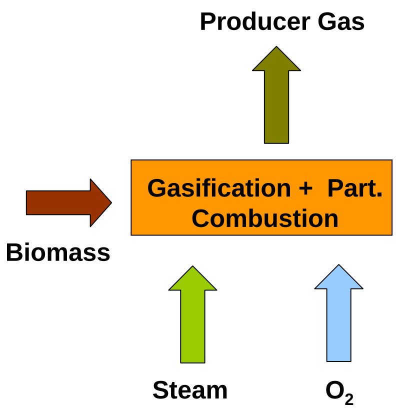
Hermann Hofbauer
Vienna University of Technology
Institute of Chemical Engineering

Outline of the presentation

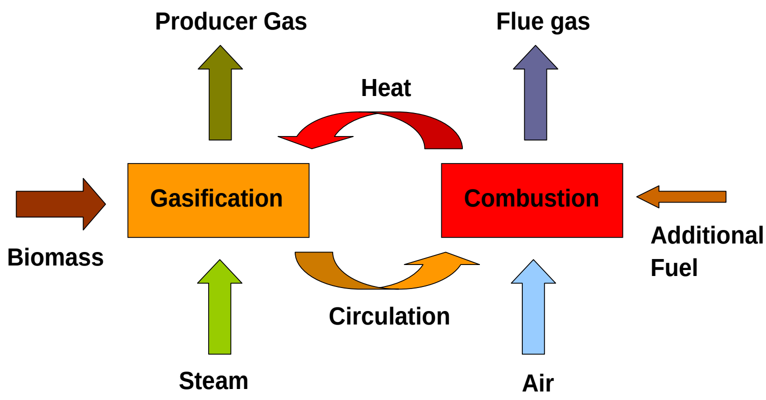
- Principles of steam blown gasifiers
- Development of a dual fluidized bed gasifier
- Güssing demonstration plant
- Further industrial plants (projects)
- Industrial experience and open points for improvements
- EU-project UNIQUE
- Conclusions and outlook

Basic Processes Configurations for Steam Gasificaiton

Autothermal Steam Gasification



Allothermal Steam Gasification

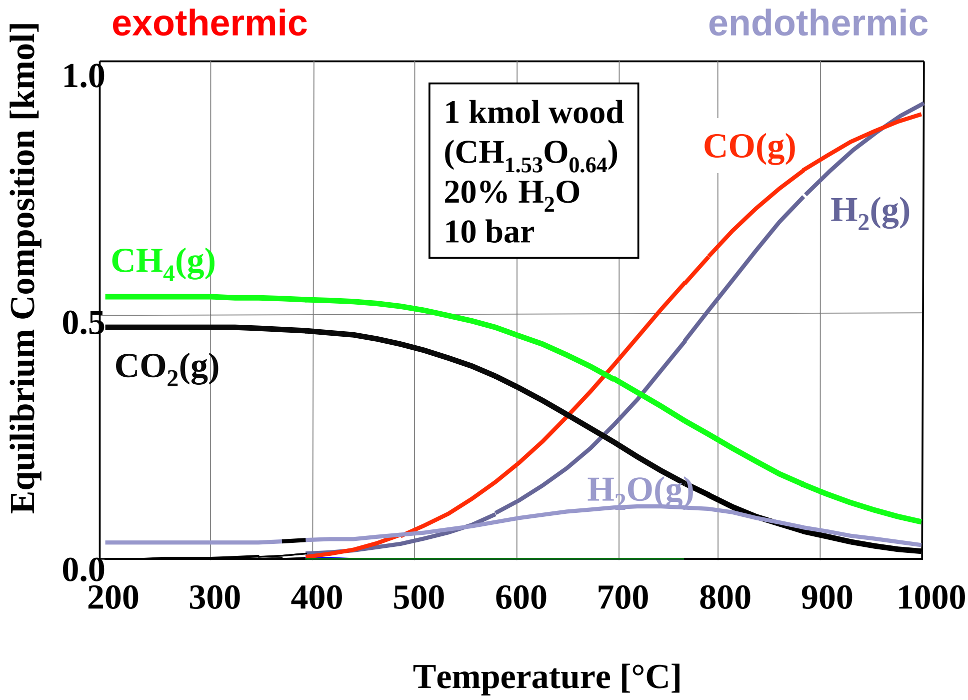


Typical ranges of producer gas composition for selected gasifiers

		Low temperature atm. steam blown dual fluidized bed gasifier 1)	Low temperature press. oxygen blown fluidized bed gasifier2)	High temperature press. oxygen blown entrained flow gasifier3)
H_2	%	35 - 40	23 - 28	29 - 35
CO	%	25 - 30	16 - 19	35 - 44
CO_2	%	20 - 25	33 - 38	17 - 22
CH_4	%	9 - 11	10 - 13	<1
N_2	%	<1	<5	<5

1) Güssing FICFB gasifier 2) Bioflow gasifier 3) CHOREN and FZ Karlsruhe

Equilibrium of the System Biomass – Water (S.Stucki, PSI)



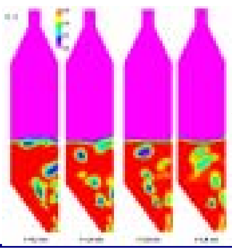
Technische Universität Wien
Vienna University of Technology
Institut für Verfahrenstechnik, Umwelttechnik und Technische Biowissenschaften

Scale Up Process

Cold flow model

Hot test rig

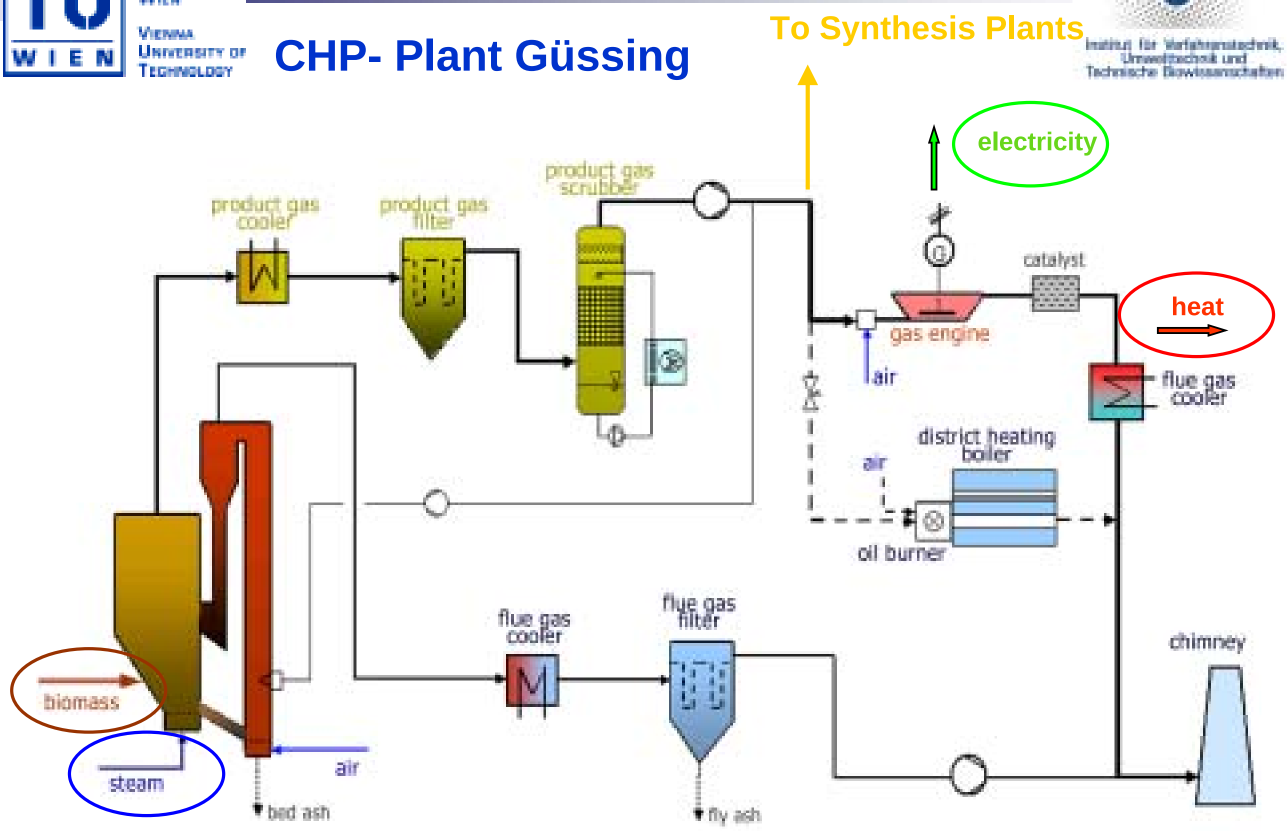
Simulation



Pilot plant Trisaia 0,5 MWth

Demonstration plant Güssing 8 MWth

CHP- Plant Güssing



CHP-PLANT GÜSSING (design data)

■ Start of construction	September 2000		
■ Start up	January 2002		
■ Fuel	2,2	to/h	(Wood chips)
■ Water content	15	%	(35 %)
■ Fuel power	8	MW	
■ Electrical power	2	MW	
■ Thermal power	4,5	MW	
■ Electrical efficiency	25	%	
■ Total efficiency	80	%	
■ Total operation hours	more than 44.000		

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CHP-Plant Güssing with castle of Güssing

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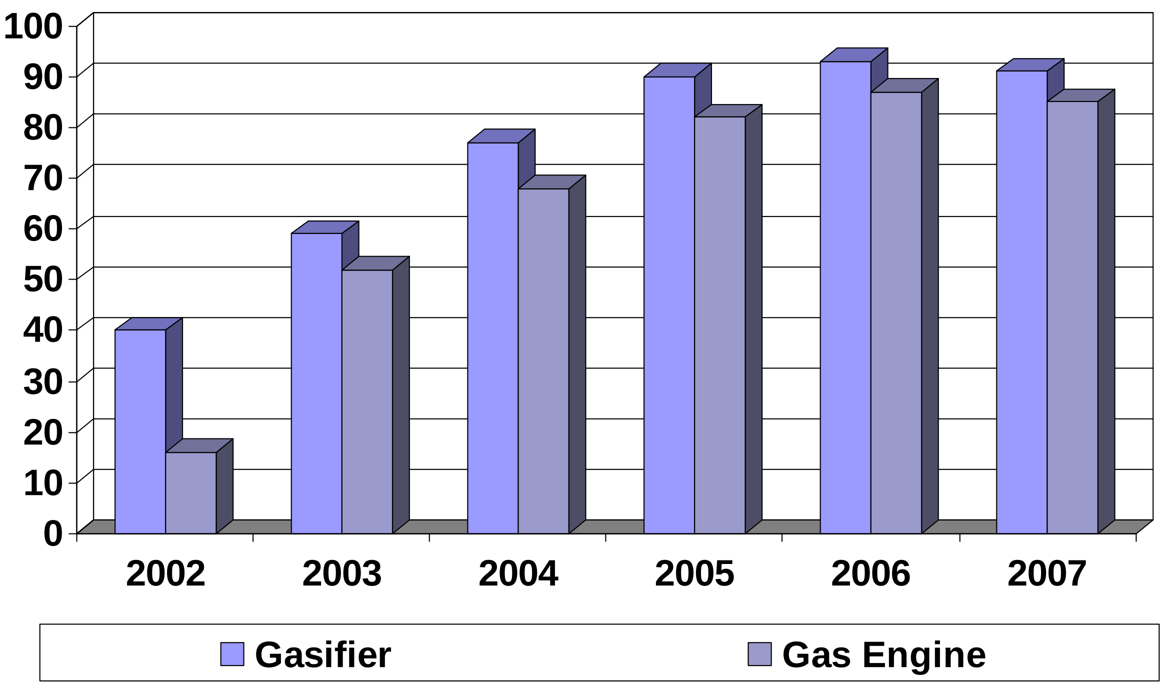
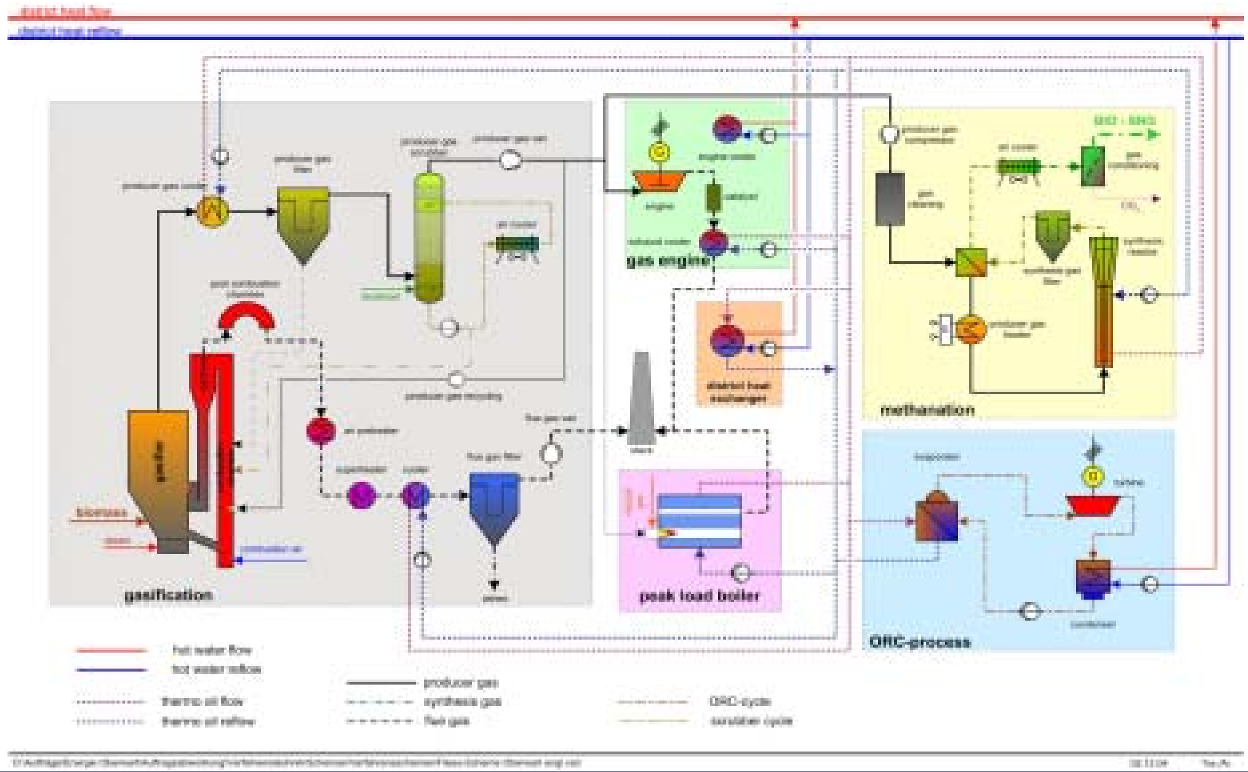
Availabilities of the Güssing Plant



From Demonstration Plant to First Industrial Plant

- Including a biomass drying step with waste heat from the process
- New optimized control system without using valuable producer gas
- Combined cycle for maximising electricity output (gas engine + ORC)
- 2 gas engines instead of one
- Methanation option

Flow Sheet of Oberwart Plant, AT



Design Data of the Oberwart Plant

$P_{th,\ plant}$	8500	kW
$P_{el,\ tot}$	2740	kW
$P_{el,\ gas\ engine\ 1+2}$	2300	kW
$P_{el,\ ORC}$	440	kW
$Q_{dh\ max,\ incl.\ Natural\ gas\text{-}boiler}$	6000	kW
$Q_{dh,\ max.\ el.\ output}$	1500	kW
$Q_{engine\ 1+2}$	1300	kW
$\eta_{chem,\ gas\ generation}$	73	%
$\eta_{el,\ brut}$	32	%

View of the Oberwart plant, Dec. 2007

Integration of particulate abatement, removal of trace elements and tar reforming in one biomass steam gasification reactor yielding high purity syngas for efficient CHP and power plants

UNIQUE

EU – PROJECT / FP - 7

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Institut für Verfahrenstechnik, Umwelttechnik und Technische Biowissenschaften

Project Details

Program:

- **European Union FP 7**

Type of funding scheme:

- **Collaborative project – Small - medium scale focused research project**

Work Program topic addressed:

- **ENERGY 2007 2.2.1: Advanced gas cleaning technologies for biomass**

Duration of the project:

- **3 years**

List of Project Partners

Participant no.	Participant organisation name	Country
1 (Coordinator)	University of L'Aquila	Italy
2	Pall Filtersystems GmbH Werk Schumacher	Germany
3	Université Louis Pasteur, Strasbourg	France
4	Vienna University of Technology	Austria
5	"Politehnica" University of Timisoara	Romania
6	Consejo Superior de Investigaciones Científicas	Spain
7	Instytut Energetyki	Poland
8	ENEA	Italy
9	Forschungszentrum Jülich GmbH	Germany
10	Biomasse Kraftwerk Güssing GmbH & Co KG	Austria

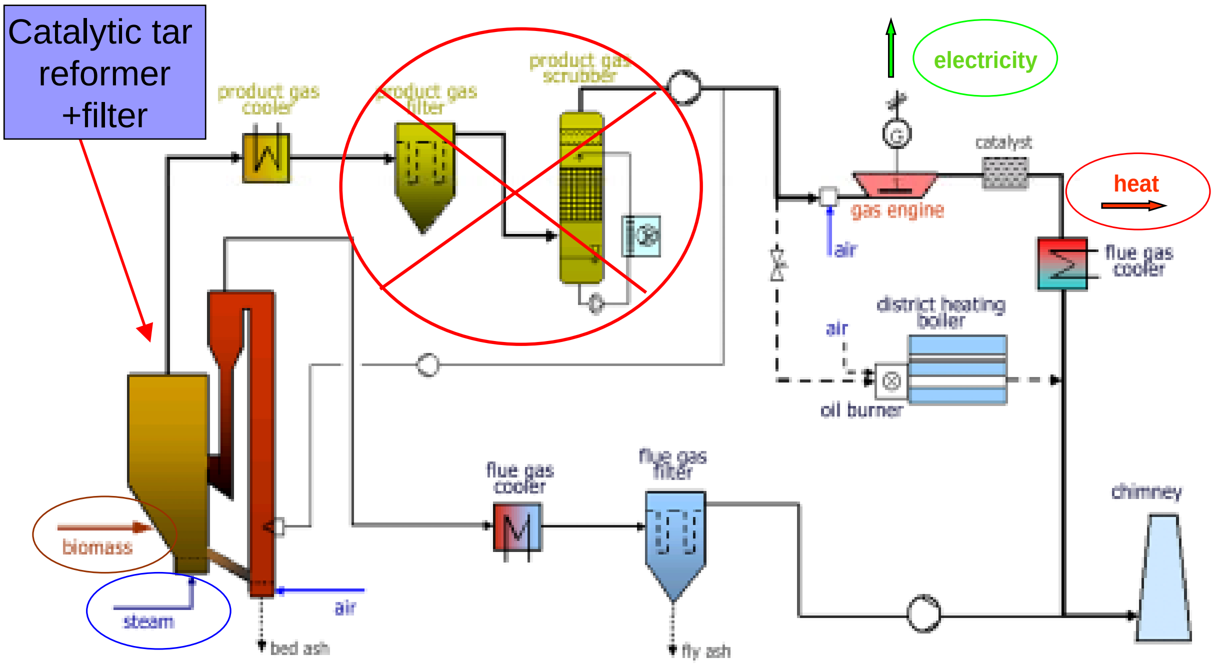
Project General Objective

This proposal aims at a compact version of a gasifier by integrating the fluidized bed steam gasification of biomass and the hot gas cleaning and conditioning system into one reactor vessel.

This can be obtained by placing a bundle of catalytic ceramic candles that will operate at a temperature as high as the gasification temperature (800-850°C) in the gasifier freeboard;

furthermore, by using a catalytically active mineral substance for primary tar reforming and by optimising the addition of sorbents into the bed for removal of detrimental trace elements.

8 MWth Güssing CHP-Plant



Technical Objectives and Work Approach (1)

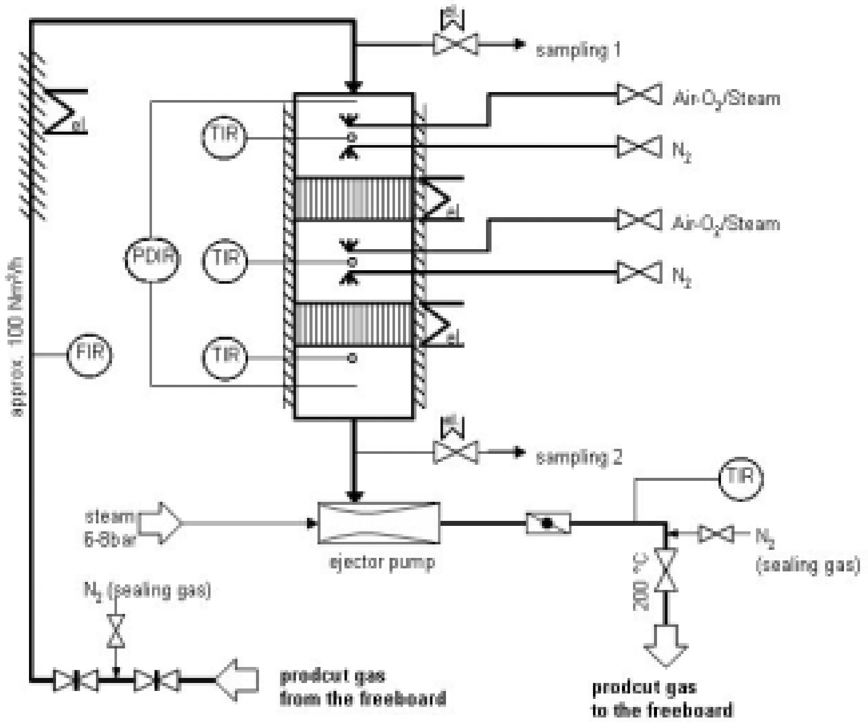
- Development of an innovative catalytic system for in-bed primary reduction of heavy hydrocarbons (iron based)
- Optimisation of tar reforming by using catalytic filter elements
- Synthetic sorbents to be added properly to the gasifier to trap sulphur compounds and additional, detrimental trace elements

Technical Objectives and Work Approach (2)

- Experimental check of the feasibility of the integrated arrangement proposed for the gasification reactor
  - Bench scale, in a bubbling fluidized bed gasifier with nominal load of 1 kg/h of biomass feedstock.
  - 100 kWth FICFB (dual fluidized bed steam blown biomass gasifier) pilot plant
  - Pilot scale bubbling fluidized bed unit (1 MWth)
  - Industrial-scale benchmark (Güssing plant, 8 MWth).

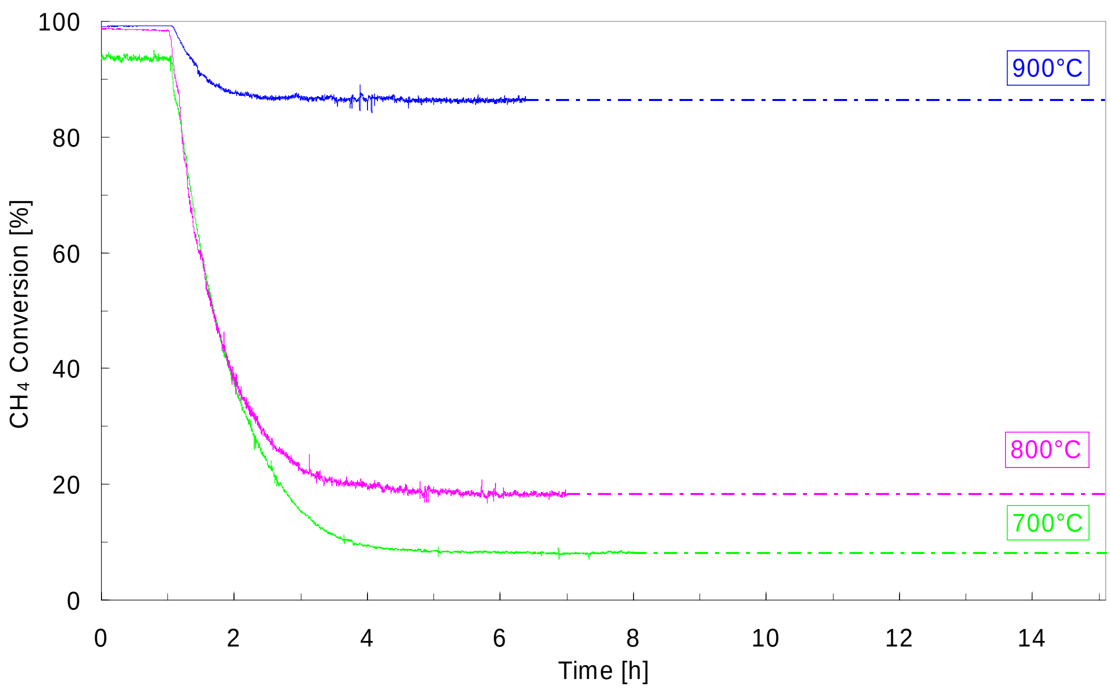
- Modelling and simulation
  - Mathematical modelling studies
  - CFD studies of the reactor freeboard, to optimise candles configuration in it
  - Flow sheeting program for mass- and energy balances

100 m³/h Tar Reforming Test Facility at the Güssing Plant

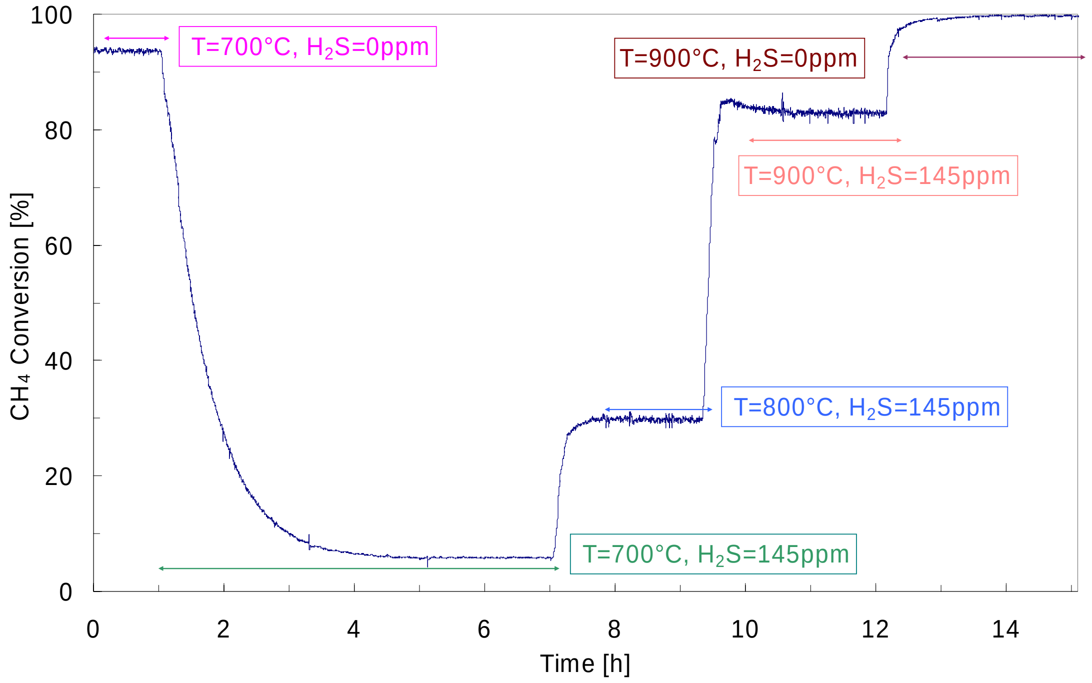


Slip stream for Catalytic Reforming

Influence of Temperature on H_2S Poisoning
H_2S Concentration=108 ppm



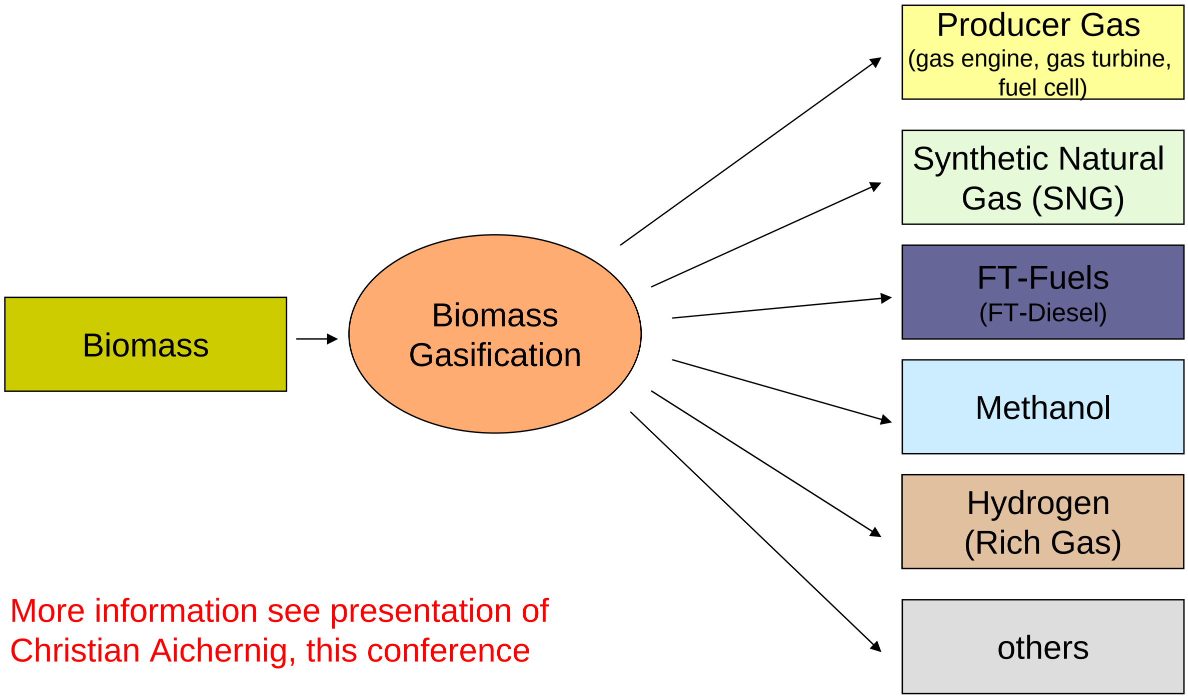
Recovery of Catalyst Performance by Temperature Enhancement



Conclusions

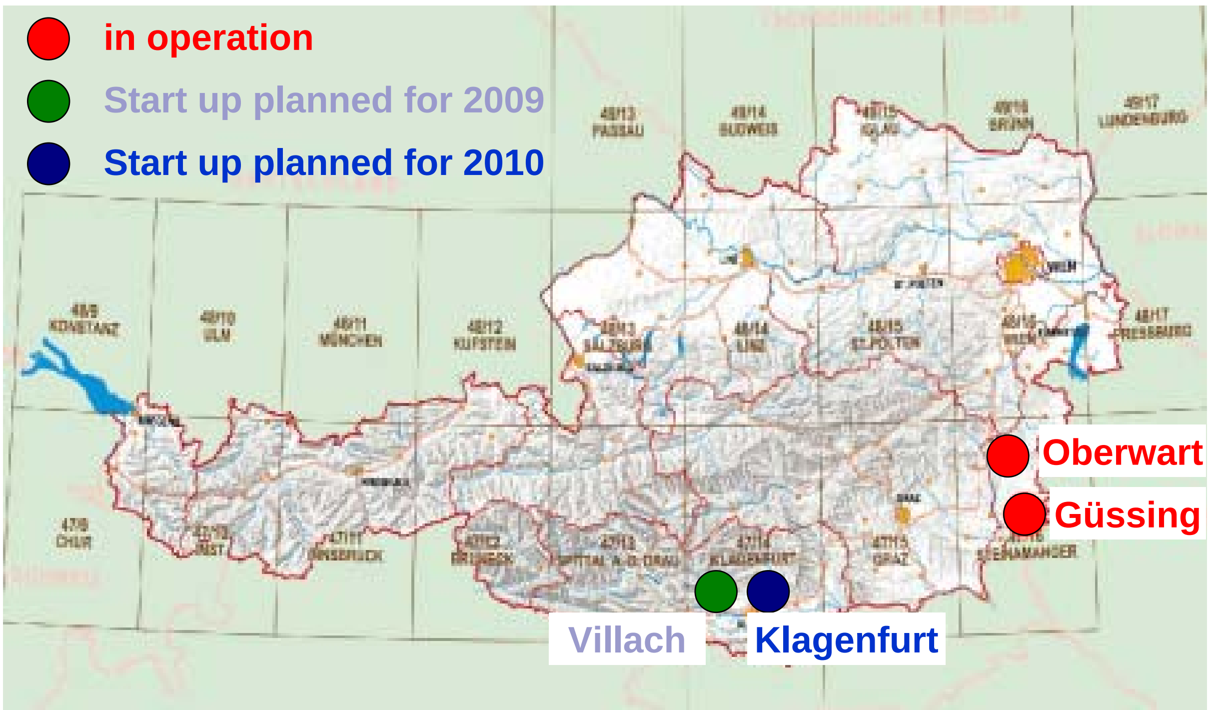
- Steam gasification of biomass leads to a syngas for a wide variety of applications
- Combined heat and power (CHP) production are well proven and plants are available at the market at industrial size (10-50 MW)
- However, there are still several important points for improvements
  - Drying of biomass
  - Too high tar content leads to deposits on heat exchanger surfaces
  - Fine particle are difficult to keep in the reaction zone
  - Too complex configuration leads to high investment and operation costs
- In the European project UNIQUE several improvements are developed
  - Development of catalytic bed material without nickel compounds
  - Addition of additives to captures several undesired elements
  - Internal high temperature filters for particles separation and catalytic tar reforming

The basic concept “Green Chemistry”



More information see presentation of Christian Aichernig, this conference

Commercial Steam Gasification Plants in Austria



Operation Experience at Industrial Plants

- Biomass drying should be obligatory, high water content leads to less electrical efficiencies (opt. 15-20 %)
- Constant biomass feeding necessary for smooth gas production (hardware and control system crucial)
- High tendencies to deposits at producer gas (tar content) as well as flue gas heat exchangers (recalcination)
- Ash recycling and addition of additives (Ca-based) are necessary
- Small and light particles (e.g. char) are elutriated easily
- High excess of steam necessary
- High complexity and therefore high investments and operational costs

Biomass Gasification: Experience and Current Projects

Presented at
International Seminar on Gasification – Production Technologies and Applications

9 October 2008
Malmö, Sweden

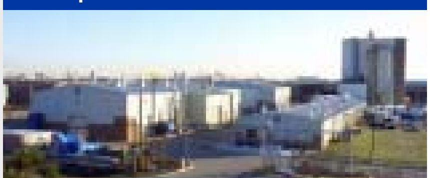
By
Vann Bush, Managing Director

GTI Overview

- Not-for-Profit Research, with 60+ Year History
  - Over $50MM/yr energy R&D
  - Facilities
    - 7.3 ha campus near Chicago
    - 18,600 m^2 in 28 specialized labs
    - Other sites in Oklahoma and Alabama
- Staff of 250
- Commercialization activities
    - 1000 patents, 380 licenses, 72 active licensees
    - 12 companies in venture portfolio
    - Commercial activity in gasification and gas processing

Flex-Fuel Test Facility

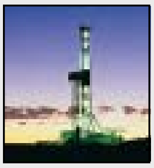
Headquarters Offices & Labs



Energy & Environmental Technology Center

Alignment with the Energy Industry Value Chain

SUPPLY	DELIVERY	END USE



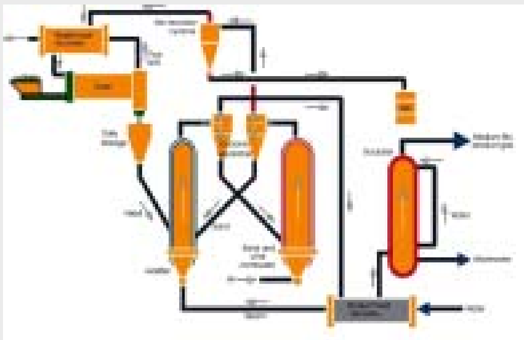

Needs

Secure, stable, competitive domestic energy supply	Address strategic concerns of domestic gas T&D infrastructure	Maintain industrial competitiveness and improve affordability of end use technologies

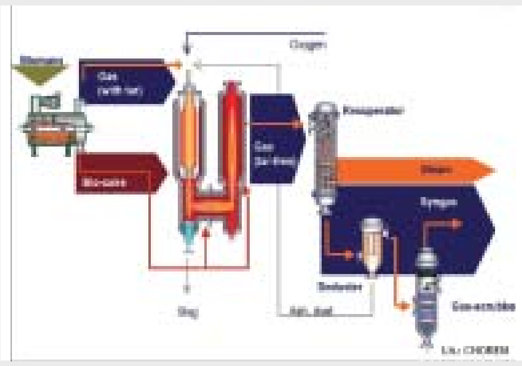
Strategic Focus

• Unconventional Gas Resources • Gasification for Alternative Supply	• Safety • Pipeline Integrity • Cost Reduction • Efficiency	• Energy efficiency • Environmental performance

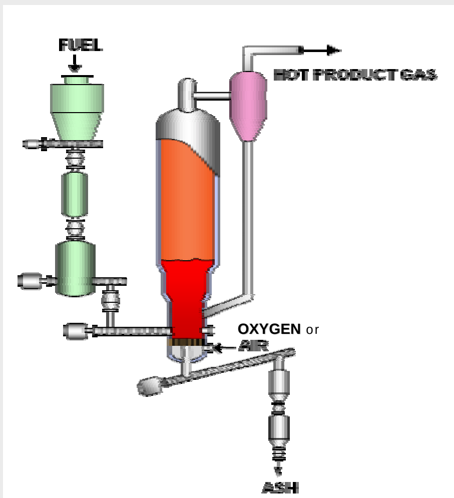
Biomass Gasifier Technologies



Battelle/FERCO/SilvaGas indirect gasifier

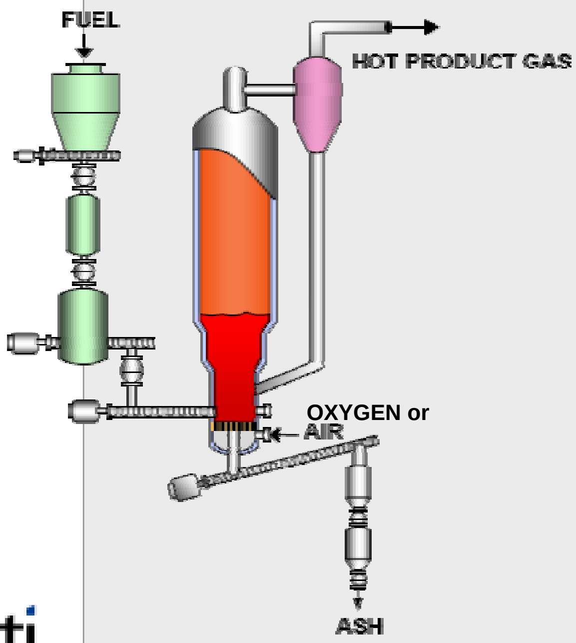


Choren three-stage Carbo-V process



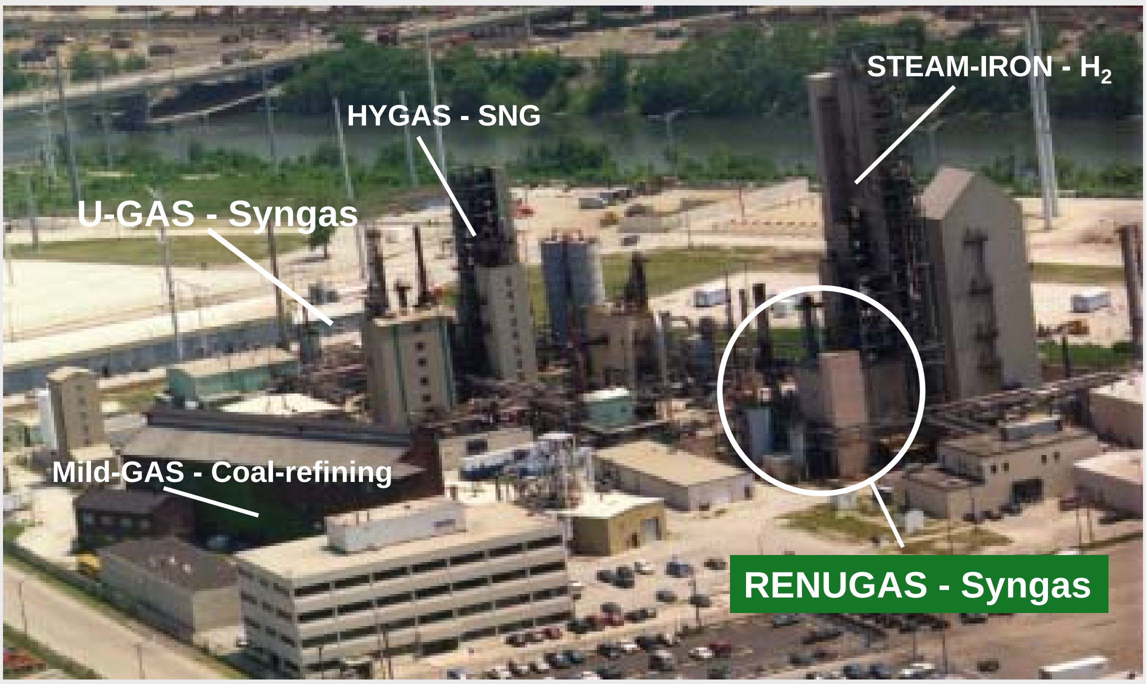
Carbona single-stage fluidized bed

GTI-Carbona Fluidized-Bed Biomass Gasifier



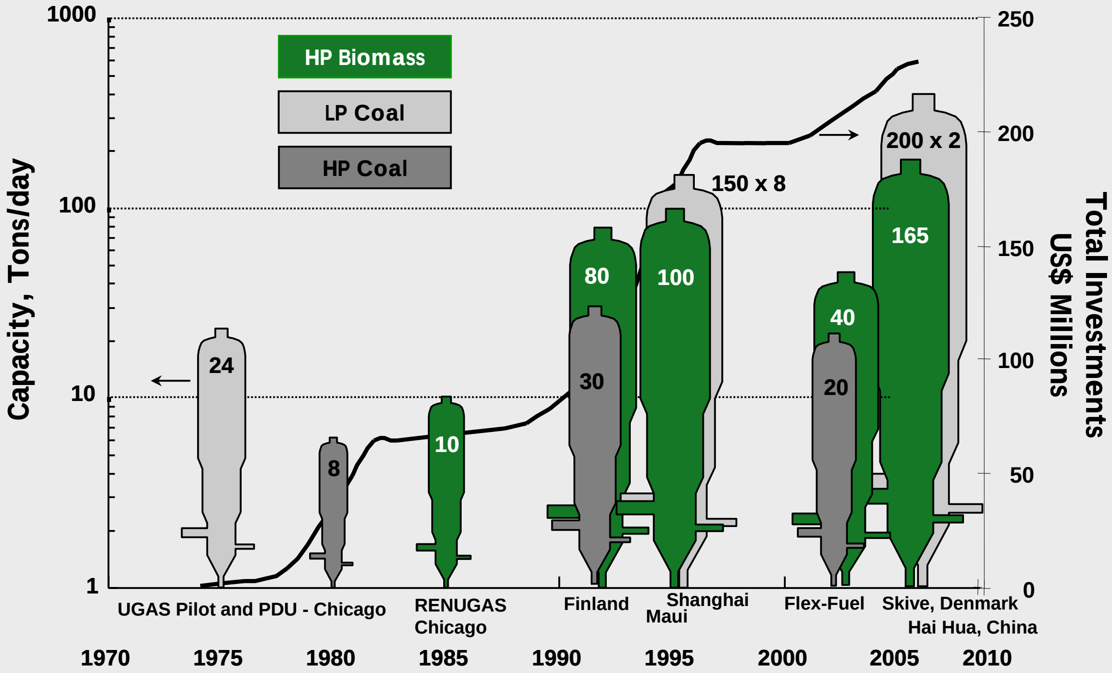
- High carbon conversion, 95-98%+
- Capability to gasify a wide variety of fuels, including coal/biomass mixtures
- Simple design with safe, reliable operation
  - Air-blown, enriched-air or oxygen-blown operation
  - Atmospheric to 30+ bara
- Operates at a lower temperature than a slagging gasifier (to 1000°C)
  - Longer metal component and refractory life
- Good turndown capability, 30 – 50%
- Demonstrated at commercial scale by Carbona

GTI Energy Development Center



1951-1996

Scale-up and Investment History of GTI Gasification Technology



Biomass Gasifier Projects

80 ton per day Gasification Pilot Plant in Tampere, Finland using biomass & coal

100 ton per day Bioenergy Demo Plant in Maui, Hawaii using bagasse

165 ton per day CHP Plant in Skive, Denmark using wood

40 ton per day Flex-Fuel Test Facility in Des Plaines, IL for biomass & coal

Tampere, Finland Pilot Plant (1992)

- 26 Tests
- 3850 h operation
- 80 tpd biomass
- 30 tpd coal
- up to 20 bara

- 700+ tons coal, 5300 tons biomass processed
- Multifuel capability; mixed coal and biomass (wood & straw) tested
- Demonstration of clean syngas for IGCC; cogen heat & power

GTI/Carbona Biomass Feedstocks

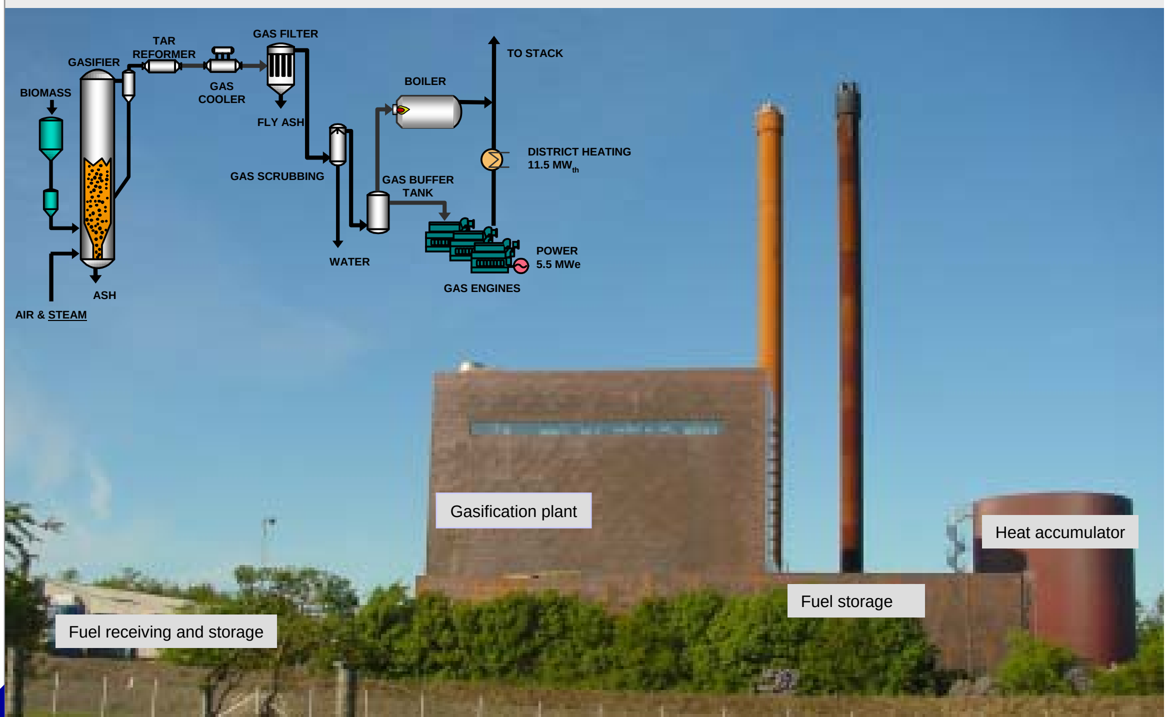
- Hard wood chips
- Soft wood chips
- Hard & soft wood mix
- Forest residue
- Bark
- Paper mill waste
- Wood pellets
- Saw dust
- RDF pellets
- Wheat straw
- Willow
- Alfalfa
- Rice straw
- Oil palm
- Bagasse

Flex-Fuel Test Facility: Pilot-Scale Fluidized Bed Gasifier

- Pilot-scale process R&D
- Periodic test campaigns
- ~30 testing staff

- Biomass – 20 tpd w/air; 40 tpd w/oxygen
- Gasification Pressure to 27 bara
- Extensive On-line Syngas Analysis Systems

Skive, Denmark Combined Heat & Power Project



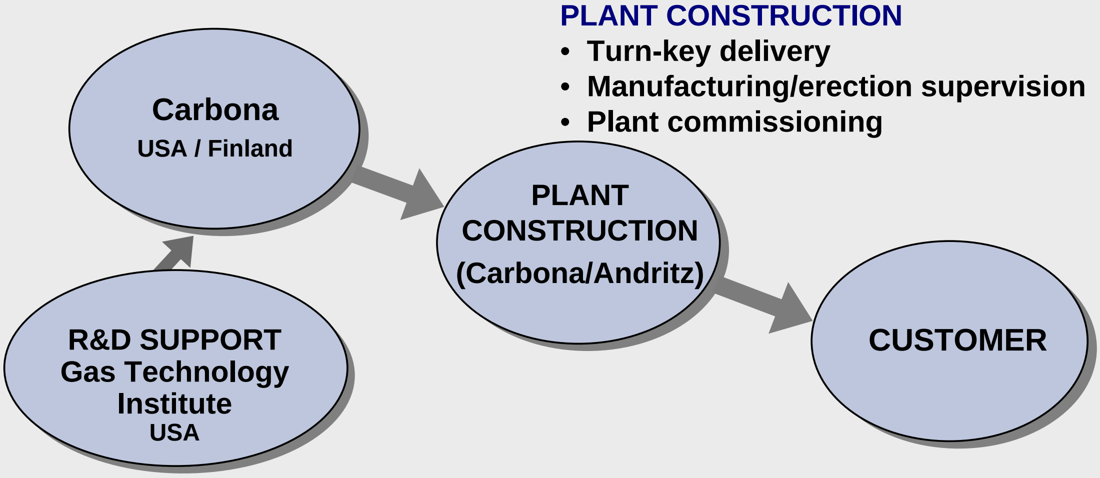
CARBONA Scope of Supply

BIOMASS GASIFICATION TECHNOLOGY

- **Process design**
- **Proprietary gasification technology**
- **Proprietary syngas treatment technology**
- **Plant design**

PLANT CONSTRUCTION

- **Turn-key delivery**
- **Manufacturing/erection supervision**
- **Plant commissioning**

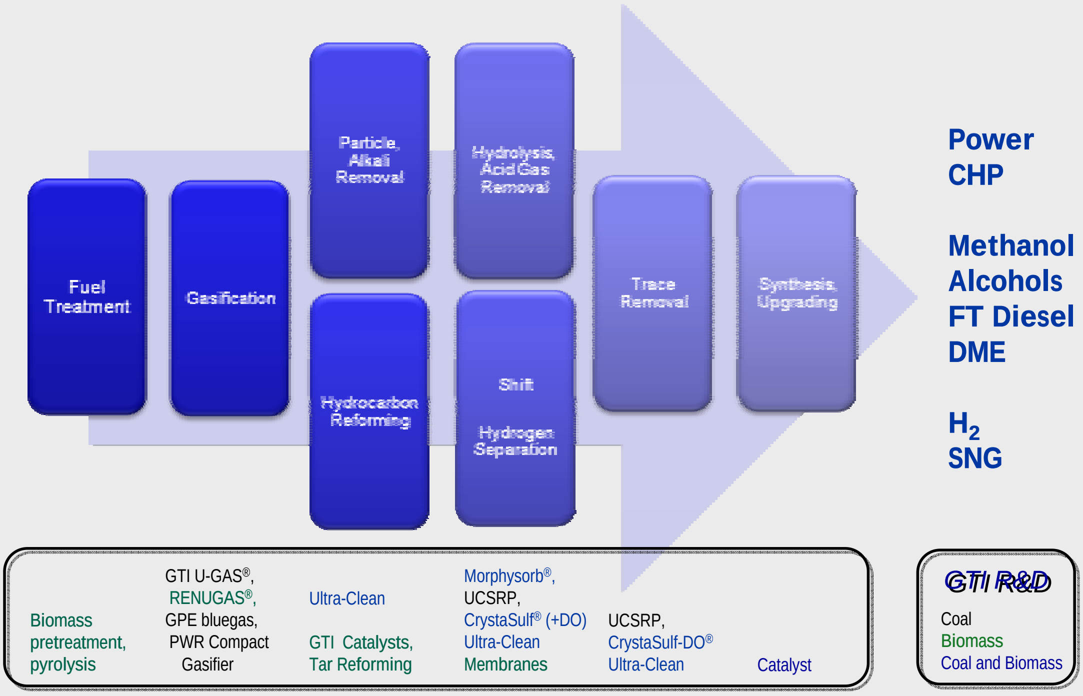


Some Syngas Application Options

- Biomass-to-power in boiler
  - Low efficiency (20-30%); limited co-firing range; boiler and site modifications required; commercial
- Biomass-to-power with engines or gas turbine
  - Varying efficiency (28-50%) without waste heat integration; high efficiency possible in CHP application requires consistent heat load; commercial
- Cellulosic fermentation for ethanol
  - Medium efficiency (50%); limited distribution system; high water demand; technology still in R&D
- BtL via Fischer-Tropsch
  - Modest efficiency (35-45%); can be improved with significant heat/steam integration; ultra-clean gas required; product needs further refining; commercial technology available
- Substitute Natural Gas (SNG)
  - High efficiency (65-70%); increased efficiency with waste heat integration; pipeline infrastructure-ready, storable product; ultra-clean gas required; commercial technology available

(efficiency on HHV basis)

Synthesis Gas Process

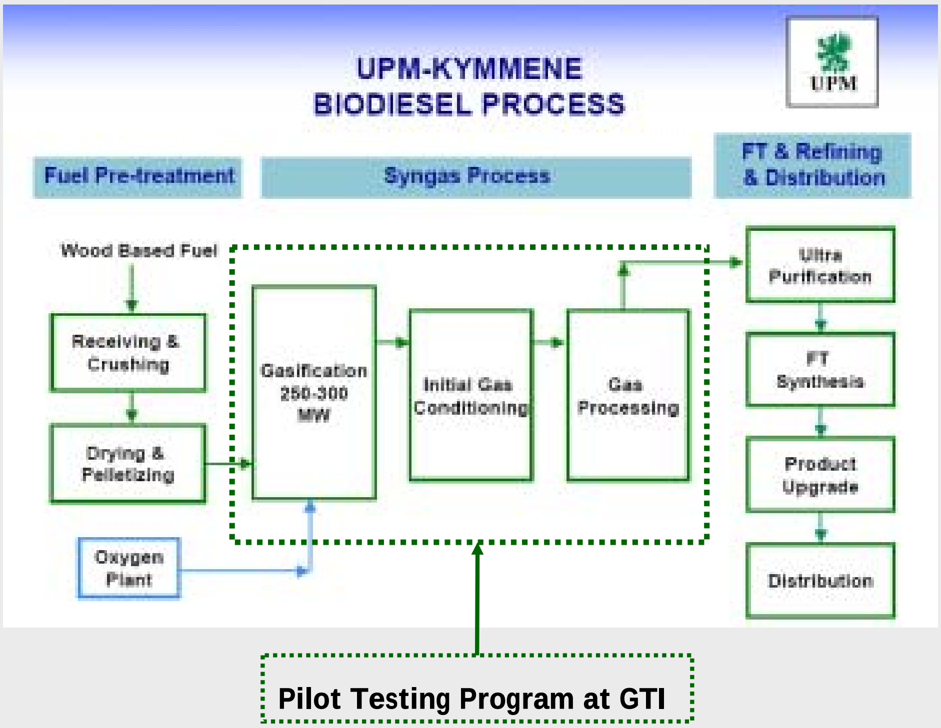


Current Biomass Gasification Activities

- Commercial Deployment Support
  - Carbona/UPM BtL Project
- Biomass Pretreatment
  - Hydrothermal treatment and pyrolysis
- Biomass Syngas Processing
  - Engineered Catalyst for Tar Reduction
  - H_2 from Biomass Gasification
  - Gas Cleanup for Fischer-Tropsch Application of Synthesis Gas
- Miscellaneous
  - IEA Bioenergy Task 33 Thermal Gasification of Biomass
  - Biomass Gasification R&D Laboratory (Auburn University, Natural Resources Management & Development Institute)

2^{nd} Generation Biofuel Production from Wood by Fluidized Bed Gasification and F-T

CARBONA



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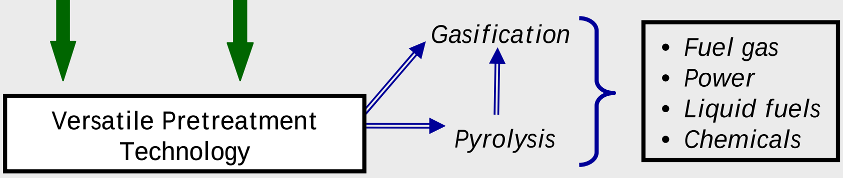
Commercial Plant Operational 2012

Biomass Pretreatment Project

Develop a process to render any ligno-cellulosic biomass into material amenable to efficient gasification or pyrolysis.

- We must use forestry and agricultural biomass sources to reach biofuel goals.
- Logistics of biomass supply is a major economic and carbon intensity hurdle.
- Higher energy density bio-feedstock would allow larger, more economic process scale.
- Gasification and pyrolysis both benefit from feedstock consistency.



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Gas Cleanup for Fischer-Tropsch Application of Synthesis Gas

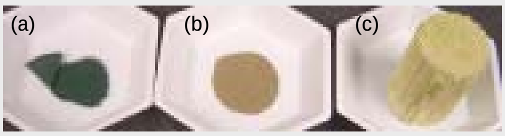
- Project funded by U.S. Department of Energy
- Integrated with GTI pilot-scale pressurized, oxygen-blown gasification of wood
- Slipstream raw syngas cleaned up to 30 kg/hr net feed to third-party Fischer-Tropsch (FT) unit
- H_2/CO ratio adjusted to 2/1
- Remove dust, tars, alkali, NH_3, and sulfur in novel warm-gas process, and remove pure CO_2 with solvent, all to acceptable levels for FT
  - Phase I 300 hrs w/o FT – evaluate cleanup performance, achieve specs
  - Phase II 500 hrs with FT – confirm catalyst poisoning does not occur
- Slipstream system currently in design stage
- Initial operation in Phase I to start in January 2009

GTI Innovations in Catalysts

> GTI patented method of thermal impregnation (TI)

- to infuse catalytic metals into the surfaces of a variety of natural olivines.
- to incorporate metals into specific formulations of olivine-structured silicates.

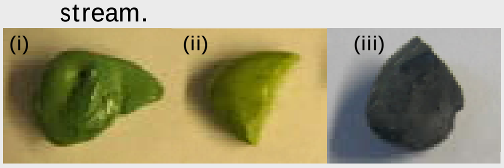
> TI materials completely decompose tar (as naphthalene) and methane and resist poisoning by up to 20 ppmv of H_2S at 900°C.



(a) Cobalt bulk catalyst
(b) Nickel and Iron bulk catalyst
(c) Nickel monolithic catalyst

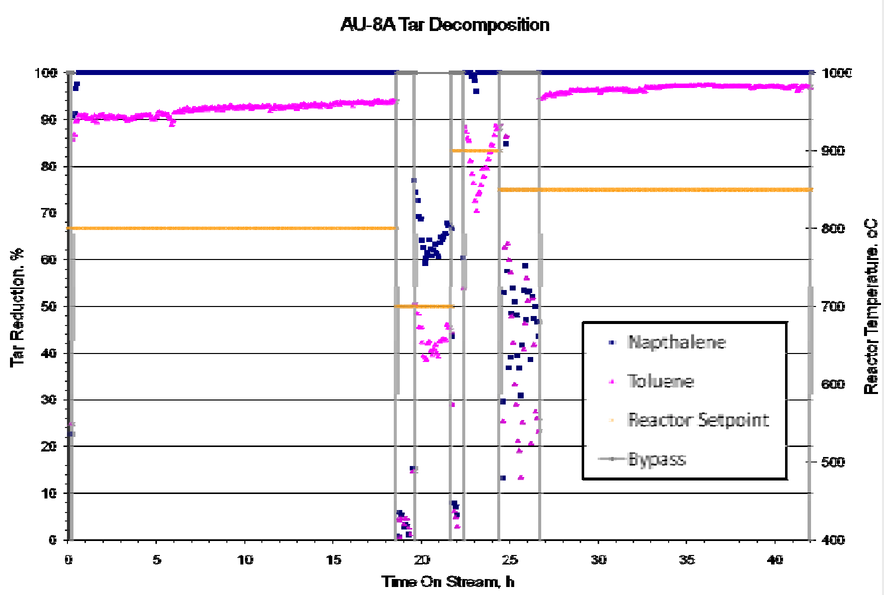
> GTI has filed for patent on glass-ceramic materials

- a number of glass-ceramic formulations that contain up to 40% catalytic metals.
- laboratory tests reveal up to100% naphthalene decomposition over 100 h time on stream.

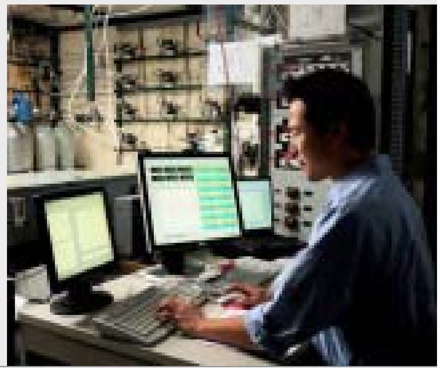


i. base material, as an amorphous glass,
ii. material after heat treatment to create a microcrystalline glass-ceramic,
iii. glass-ceramic after reduction under hydrogen to create Ni metal on all exposed surfaces.

New Catalyst for Tar Decomposition



Evaluating catalyst materials with surrogate gases



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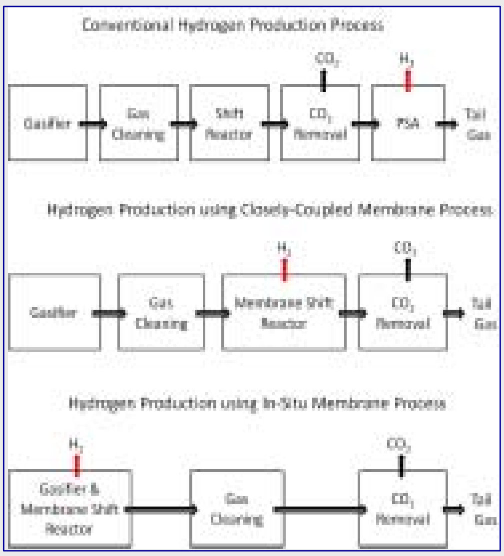
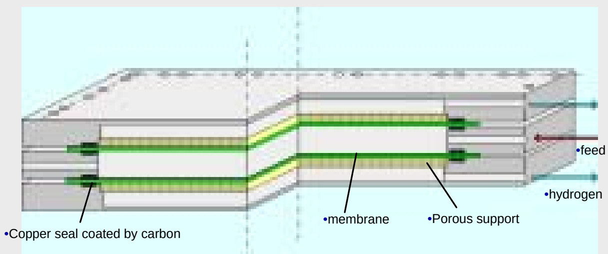
Hydrogen Production from Biomass

> Laboratory Screening of H_2 Membranes
  - Ceramic membranes
  - Metallic membranes
> Field Prototype Tests
  - Biomass gasifier
  - Integrated system
    > guard-shift-membrane
  - H_2 flux, purity targets





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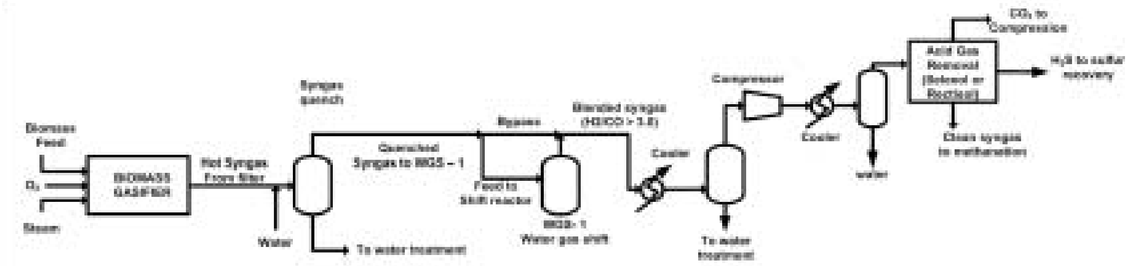
Biomass to SNG Process Simulation



SNG from Biomass: Biomass Gasifier, Water Gas Shift, & Acid Gas Removal Units

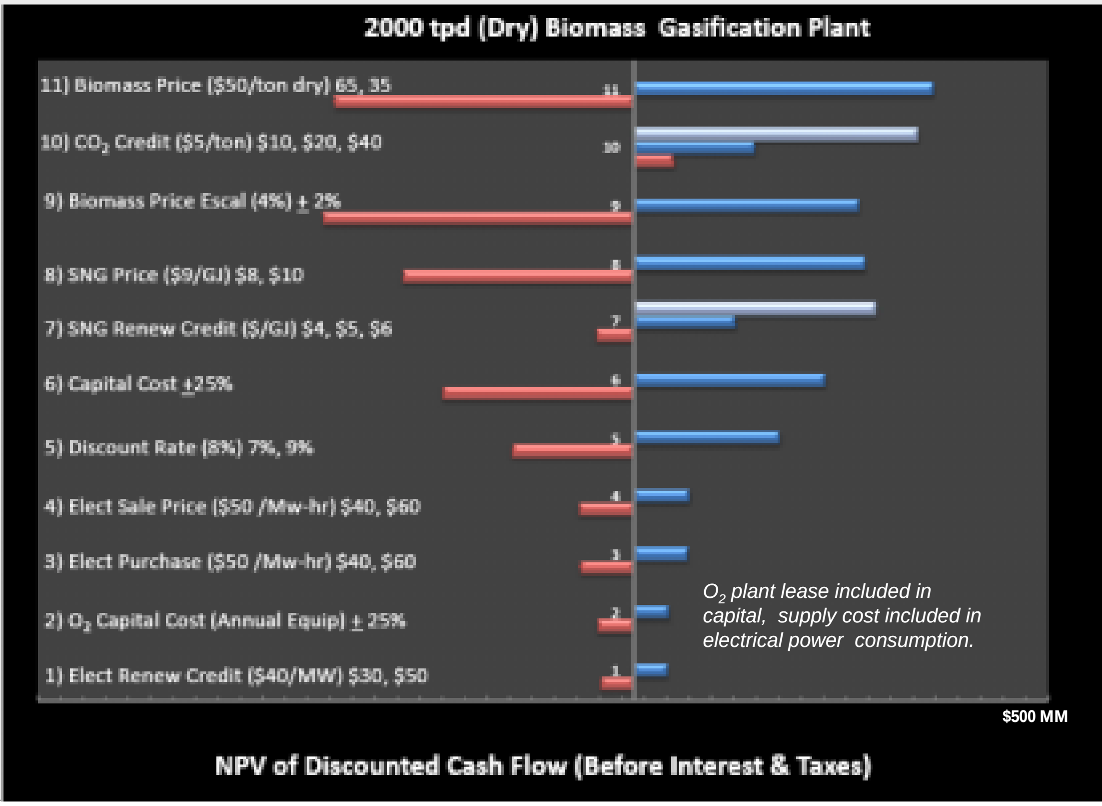
Commercial Systems Basis

- ➢Oxygen-blown, pressurized fluidized bed gasifier (10 bar_a)
- ➢Hydrocarbon reforming (including inherent CH_4)
- ➢Sour water-gas shift to achieve H_2:CO >3
- ➢Compression for commercial acid gas removal for CO_2 and S
- ➢USDOE simulation for AGR used in process
- ➢Two stage + trim methanation reactor
- ➢Dehydration to achieve gas pipeline specifications

~ 68% conversion efficiency

gti.

SNG Production Cost Sensitivity



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Biomass Gasification Considerations

- Biomass price dominates economics. Therefore, processes should maximize conversion efficiency.
- Pressurized gasification has significant efficiency benefits
  - Larger scale systems possible with more compact gasifier
  - 10 bar gasification increases SNG production efficiency by 11-18% vs 2 bar gasification according to process simulation
  - Reduction in syngas volume for gas treatment (reduced equipment size) and improved cleanup efficiency

    (O_2 capital costs are not significant in plant economics)
- There are limited commercial options in syngas processing. Advanced syngas cleanup and conversion systems can improve process economics.

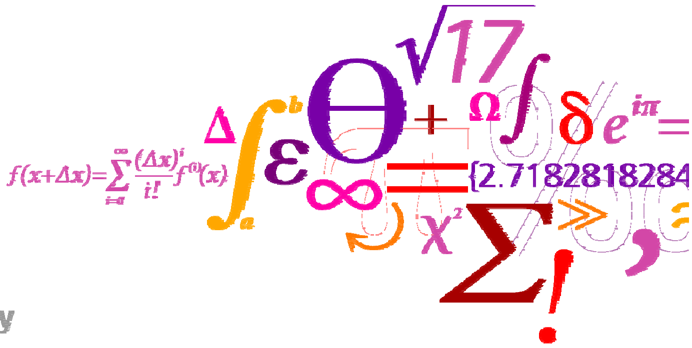
Summary

- GTI is supporting Carbona commercial applications of fluidized bed gasifier for 2nd generation biofuels.
- GTI is developing syngas cleanup technologies to improve process economics.
- GTI is working as a development partner to evaluate and prove new biomass conversion processes.

Up-Scaling and Commercialization of the DTU TwoStage Gasifier

Ulrik Henriksen

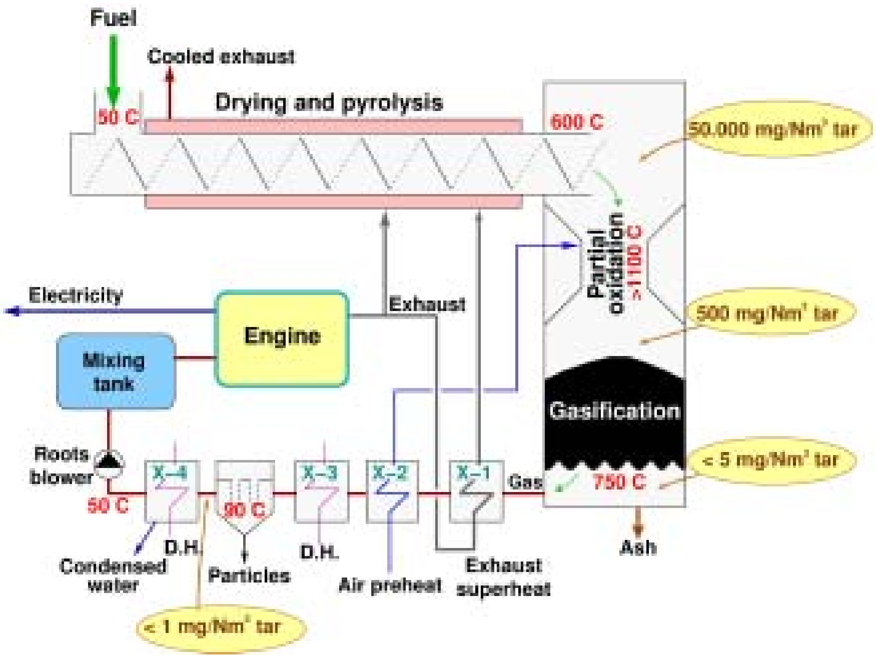
Jesper Ahrenfeldt



Risø DTU
National Laboratory for Sustainable Energy

DTU TwoStage Gasification

- Tar reduction:
  - partial oxidation of all volatiles
  - tars through hot char bed

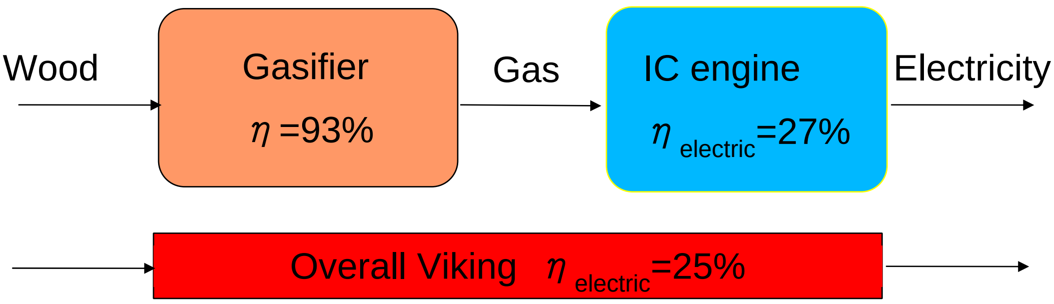


The Viking TwoStage Gasifier

- Small scale fixed-bed CHP(70 kW fuel)
- Commissioned August 2002
- Fully automated and unattended operation

The Viking TwoStage Gasifier

Performance



The Viking TwoStage Gasifier

Results

- 3600 hours of operation
- 25% efficiency measured from biomass to electricity
- Stable and controllable engine performance
- Easy load regulation of gasifier and engine

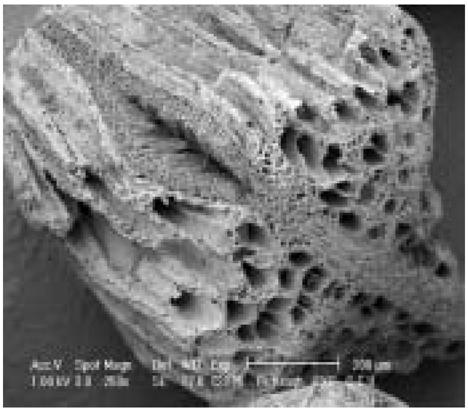
The Viking TwoStage Gasifier

Results

- Dry gas cleaning with baghouse filter:
  - Neither tar nor particles in the cleaned gas
  - Dust and condensate can be treated separately
  - Condensate not a waste problem
- Wood fuel flexibility: Hard-wood, soft-wood and short rotation wood have been applied as fuel
- 150 hours of stable fuel-cell operation on producer gas
- Methanol production from the producer gas

Up-Scaling of DTU TwoStage Gasification

Based on the results of the Viking project the DTU TwoStage process is being up-scaled in cooperation with COWI and Weiss A/S



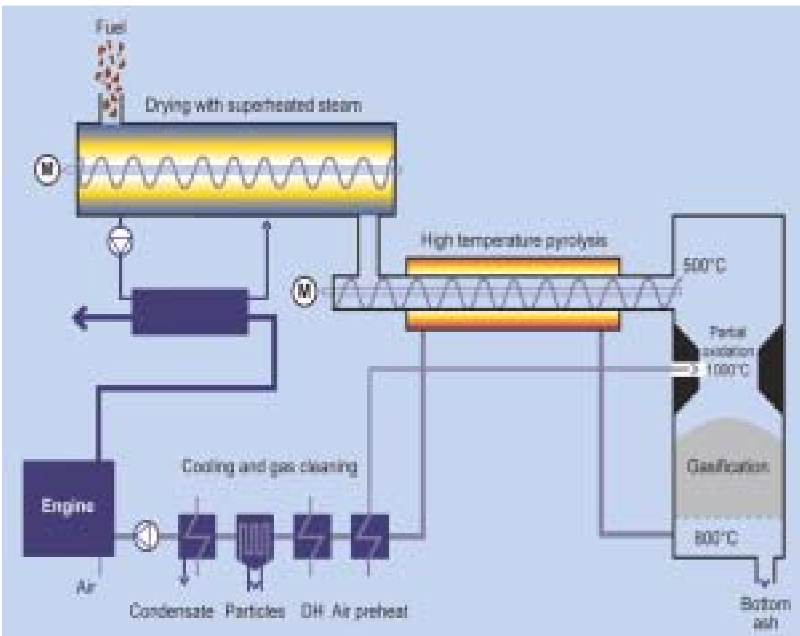
Up-Scaling of DTU TwoStage Gasification

Steam dryer

- Excess heat from engine used for the steam dryer
- The produced steam remaines in the proces

Pyrolyser

- Product gas from gasifier is used as heat source for pyrolyser



Up-Scaling of DTU TwoStage Gasification

Prospects

- Up-scalable to 0.2 - 2 MW electrical
- Compact reactors
- Electrical efficiency, biomass to power: > 37 %
- Total energy efficiency: > 98 % (through condensation of steam in exhaust gas, based on LHV)

TwoStage Pilot Plant at Weiss A/S

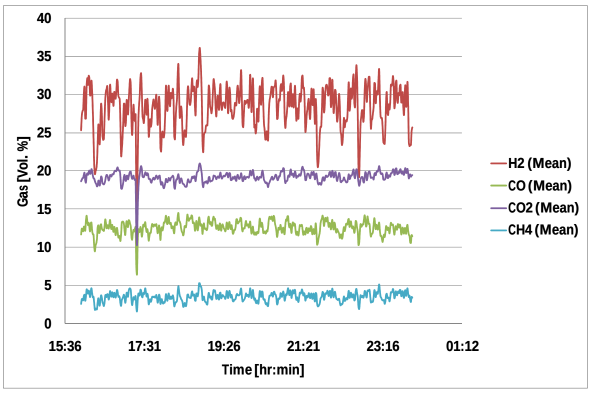
1:1

1:10

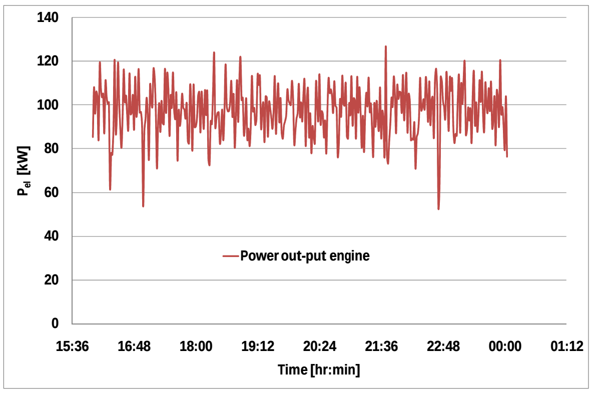
TwoStage Pilot Plant at Weiss A/S

TwoStage Pilot Plant at Weiss A/S

Gas composition

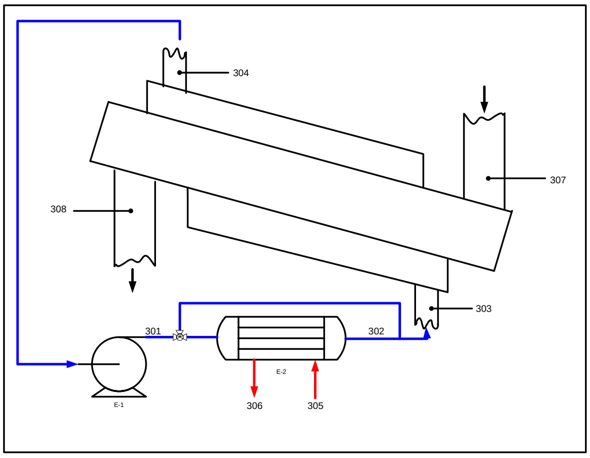


Part Load Performance of Engine

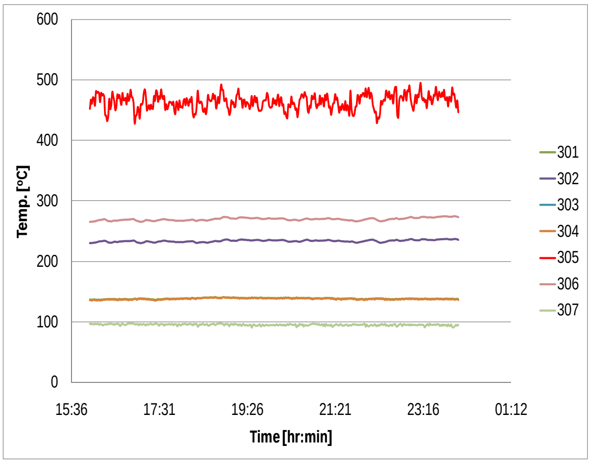


TwoStage Pilot Plant at Weiss A/S

Dryer lay-out



Dryer performance

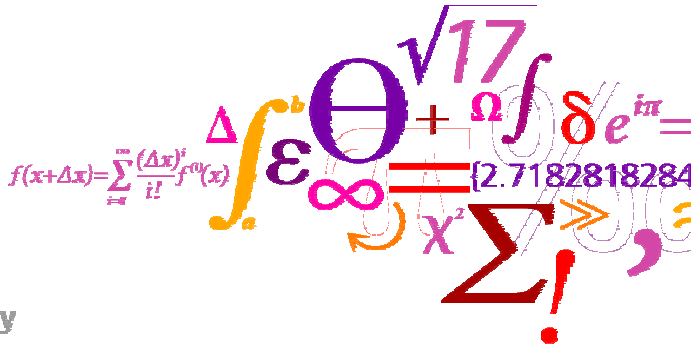


Optimal use of Biomass

- High electrical efficiency (close to 40%)
- High total efficiency through CHP
- Small decentral plants

This is the vision of TwoStage biomass gasification

Biomass Gasification Group



Risø DTU

National Laboratory for Sustainable Energy

Development and experience of Biomass Gasification in Metso Power

International seminar on Gasification
9-10 October 2008 in Malmö, Sweden

Pekka Saarivirta

Development and experience of Biomass Gasification in Metso Power

Metso Power

History of Gasification in Metso
- Tampella experience
- Götaverken experience

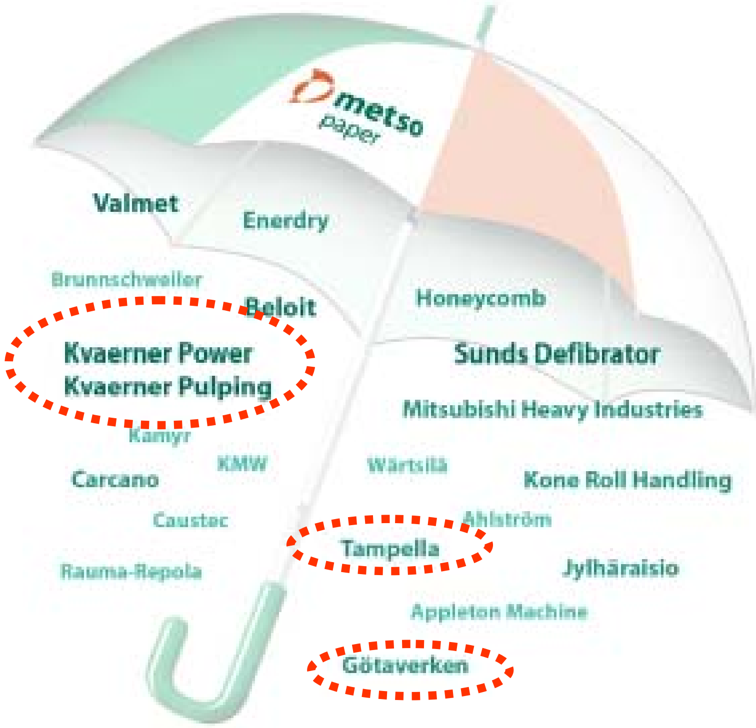
View on gasification today

Recent Development
- Waste gasification
- Biomass gasification

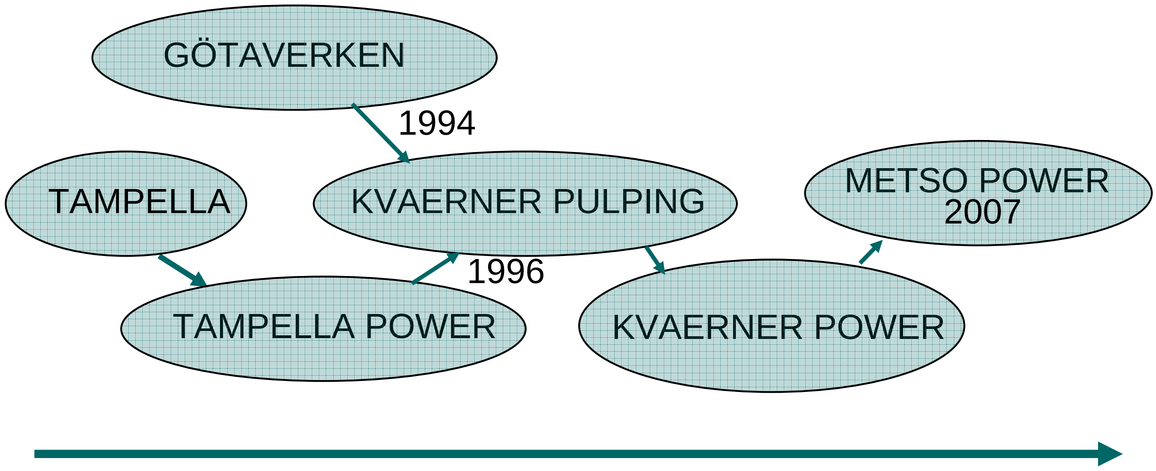
Metso - a global technology company

- We serve the pulp and paper industry, rock and minerals processing, the energy and selected other industries
- Net sales approx. EUR 6,250 million in 2007
- We operate in 50 countries with over 27,000 employees
- Listed on the OMX Nordic Exchange in Helsinki
- Some 26,000 shareholders

Metso Paper
Consolidation and continuous development



From Tampella/Götaverken to Metso Power



Metso Power

- 1500 employees
- Sales and engineering offices around the world
- Four own manufacturing facilities worldwide

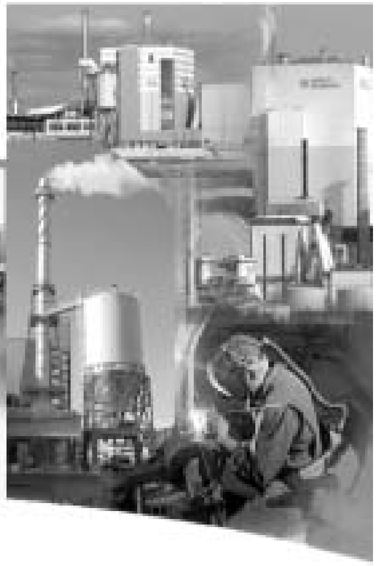
Metso Power's products

Boilers
- HYBEX for biomass and recycled fuel
- CYMIC for biomass, recycled fuel and coal
- RECOX for chemical recovery
- Oil and gas boilers

Evaporators
- EVAPS for black liquor concentration

Environmental systems
- ODOCON products for odour control for the pulp and paper industry
- GASCON products for flue gas treatment for the pulp and paper and power generation industries

Service
- Rebuilds and upgrades
- Maintenance
- Spare parts
- Accessory products
- Partner Services



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History of Gasification in Metso Power

TAMPELLA POWER

Tampere pilot plant
•15 MWth pressurized FB gasifier
• Biomass and coal gasification development
• Hot gas cleaning development

GÖTAVERKEN

Atmospheric CFB gasification development
• Värö lime kiln gasifier 1987

ENVIROPOWER

Founded by Tampella Power and Vattenfall 1992
• Upkeep Gasification know-how
• Now owned by Metso Power

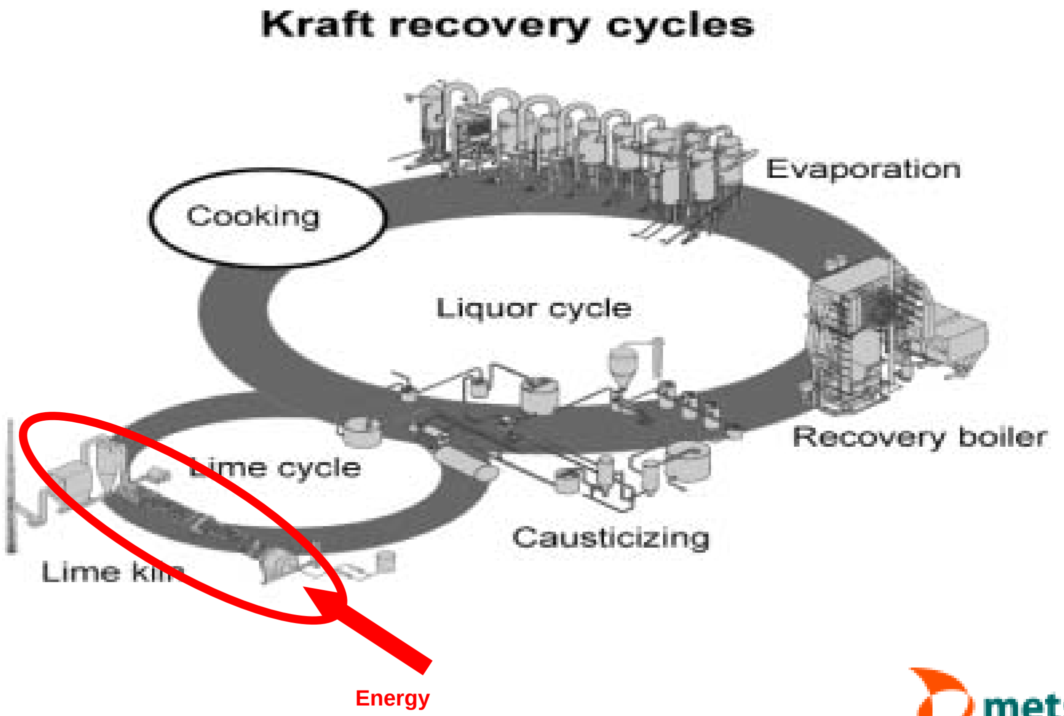
METSO POWER GASIFIER

NEW DEVELOPMENT ACTIVITY
• Initiated 2002
• Biomass gasification for limekilns
• Biomass gasification for power production
• Waste gasification
• Fuel drying
• Gas cleaning

metso power

 Juhani Isaksson / International Seminar on Gasification. 9.-10.10.2008 Malmö.

Limekiln operation with biogas



Biomass Gasifier for Lime Kiln

- Limekiln is easy to switch for gasification gas – size is usually feasible and fuel is typically available.

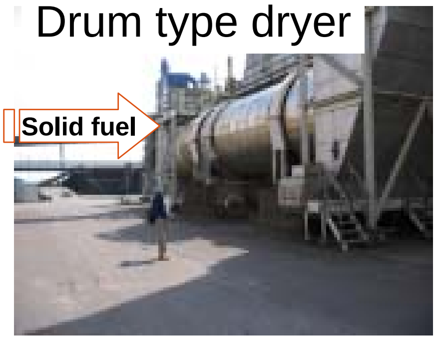
- At 1980's, during second oil crisis, several gasifiers were built, in order to replace oil with biomass.

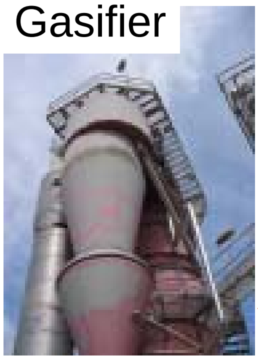
- At Värö, Södra Cell Sweden, Metso Gasifier (Götaverken) has been in use from 1987.

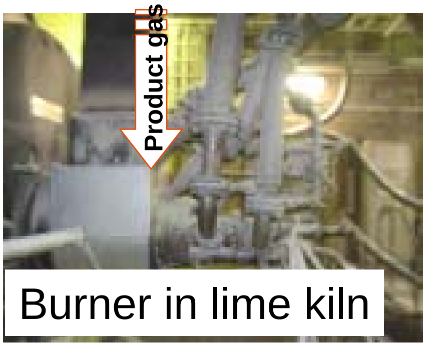
=> Over 20 years of industrial experience.

Biomass gasifier

Värö mill – existing and operating reference







Limekiln gasifier- Economy today

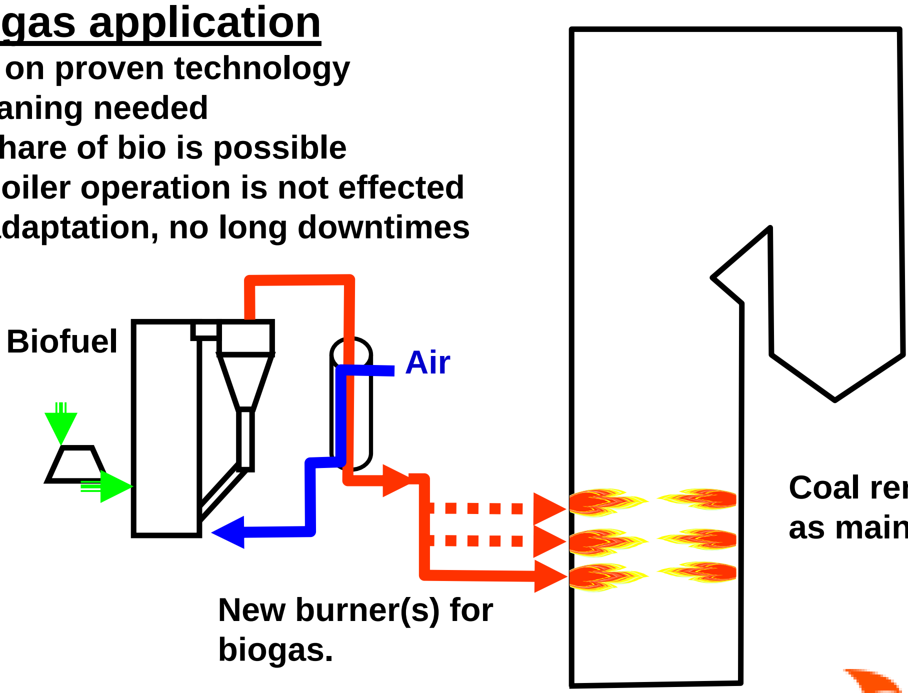
650 000 tn/a pulp mill		Bio	HFO
Fuel	MWh	381 500	350 000
Fuel unit cost	€/MWh	13	45
Annual fuel cost	M€	5,0	15,8
CO2 emission/MWh	tCO2/MWh	0,0000	0,2786
Annual CO2 emission	tCO2/a	0	97 510
CO2 credit	€/tCO2	20	20
Annual CO2 cost	M€	0,0	2,0
Consumables (Electricity, lime etc.)	M€/a	0,8	0,0
Total	M€/a	5,8	17,7
Annual savings if bio selected	M€/a		**11,9**
Estimated investment	M€		
- Gasifier	7 -11		
- Dryer (based on waste heat)	3 - 6		
- Fuel handing etc.	2 - 4		
TOTAL INVESTMENT	12 – 21		

Juhani Isaksson / International Seminar on Gasification. 9.-10.10.2008 Malmö.

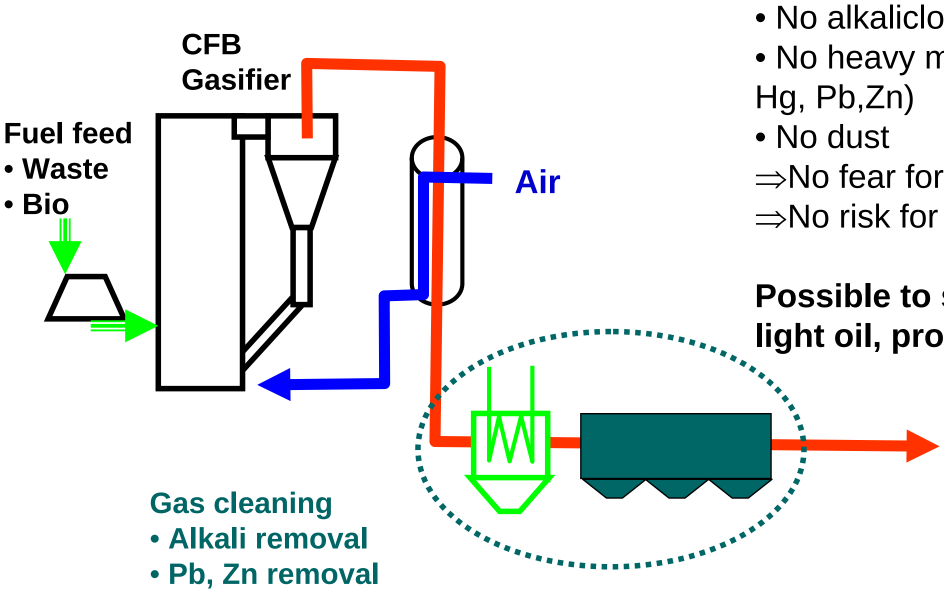
Cofiring in PC boilers through gasification

Dirty gas application

- Based on proven technology
- No cleaning needed
- High share of bio is possible
- Main boiler operation is not effected
- Easy adaptation, no long downtimes



Clean gas applications



Clean product gas
- No alkalicloride s
- No heavy metals (except Hg, Pb,Zn)
- No dust

⇒No fear for corrosion
⇒No risk for contamination

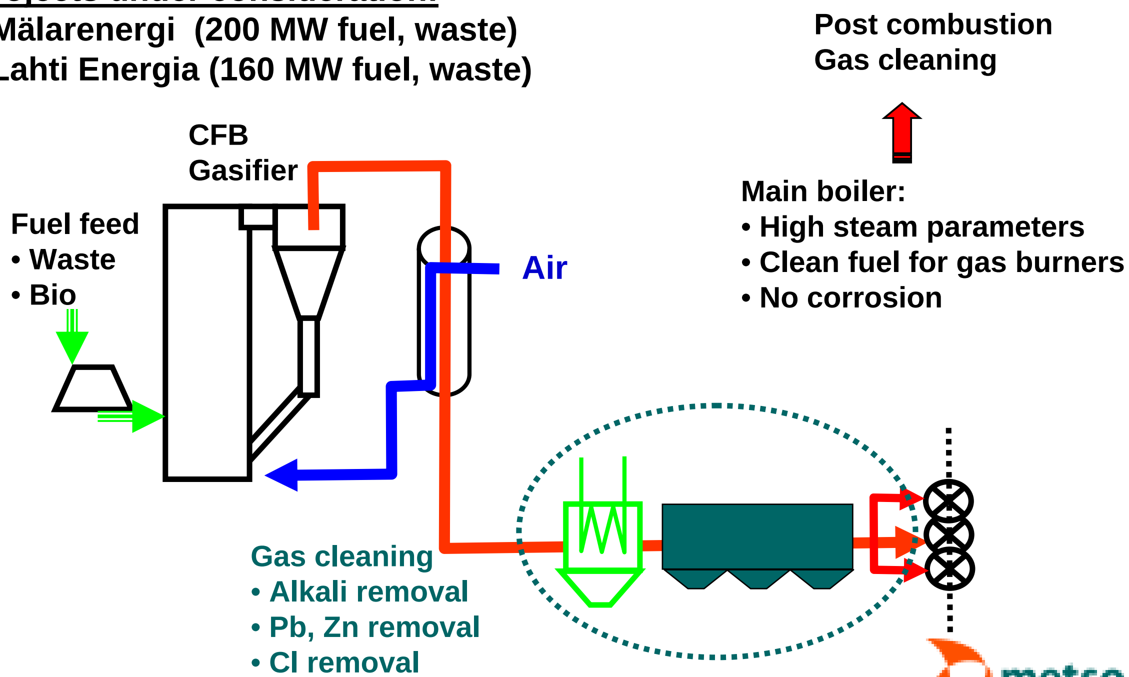
Possible to substitute light oil, propane or NG

Gas cleaning
- **Alkali removal**
- **Pb, Zn removal**
- **Cl removal**

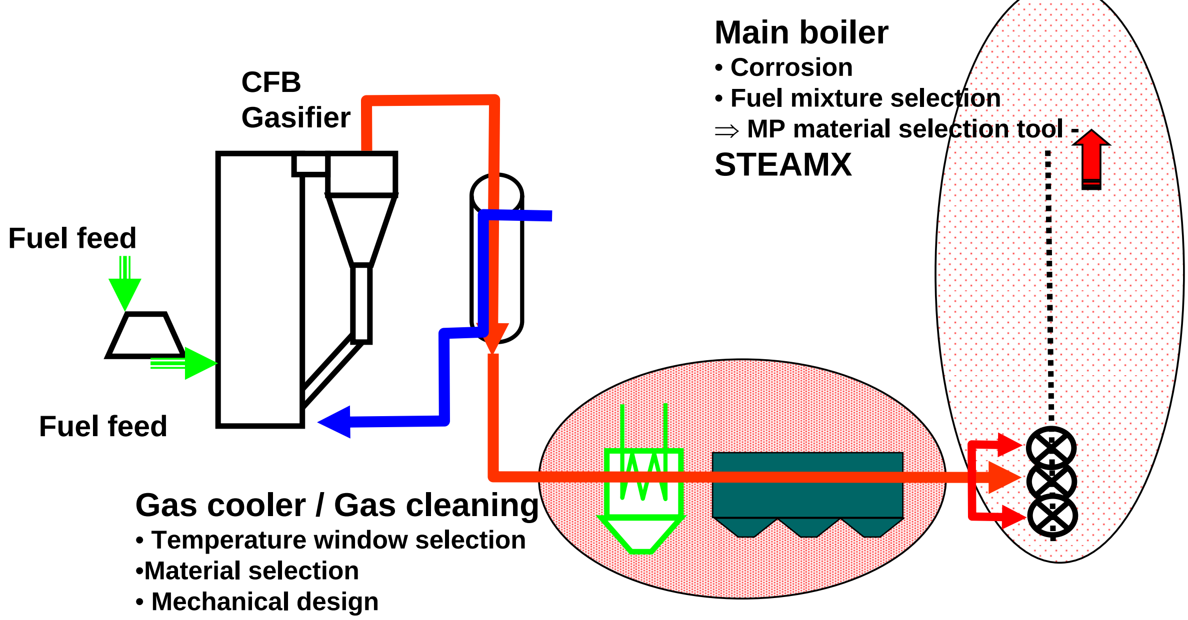
Juhani Isaksson / International Seminar on Gasification. 9.-10.10.2008 Malmö.

High efficiency boiler for waste
or for high alkali/high chlorine biofuels

Projects under consideration:
- Mälarenergi (200 MW fuel, waste)
- Lahti Energia (160 MW fuel, waste)



High efficiency boiler for waste
Development activities



Gas cooler / Gas cleaning
- Temperature window selection
- Material selection
- Mechanical design
- Cleaning system design

=> Värö test rig

Värö test rig

• Metso Power will construct a test rig for gas cleaning tests and demonstration into Södra Cells Värö mill.

• Test rig will be connected as a slip stream unit to the operational Metso Gasifier feeding a lime kiln.

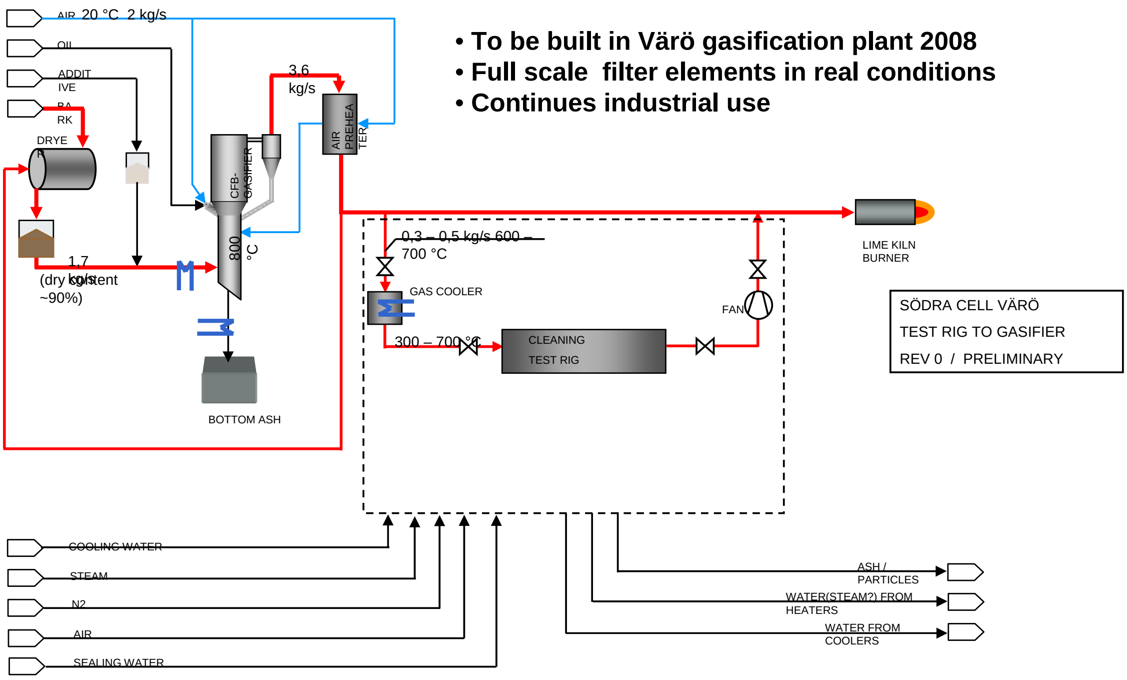
• Test rig will an industrial size demonstration of clean gas production through biomass gasification.

• Construction of the test rig is now underway .

• This 10 Msek + project is hosted by Södra Cell and financially supported by Energimyndigheten, Sweden. Metso Power will be owner and operator of the test rig.

Värö test rig

• To be built in Värö gasification plant 2008
• Full scale filter elements in real conditions
• Continues industrial use



Värö test rig

At Värö, Södra Cell Sweden, Metso Gasifier (Götaverken) has been in use from 1987.

Area for gas cleaning test rig.

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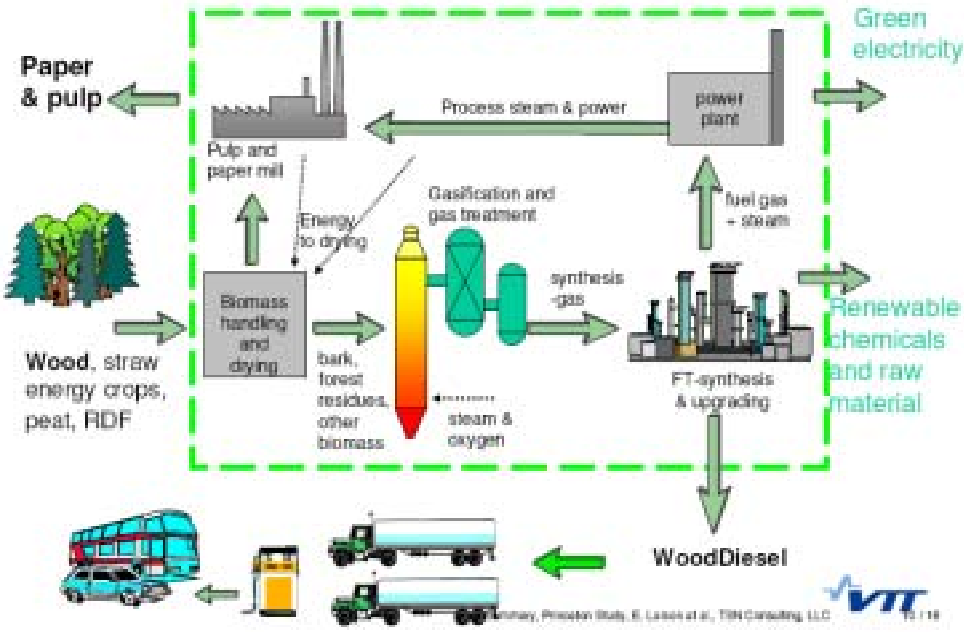
Biorefinary – still a long way to go ?



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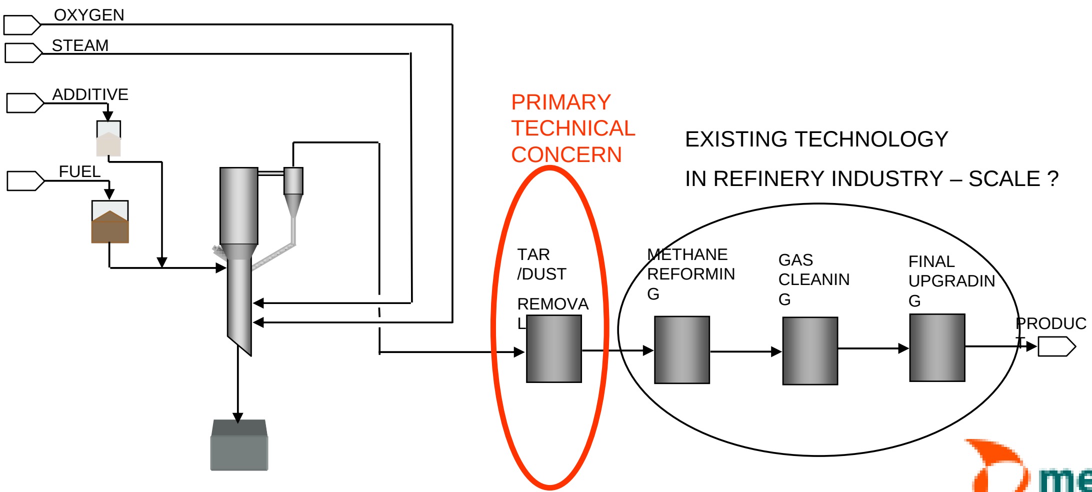
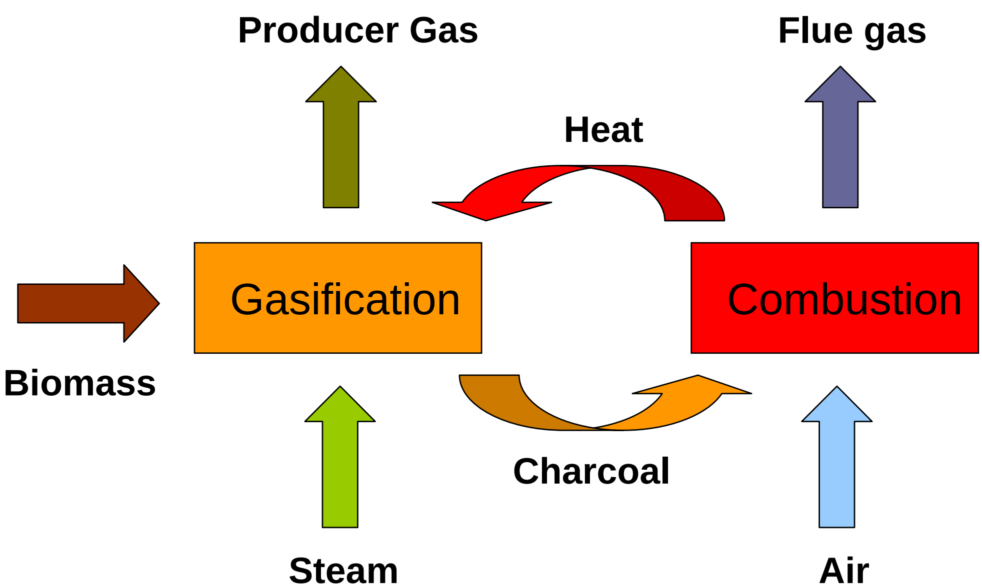
Biorefinary – still a long way to go ?

- Several development projects in pulp and paper industry
  - Economical scale ?
  - How to combine technologies for one working solution ?
  - Tars and other impurities ?

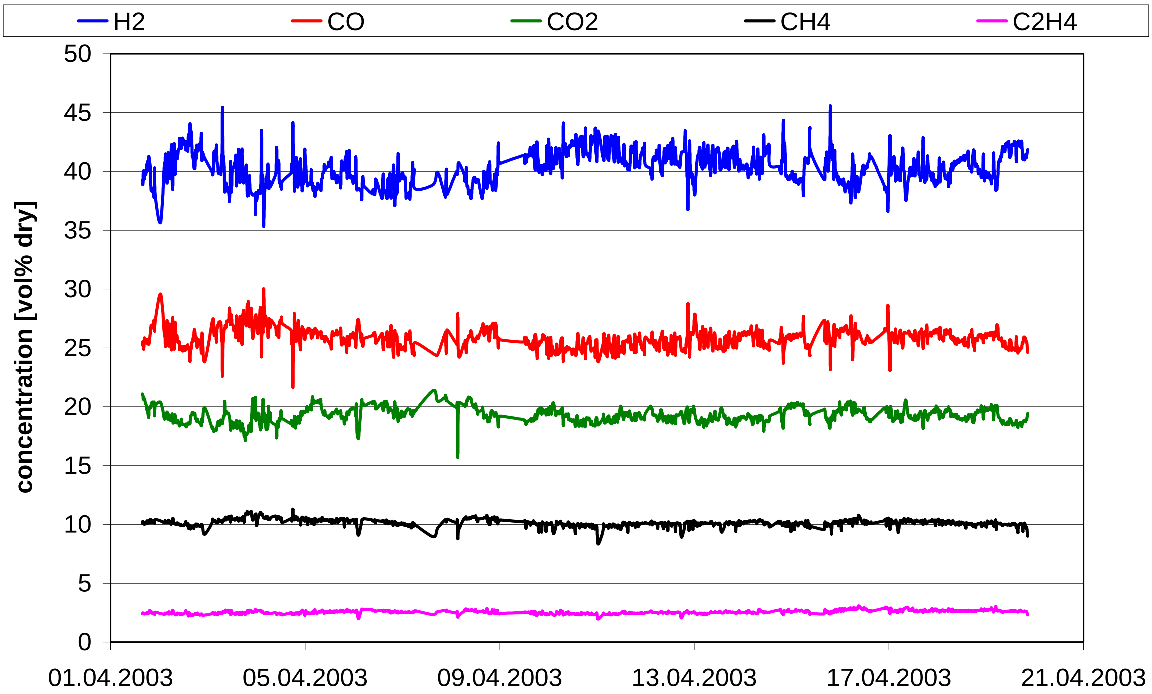


Biomass CHP Plant Güssing: Results from 5 European Research Projects.

Gasification Concept



Gas Composition



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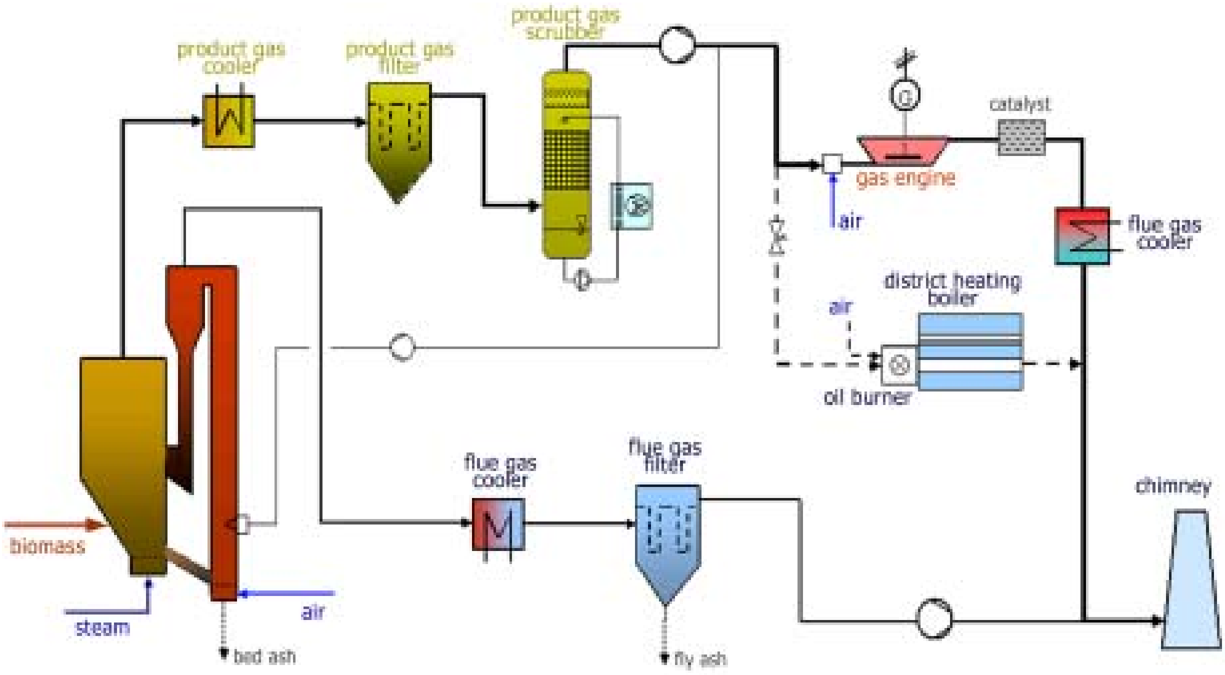
Biomass-CHP-Plant-Güssing



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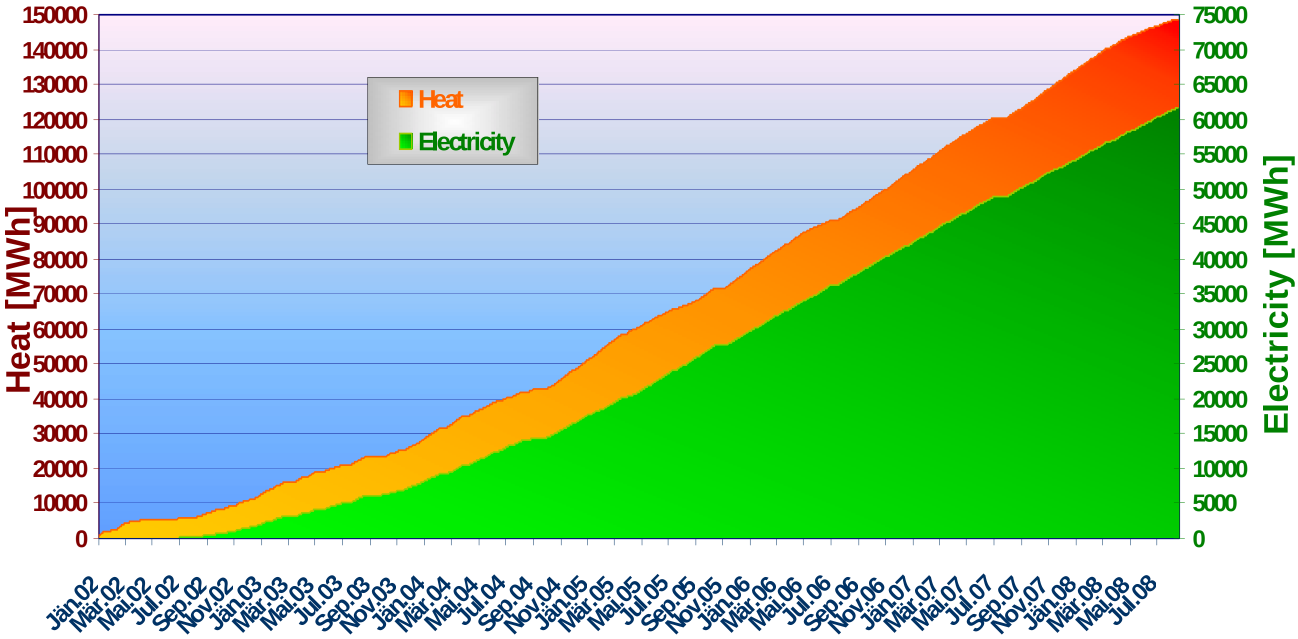
Energy Production



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EU Research Projects

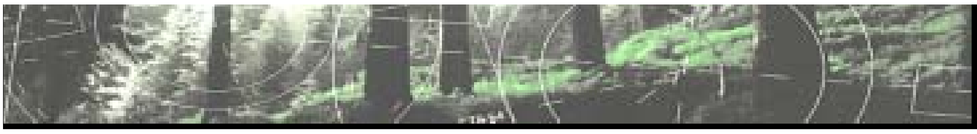
BiG Power

Bio-SNG

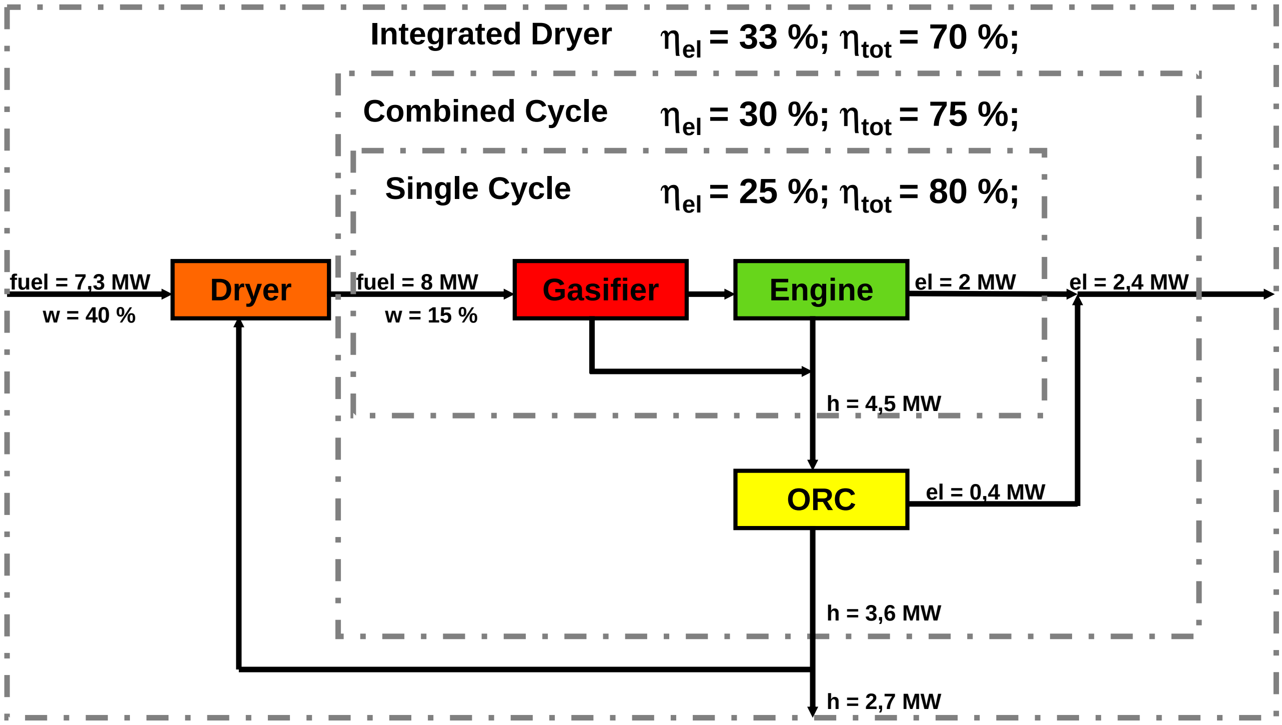
renew

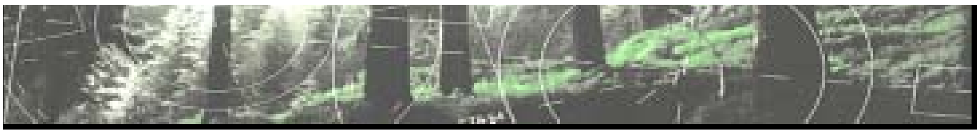
AER Gas

flexgas

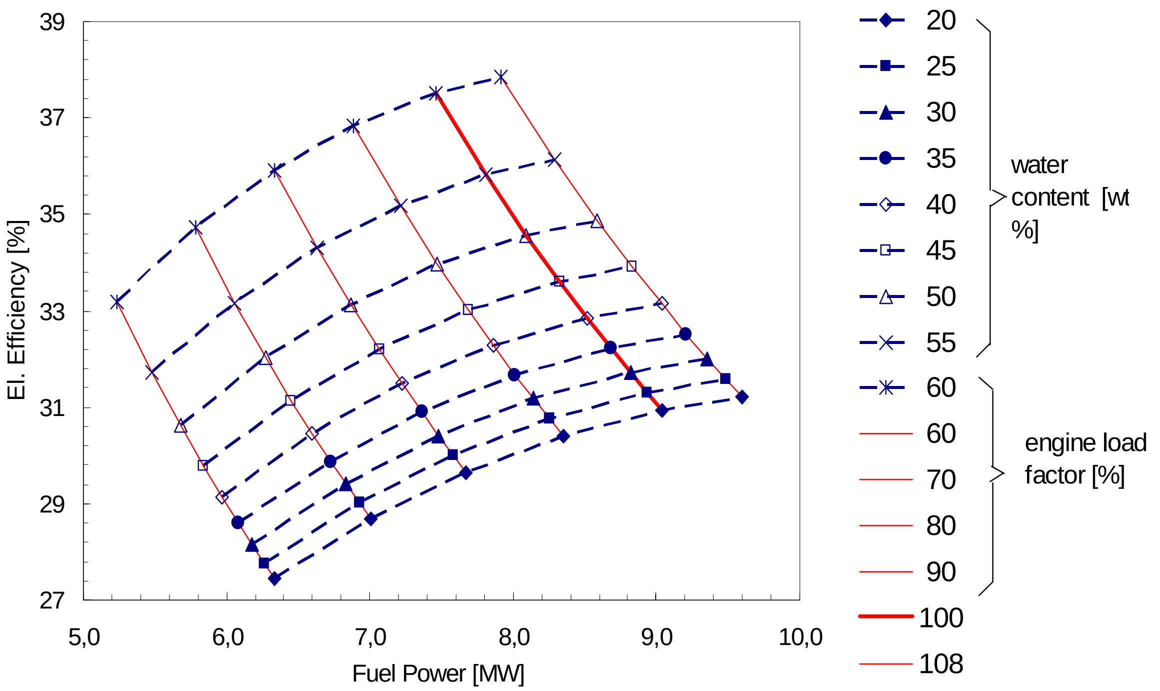


Big Power:
Optimisation of the CHP Process



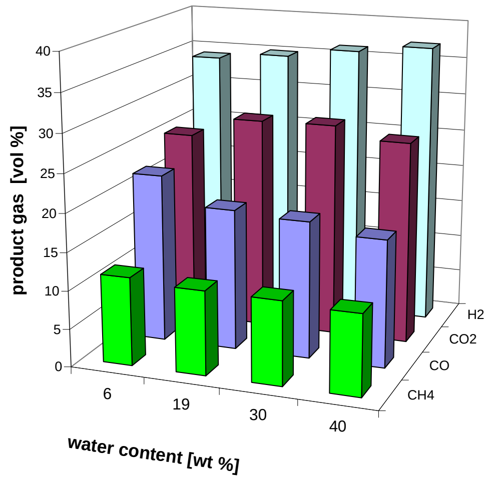


Efficiency Diagram with Dryer

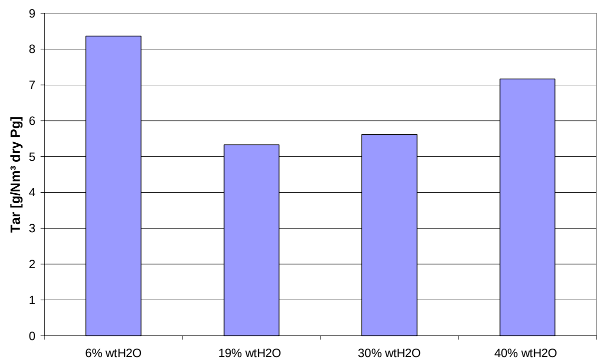


BiG Power:
Fuel With Different Water Content

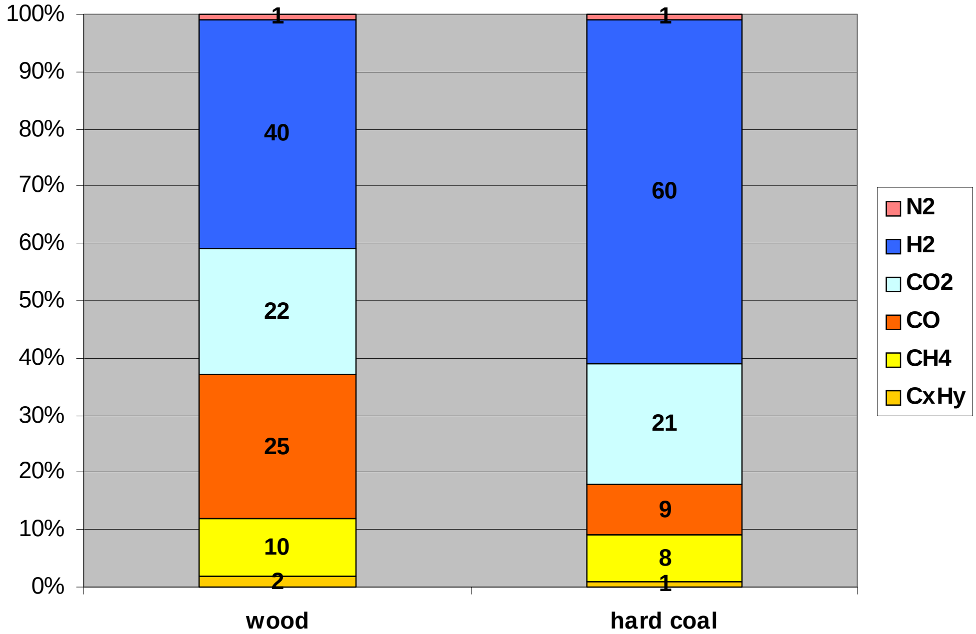
Producer Gas Composition



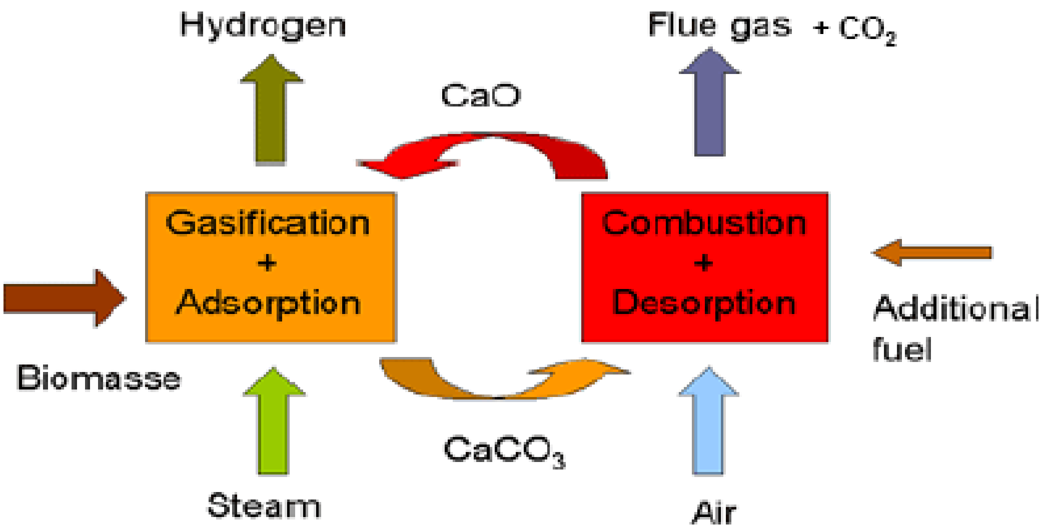
Tar Content



flexgas:
Gasification of Coal-Biomass-Mixtures
producer gas composition



AER – Gas



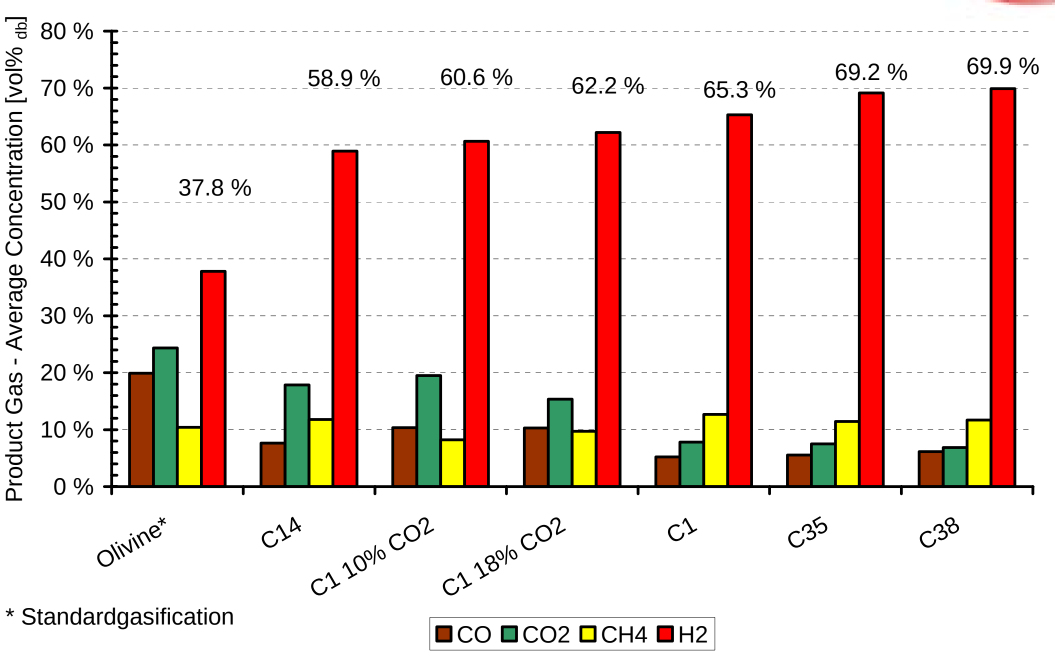
$CO_2 + CaO \rightarrow CaCO_3$

$CO + H_2O \rightarrow H_2 + CO_2 \rightarrow$

$CaCO_3 \rightarrow CO_2 + CaO$

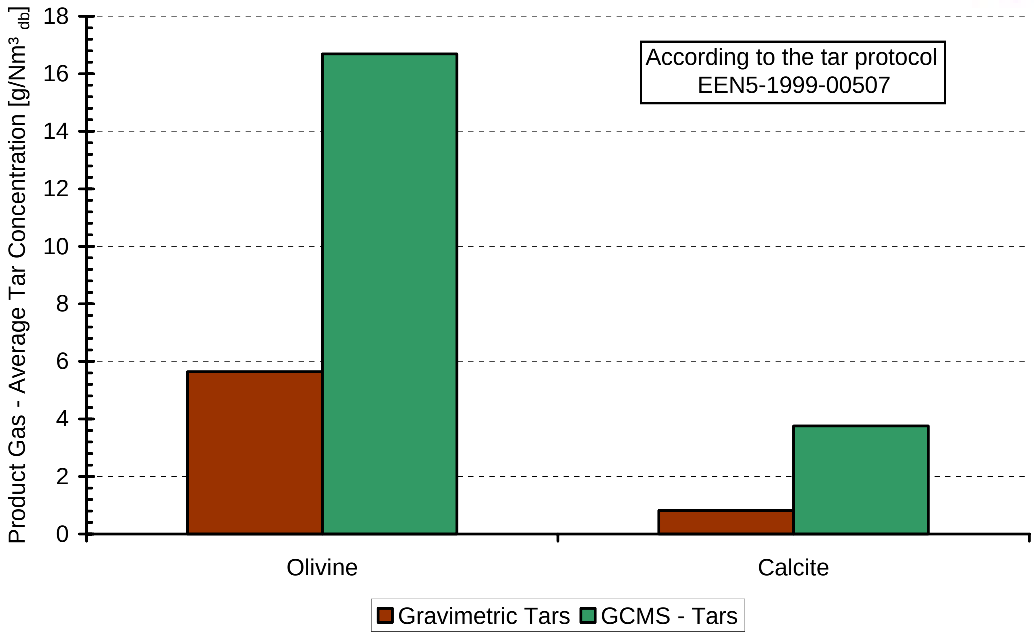
$H_2 > 70\ \%$

AER – Gas Producer Gas Composition

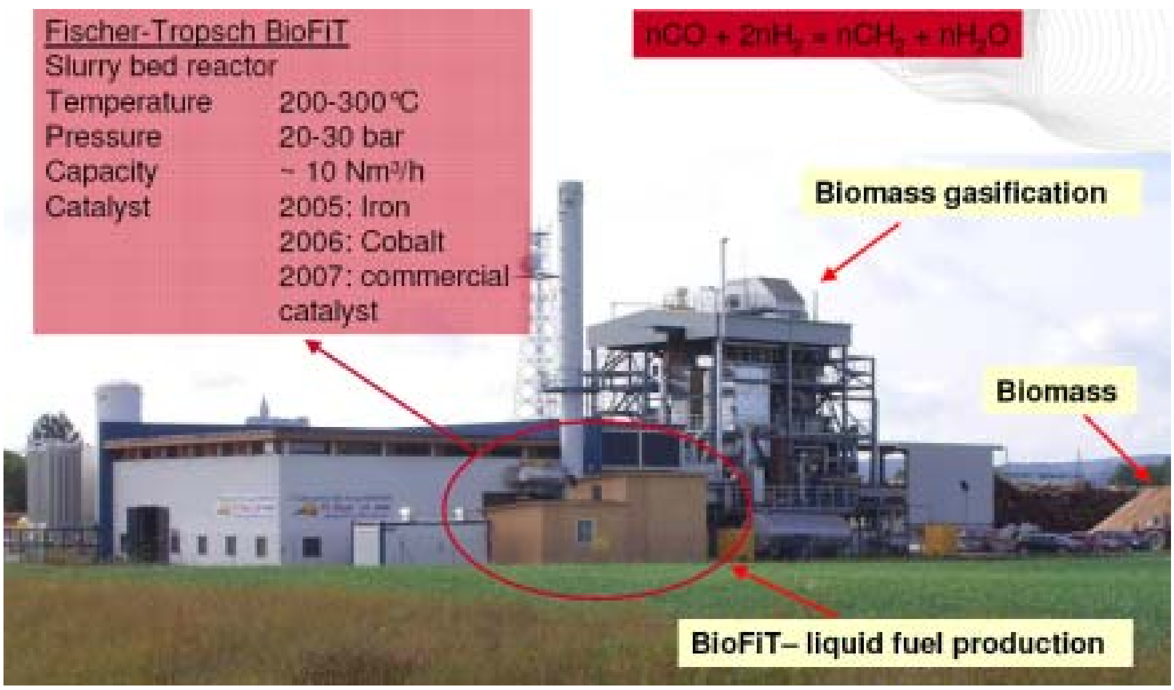


* Standardgasification

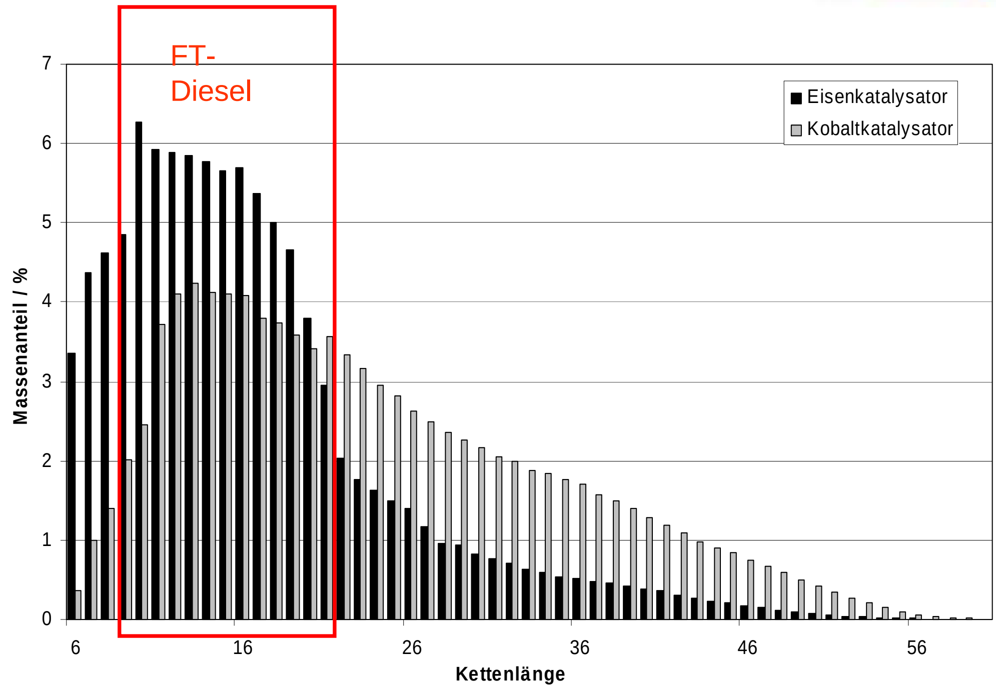
AER – Gas Tar Content



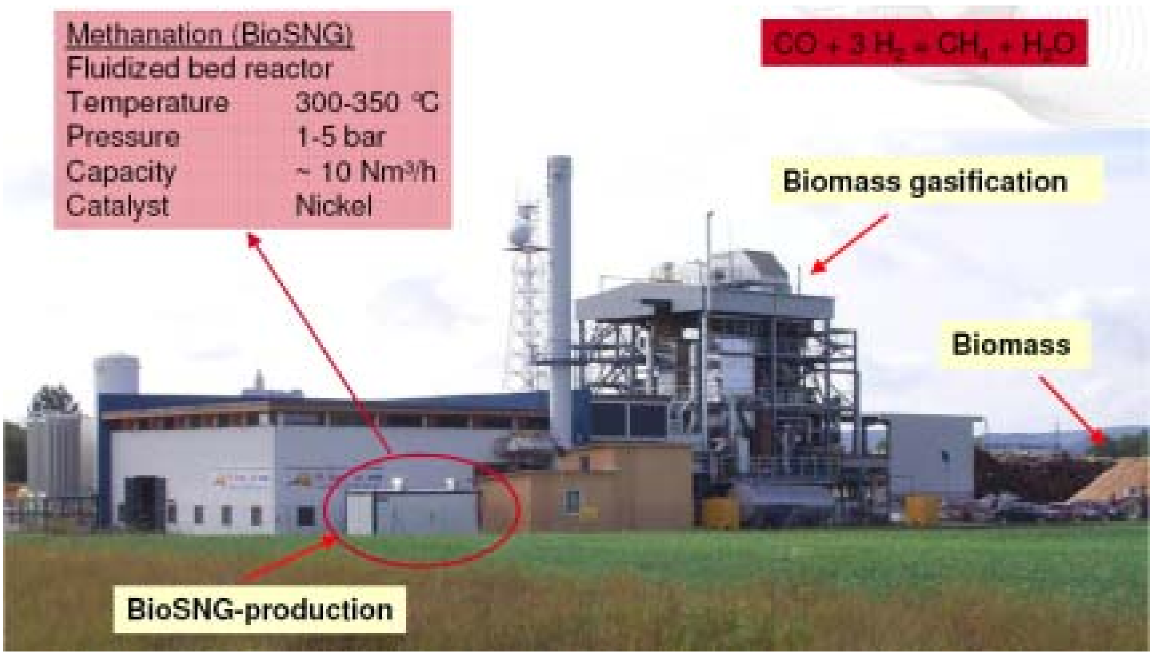
renew:
FT – Product Distribution



renew: FT – Product Distribution



Bio-SNG



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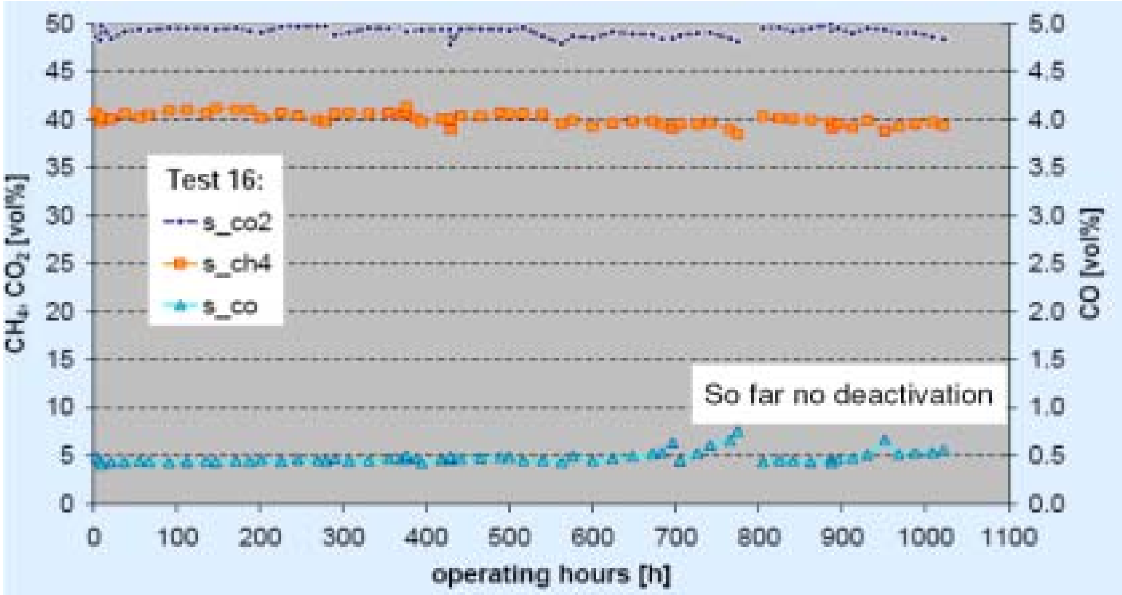
Bio-SNG:
long duration catalyst tests showed no deactivation



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Bio-SNG:
1 MW Demo Unit

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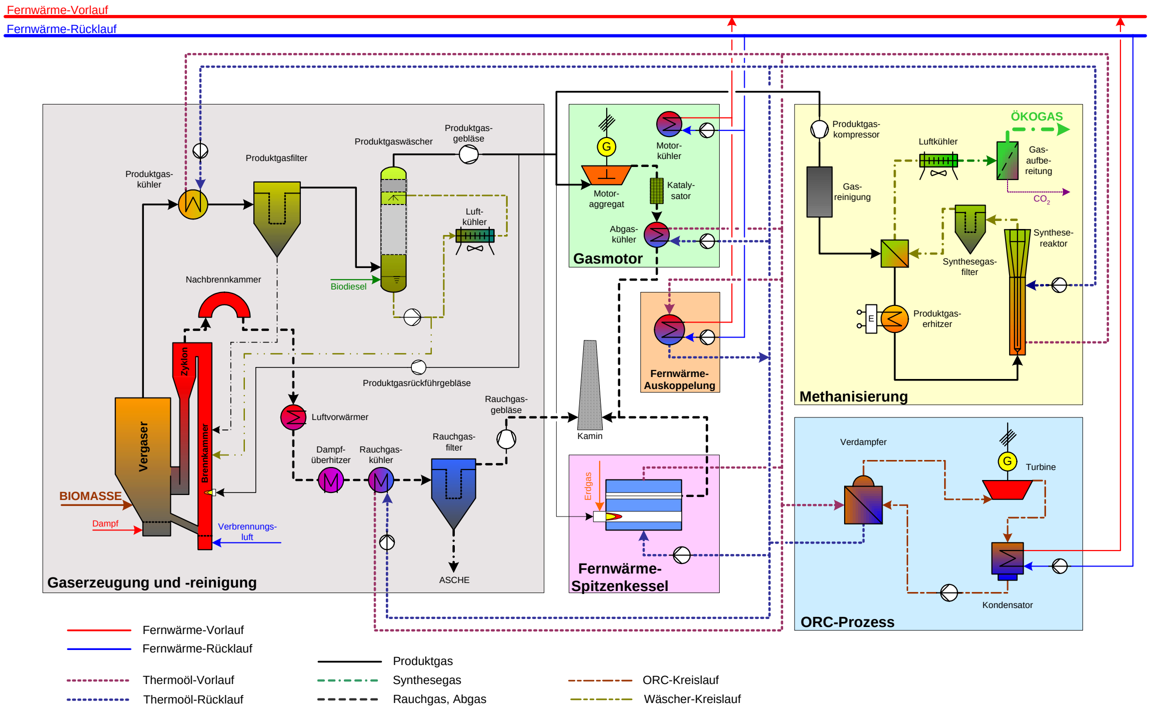
Tri – Generation Plant



29.06.2004 Tremmel H.

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REPOTEC – Renewable Power Technologies Umwelttechnik GmbH

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Gasification of Biomass and Waste Derived Fuels for Industrial Applications

Matti Nieminen, VTT

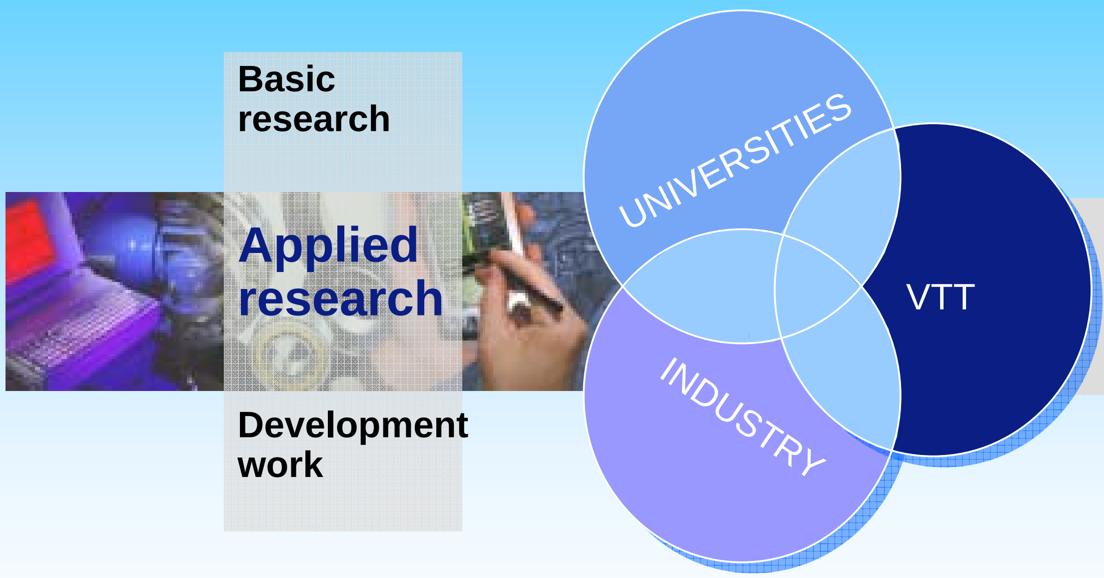
matti.nieminen@vtt.fi

Business from technology

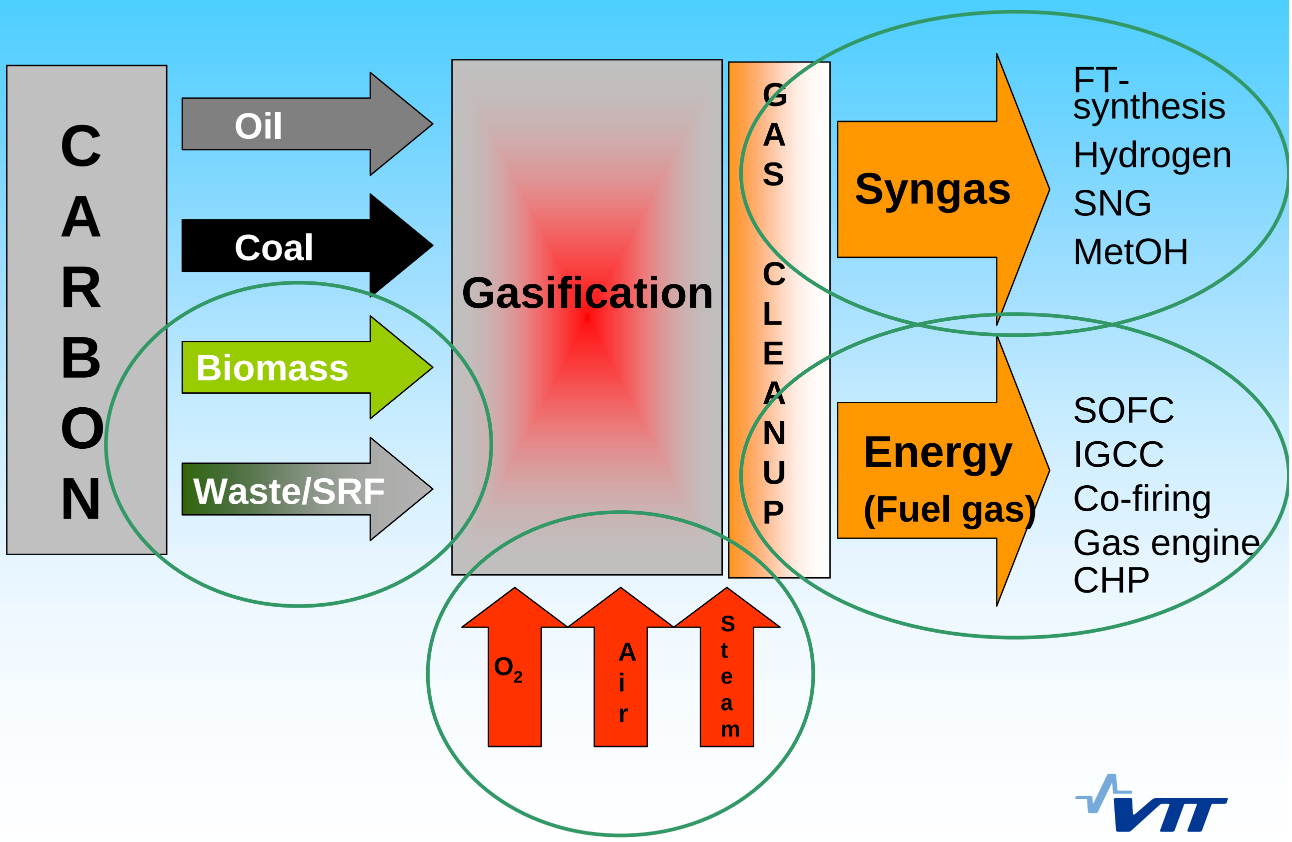
VTT (Technical Research Centre of Finland)

- impartial public R&D organisation
- active in the R&D field of gasification, gas cleaning and application of gasification based technologies
    - fixed bed gasification, fluidised bed gasification (both BFB and CFB)
    - gas cooling and cleaning, filtration
    - catalytic tar reforming
    - concept development
    - etc.

VTT's status as performer of R&D work



VTT TECHNICAL RESEARCH CENTRE OF FINLAND



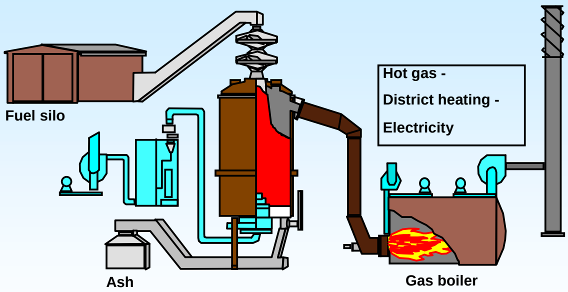
Drivers for Biomass and Waste Gasification

- High-efficiency power from biomass at small-to-medium scale
- Efficient utilisation of wastes and replacing of fossil fuels by biomass/waste derived gas
- Liquid biofuels, renewable methane or H2 for transport

UPDRAFT GASIFIER

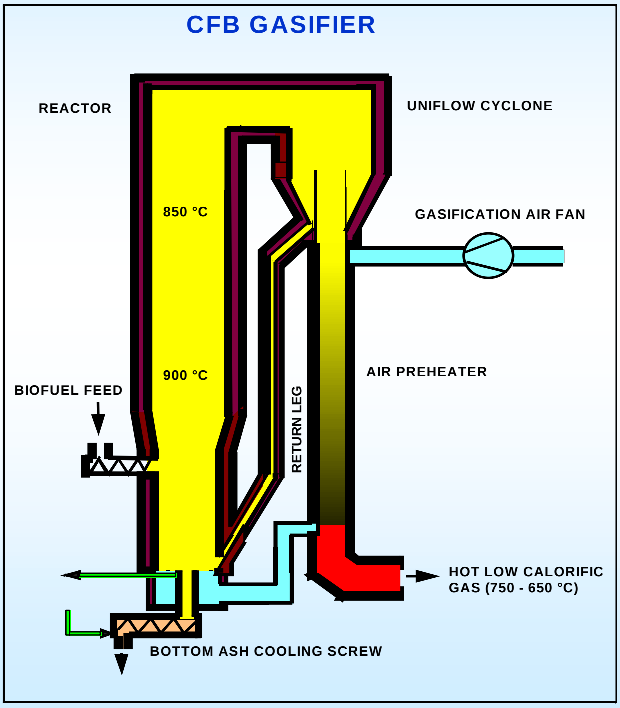
“BIONEER”

- developed in 1980’s, 10 plants
- for boilers and kilns, 5 MW scale
- tar containing gas
- high carbon conversion
- robust, flexible, fully automated



5 MW district heating plant, Jalasjärvi, Finland, in operation since 1987; 145 000 operating hours

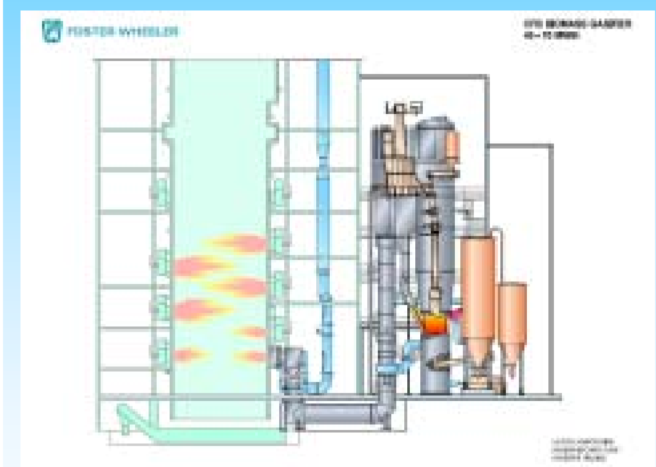
Atmospheric-pressure gasification for kilns and boilers

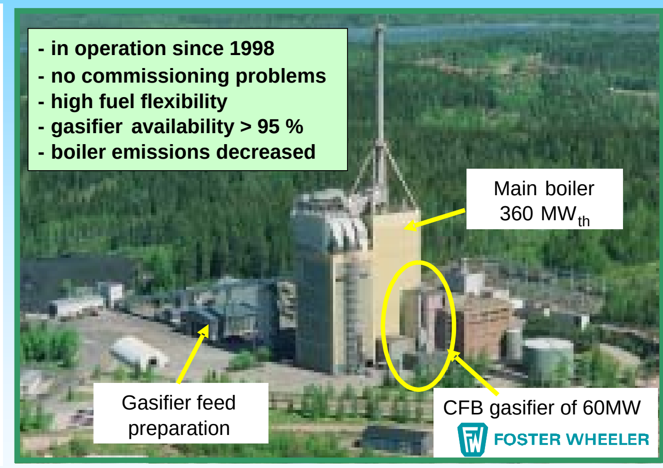


- Commercial lime-kiln gasifiers were constructed in 1980's by Ahlström Oy
- New development by Foster Wheeler in 1990's for boiler applications
- Gasifiers are now offered by
  - Foster Wheeler
  - Carbona/Andritz
  - Metso Power
- Feasible in size range 15-150 MW
- Fuel drying is often needed to achieve required flame properties

Efficient utilisation of wastes and biomass residues in existing power plants

A cost-effective way to reduce CO_2 emissions of power plants



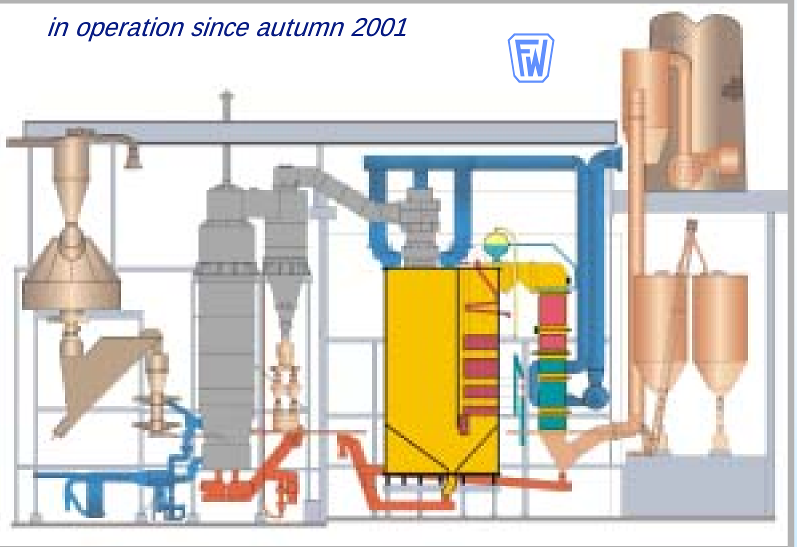


Corenso gasifier in Varkaus, Finland

- gasification of aluminium containing plastic reject material
- complete recycling of liquid packages (milk & juice packaging)
- 50 MW gas to boiler, 2100 t/year aluminium for re-use
- developed by VTT & Foster Wheeler Energia Oy in 1998 - 2000

Plastic reject material with 10 % aluminium

in operation since autumn 2001



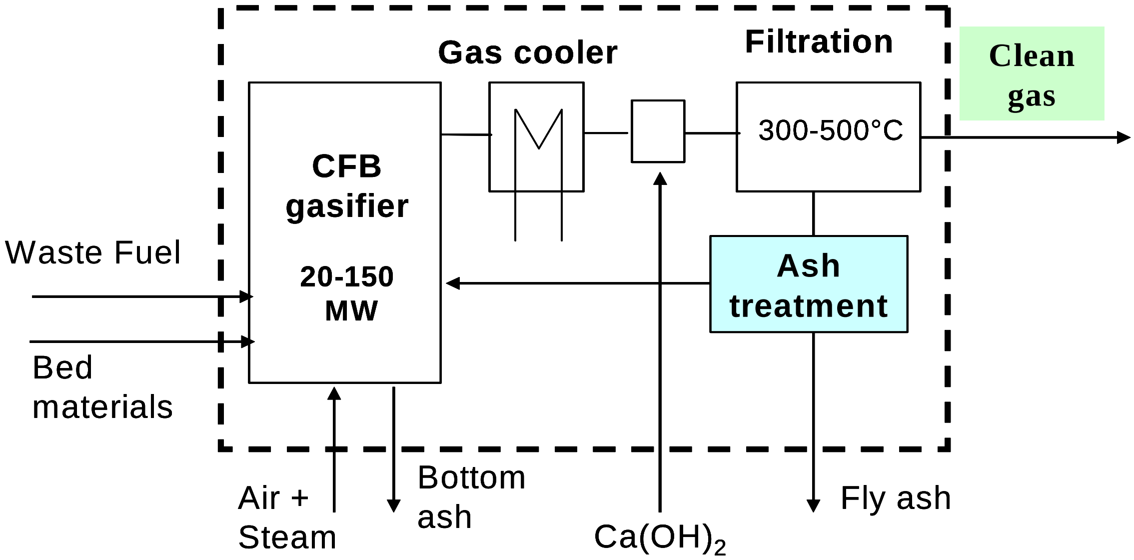
Gasification of biomass and waste containing harmful impurities

- co-firing in boilers or replacing of natural gas, oil or coal powder in industrial kilns
- fluidised bed gasification
- hot gas cleaning/dry scrubbing
  - chlorine
  - alkali metals
  - heavy metals
  - particulates

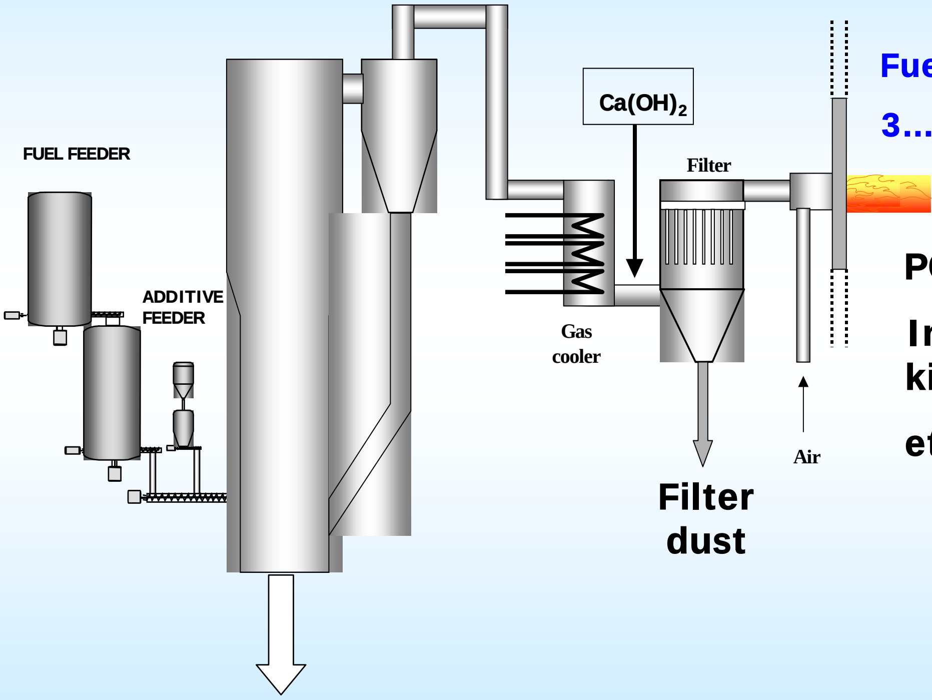
Fuels with need for gas cleaning

- **wheat straw**
- **demolition wood**
- **Solid Recovered Fuel (SRF)**
  - MSW derived fuel
- **industrial wastes**
- **sewage sludge**
- **plastic waste**
- **etc.**

Gasification process for high-alkali biofuels, demolition wood and RDF



Process concept



Fuel gas:

3…6 MJ/m³n

PC boiler

Industrial kiln

etc.

Potential filters/filtration systems

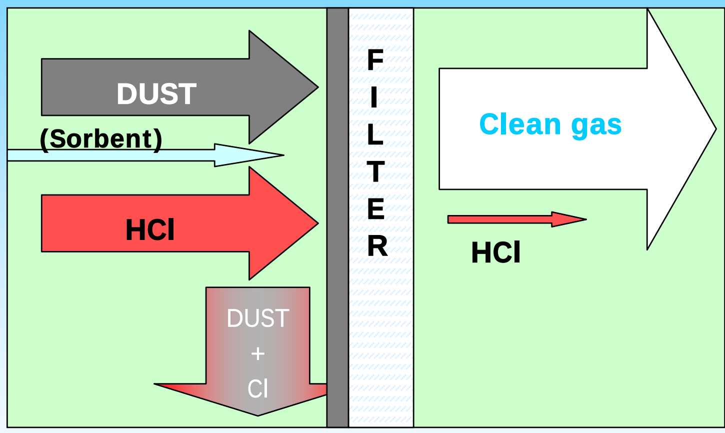
- Ceramic fabric filters
  - 3M/ FB 900, FB 700

- Rigid ceramic fibre filters
  - Madison filter / Cerafil
  - Tenmat/ Firefly
  - BWF/ Pyrotex KE 85
  - etc.

- Teflon bags… only in some specific cases (<250°C)

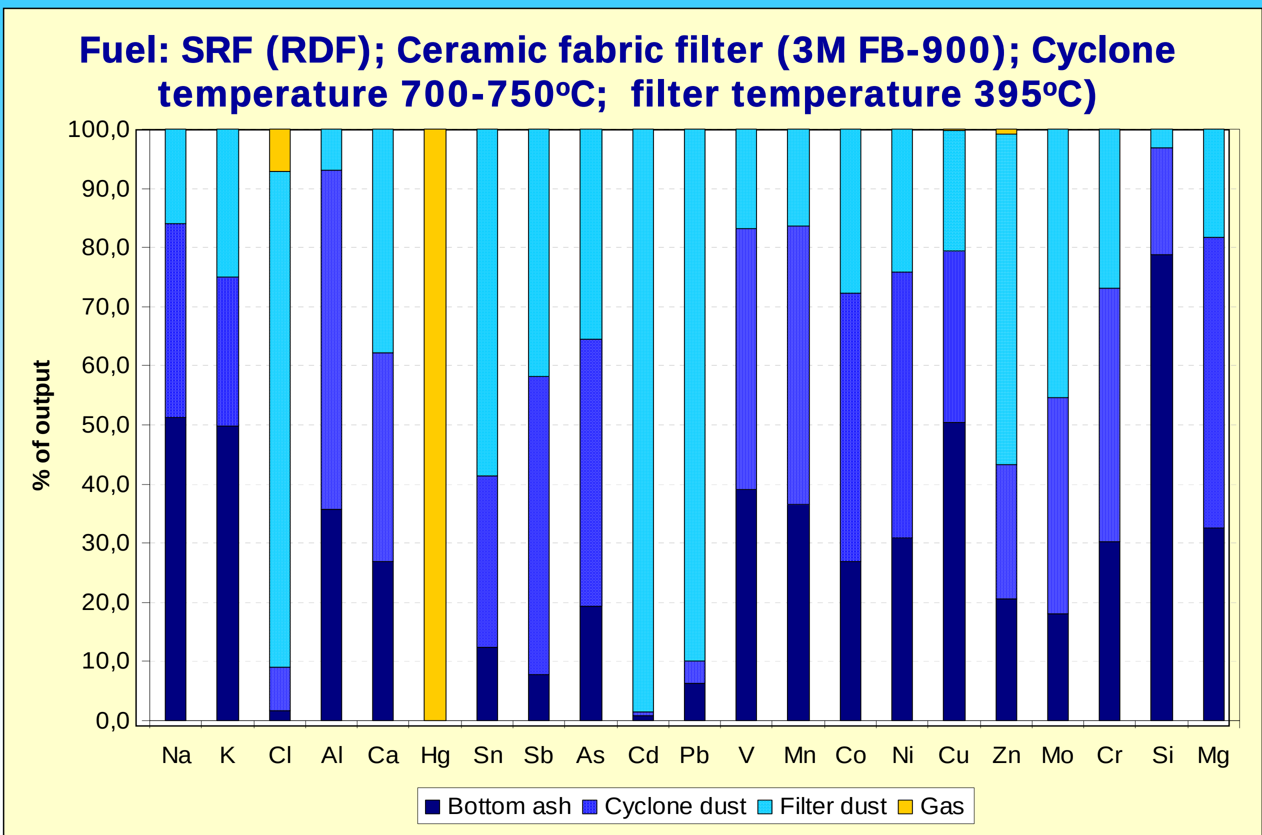
Removal of chlorine & heavy metals by barrier filtration

- **Filtration temperature range 150 – 800 °C**
- Depends on impurity to be removed, pre-reforming, filter media, etc.



Filter media

- Rigid ceramic or metal candle filters
- Rigid ceramic fibre filters (< 900 °C)
- Ceramic bag filters (< 400 °C)
- Teflon bag filters (< 250 °C)



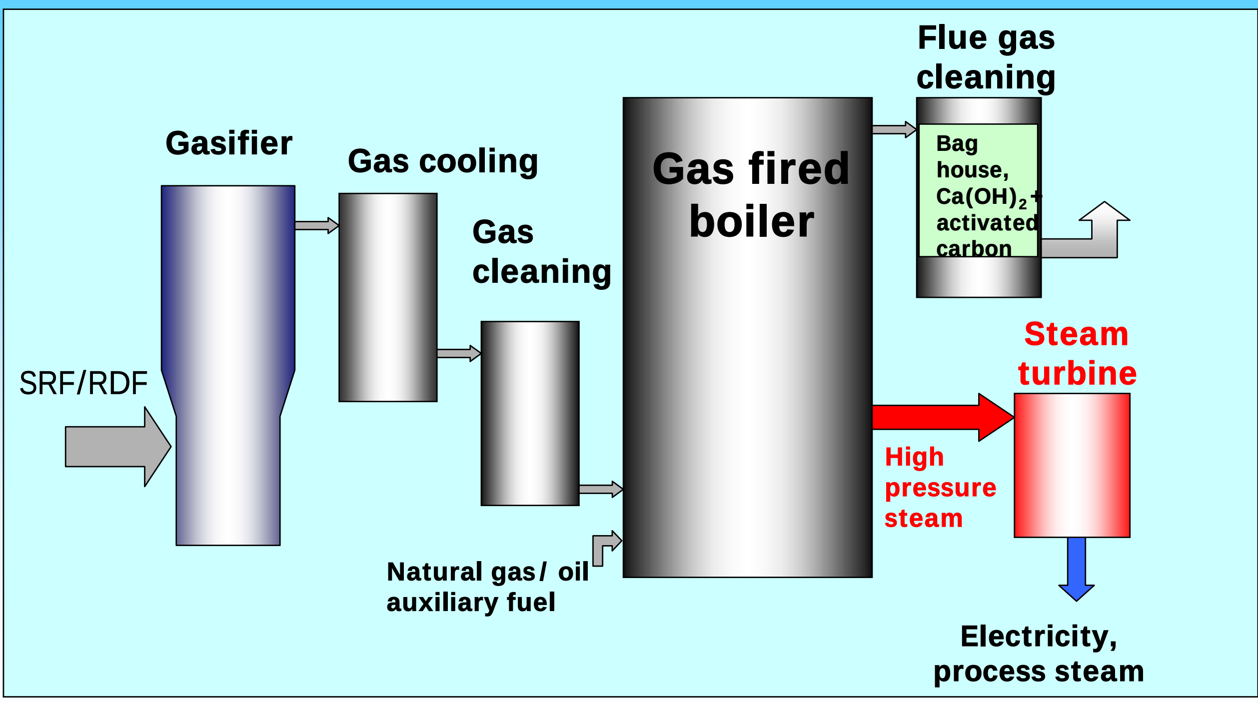
Alternative for conventional incineration: Gasification + Gas cleaning + Gas fired boiler + Flue gas cleaning

- Fluidised bed gasification of SRF/RDF
- Product gas cleaning
- Removal of (corrosive) Cl and ash components (metals)
- Clean gas fired in a gas fired boiler
- No fouling or corrosive impurities

=> High steam temperature & pressure

- High power production efficiency
- Feasibility well competitive compared to conventional incineration (mass burning)
- SRF/RDF production enables efficient recovery of metals and materials
- Fulfils all gas cleaning requirements set by WID

Lahti Energia WtE plant (plan)



Gasification & Gas Cleaning R&D activities at VTT

Gasification & gas cleaning test facilities of VTT

BFB + gas cleaning + gas fired boiler

- 1 MWth

CFB + gas cleaning (+ gas fired boiler)

- 300-500 kW

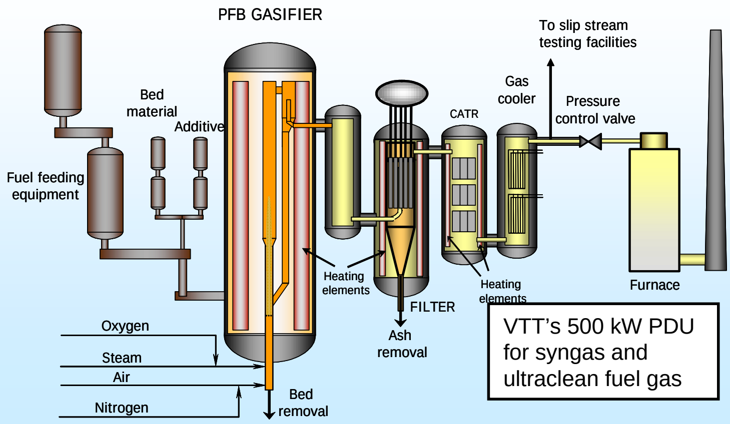
Advanced fixed bed gasifier + catalytic tar reformer + gas cleaning (+ gas fired boiler)

- 0.5 MWth

Several bench scale and lab scale gasification and gas cleaning test rigs

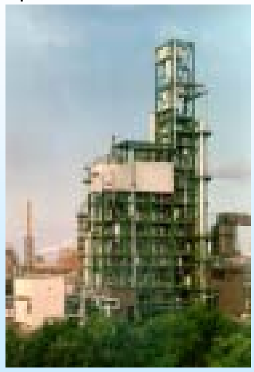
R&D Project: *UCG* Synthesis Gas from Biomass

- **VTT's UltraClean Gas project** (1.1.2004-31.5.2007)
  - VTT,TKK, Foster Wheeler, Neste Oil, Andritz, Vapo, PVO, UPM, StoraEnso, M-real, Botnia. Rintekno
  - pressurised gasification followed by catalytic reforming
  - 500 kW Process development Unit
  - studies for 150 – 400 MW plants integrated to pulp and paper industry
- **Industrial follow-up projects**
  - preliminary planning and design was made in VTT's UCG project in 2006-2007
  - demonstration in 2008-10 (lime kiln)
  - first commercial-scale FT-plant in 2012-14

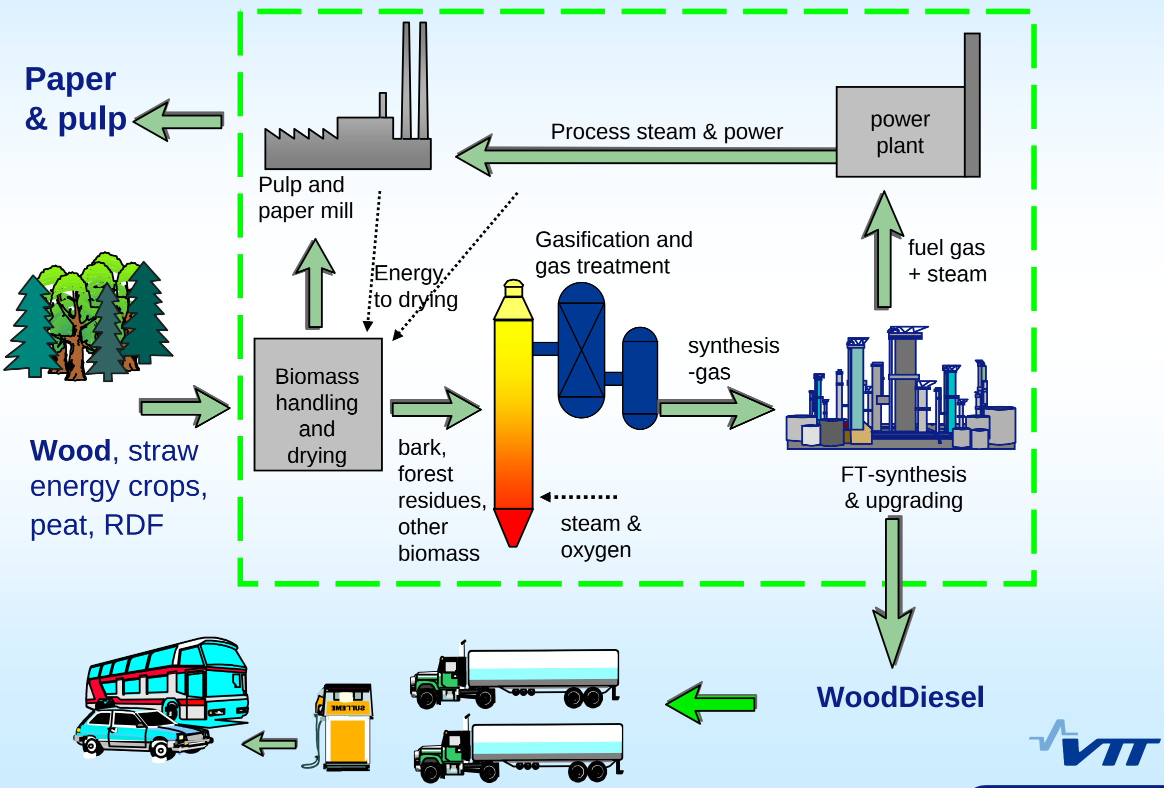


VTT's 500 kW PDU for syngas and ultraclean fuel gas

Kemira's peat ammonia plant in 1990



Integration of FT-synthesis plant to pulp and paper mill



R&D Project: UCGFUNDA 2008 - 2010
Biomass gasification for synthesis applications
- fundamental studies supporting industrial development

- VTT, TKK and Åbo Akademi, total budget 1.5 M€
- Financing by Tekes Biorefine, VTT and 7 private companies

- Biomass characterisation for pressurised steam/oxygen-blown gasification
- Filter blinding and catalyst deactivation studies
- Tar reactions in non-catalytic and catalytic processes (reforming-cracking-oxidation)
- New system studies on FT-applications
- Development of measuring methods for tars and other gas contaminants
- Follow-up of foreign R&D projects
- IEA groups: ”Biomass thermal gasification” and ”Biomass Hydrogen”

High Efficiency gasigication based WtE (Lahti)

- demonstration of gasification based high efficiency WtE technology (160 MW_{th})

- R&D related to further development of
  - gas cleaning; filtration, Hg removal
  - ash utilisation/disposal
  - development of new advanced WtE applications based on gasification
  - assessment of different advanced WtE technologies


VTT creates business from technology
Thank You
for Your attention

GoBiGas - is on track!

SGC Gasification seminar October 2008

Ingemar Gunnarsson, Göteborg Energi AB

Göteborg Energi

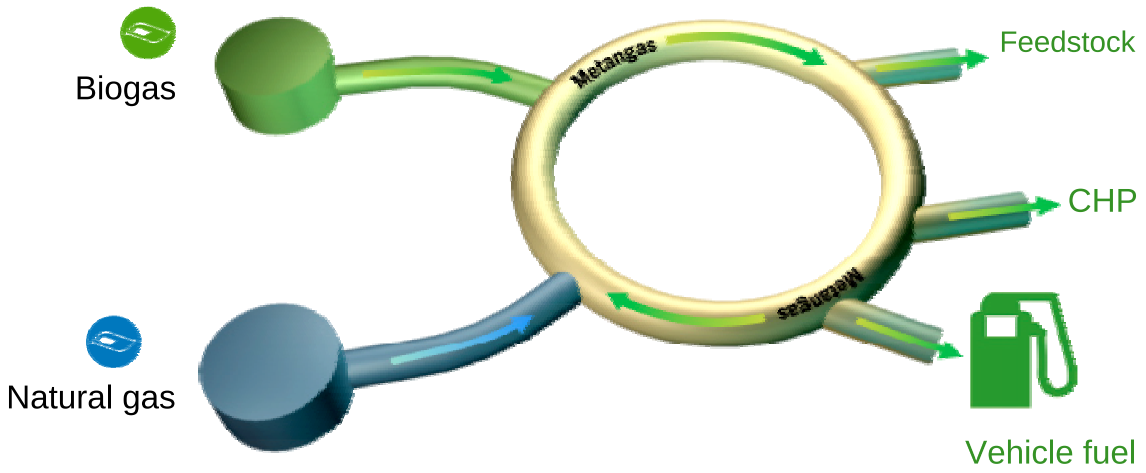
Biogas in Göteborg perspective

Fulfilling our vision:

Göteborg Energi shall actively contribute to the development of a sustainable society in Göteborg

Göteborg Energi

"Green gas concept"

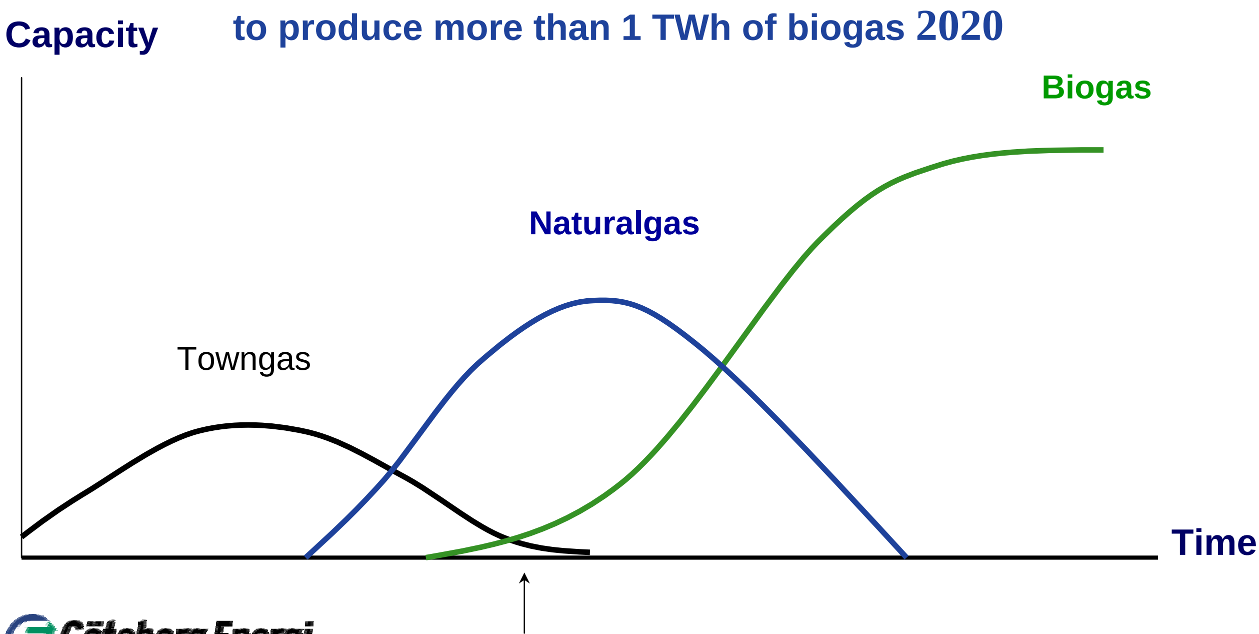


Göteborg Energi

Our vision is to only offer biogas in the future

GoBiGas is a big step towards our short term goal

to produce more than 1 TWh of biogas 2020



Göteborg Energi

GoBiGas

Gothenburg **Bi**omass **Gas**ification Project

•**Gasification of biomass** and production of biomethane

•**Commercial scale** – approximately 100 MW gas - with the potential of producing 800 biomethane GWh per year

• **High-calorific gas** (SNG) by methanation for distribution in the existing gas grid

•Also possible to use the gas as **fuel in Rya CHP-plant**

•Situated **in the harbour of Gothenburg** with the potential to transport fuel by boat or train

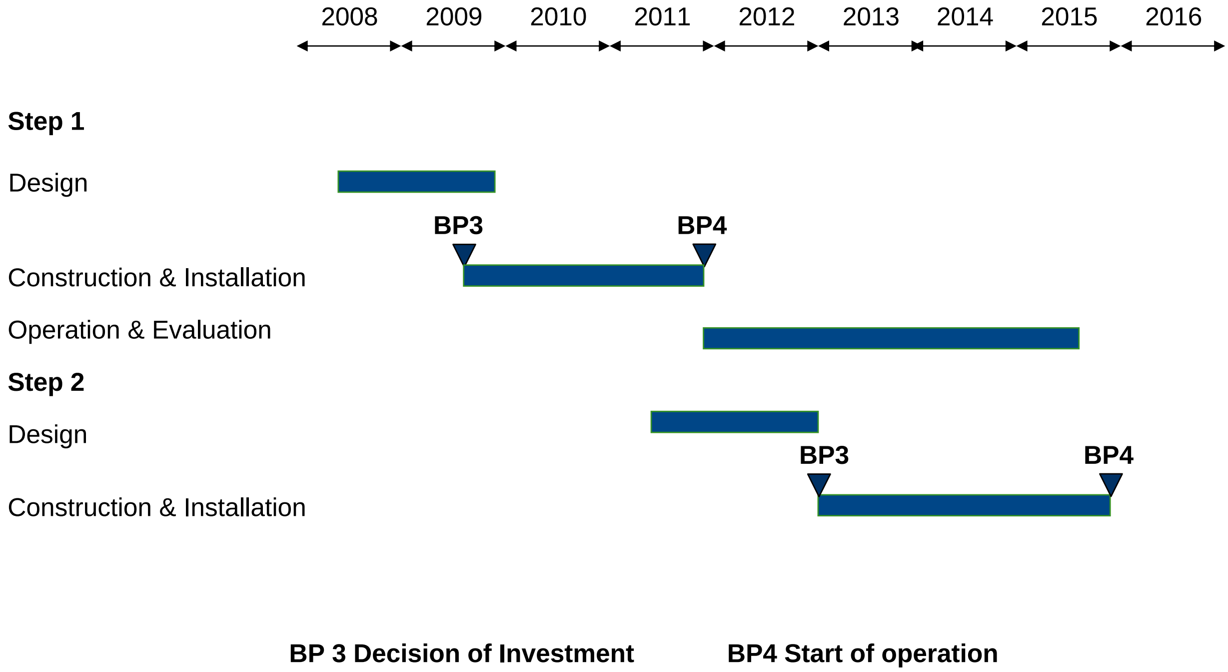
Göteborg Energi

Performance goals

- Biomass to gas efficiency 60-70 %
- Energy efficiency 90%
- Operation 8000 h/year

Göteborg Energi

GoBiGas - Main Time Schedule



Göteborg Energi

Current situation and ongoing activites in GoBiGas

- In February 2007 the board of Göteborg Energi decided to support the GoBiGas-project and in May 2008 a preliminary investment decision was made.
- An evaluation of technical solutions resulted in the selection of allothermal gasification was selected.
- Basic design of gasification/methanation plant 20 MW gasproduction (stage 1) from Zander/Repotec/CTU
- We apply for permits that will be available during spring 2009
- Supply of biomass - pellets and bark will be evaluated
- Funding from EU and Swedish government is discussed

Göteborg Energi

Cooperation with E.on

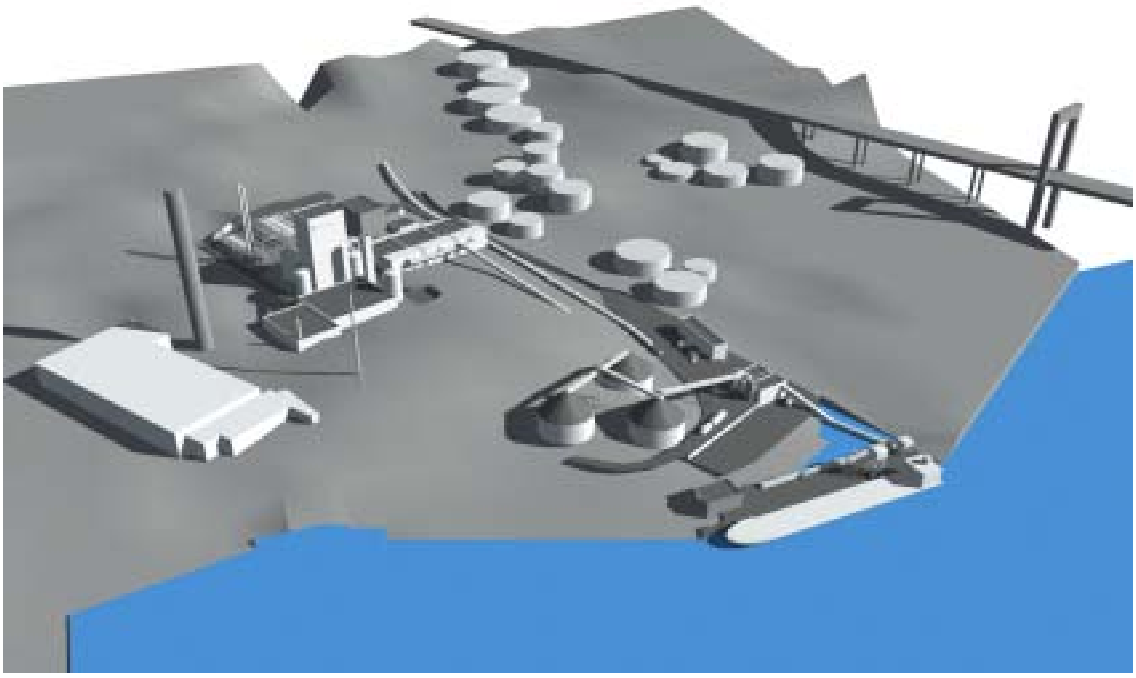
- E.ON will support the GoBiGas project with a share of 20%
- E.ON will be a active partner in the project
- E.ON, Göteborg Energi and possible other partners will put up a company which will build and run the GoBiGas plant.

Göteborg Energi

Site Location

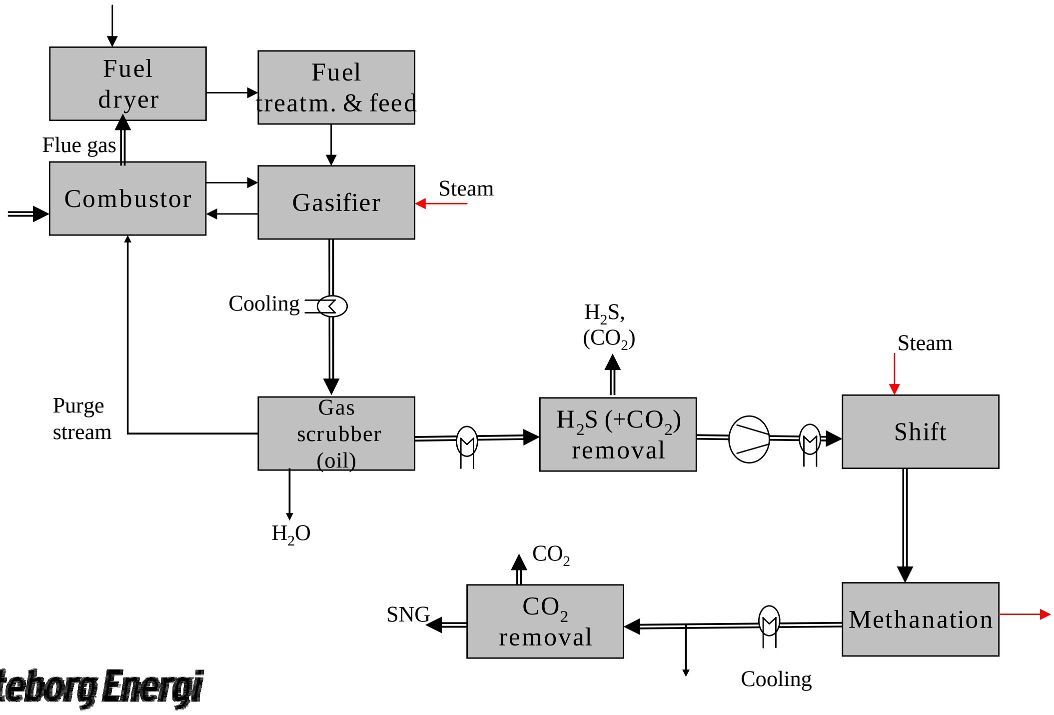
Göteborg Energi

Göteborg Energi

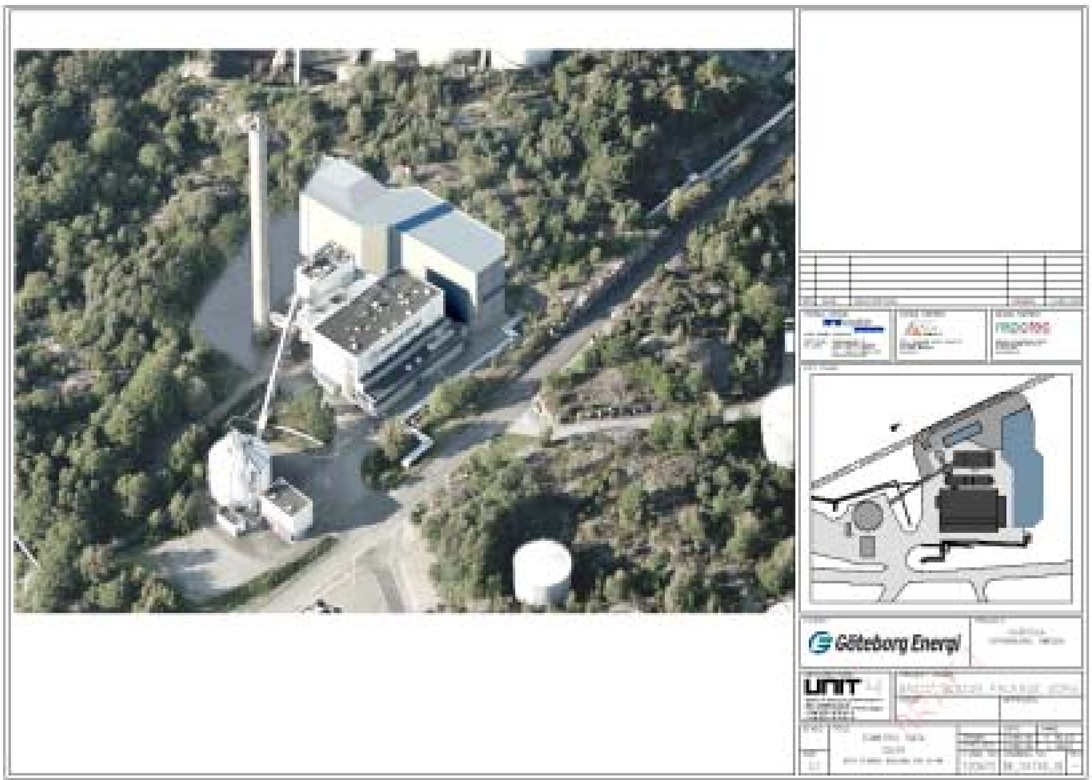


Göteborg Energi

Allothermal gasification

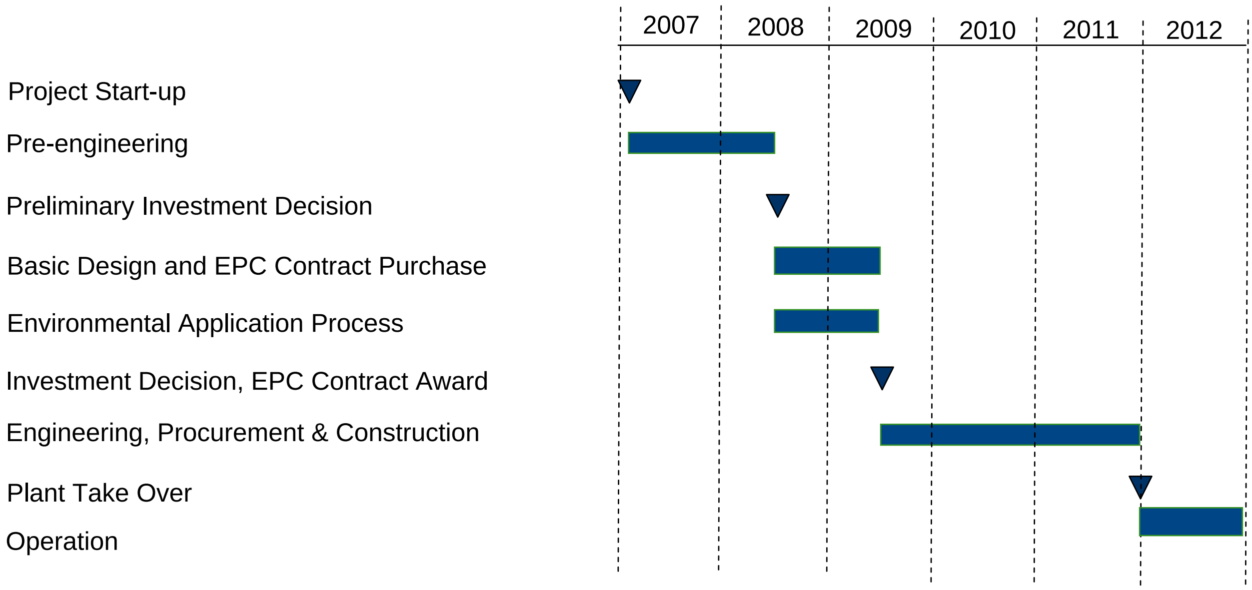


Göteborg Energi



Göteborg Energi

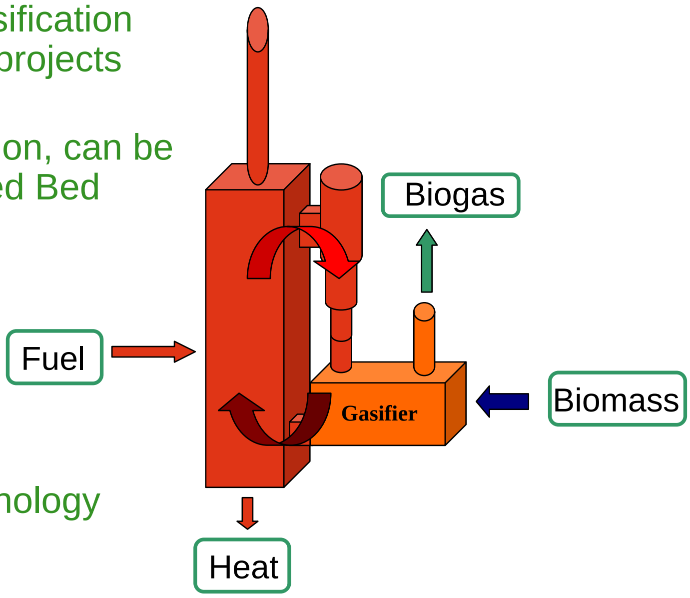
GoBiGas stage 1- Time Schedule



Göteborg Energi

Pilot: Gasification of biomass at Chalmers University of Technology

- Built to further develop indirect gasification and grow local expertise for future projects
- Large potential for commercialisation, can be added onto any Circulating Fluidized Bed (CFB) furnace
- Currently producing 2 MW of ”green gas” now being utilised in existing boiler
- Development of methanation technology would allow for local production of biomethane for e.g. vehicle fuel



Göteborg Energi

Some observations and conclusions concerning the current situation

- Further development and demonstration is needed
- There are for the moment few companies that can deliver and a lot of engineering capacity occupied by other projects.
- Downscaling from coal or upscaling of new technology is a question.
- The interest is growing both among commercial Companies, Universities, Politicians and other Decision makers
- Time is short – a lot has to be done!
- Who will take the opportunity and the risk to develop the technology of tomorrow?

Göteborg Energi

Vision for the future – GoBiGas

Göteborg Energi


Thank you for listening!

Towards Commercialisation of Biomass Gasification

SGC Gasification seminar October 2008

E.ON Sverige Göran Tillberg

My name is Göran Tillberg from E.ON Sverige AB

Co ordinator within the E.ON Group of R&D activities in Bioenergy

With focus on the following areas

- Fermentation
- Combustion
- **Gasification**
- Biomass (Raw material)

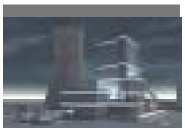
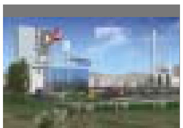
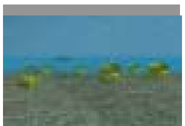
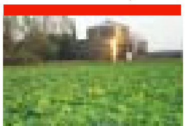
E.ON Group

- Focus on our core power and gas business and our target markets: Central Europe, the United Kingdom, Northern Europe and the Midwestern US
- Sales of just under € 69 billion
- Around 88,000 employees
- 30 million customers
- Headquarters in Düsseldorf, Germany
- 2007 a new Market Unit E.ON Climate&Renewable was established to increase focus on renewables

E.ON's R&D strategy focusing on key technologies bundled under the innovate.on umbrella

innovate.on
efficient ecological energy

Gasification and Fermentation

Future Fossil Fuel Power Plants		Renewable Energy			Efficient Energy Applications
					
High Efficient Coal Power Plant	Carbon Capture Storage	Tidal Energy	Wind Offshore	High Quality Biogas	Gas Heat Pump

We are confronted with a couple of challenges that requires investment in new technologies like Gasification

- Increased energy need
- Increased prices on today's feedstock fuels
- Increased need of using renewable sources of feedstock fuels
- Keep competitive consumer prices
- Continuous protection the environment

Gasification of biomass is a promising technology but the technology is not commercial today

E.ON Sverige therefore decided to perform a feasibility study to investigate under which conditions E.ON might invest in commercial plants for thermal gasification

The study was performed during 2007

One base in the Feasibility study was our experience from gasification of biomass from the establishment in Värnamo (6 MW_{el}, 9 MW_{heat})

- The test program was finished in October 1999
- More than 3600 hours continuous running
- About 8500 hours of tests
- No negative effects on gasification, filter or gas turbine

The results from Värnamo shows that gasification works

The study covered economical analysis and technology as well as siting and fuel supply

Analysis

- Profitability assessments
- Risk evaluation with regard to economics, the environment and technology.

Technology

- Involved identifying and evaluating various technologies and specifying development requirements and opportunities.

Siting

- Involved strategies and supporting documentation for the application processes for both the demonstration facility and future commercial facilities.

Fuel supply

- Involved logistics and costs for supply of the demonstration facility as well as future commercial facilities.

The result of the feasibility study showed on a potential for gasification plants – IGCC and SNG - in Sweden of somewhat more than twenty plants for the period up to 2025

IGCC already demonstrated in Värnamo but….

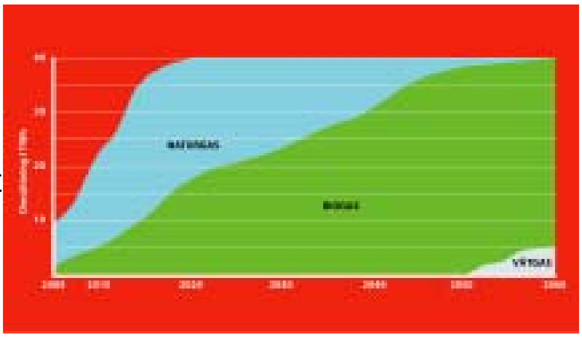
…the technology for biogas (SNG) production has to be demonstrated in an industrial scale before commercialization

Target 2020 for biogas is ambitious

Vision 2020 is 20 TWh of Biogas

Out of these 20 TWh it is assumed that

10 TWh to be gasification

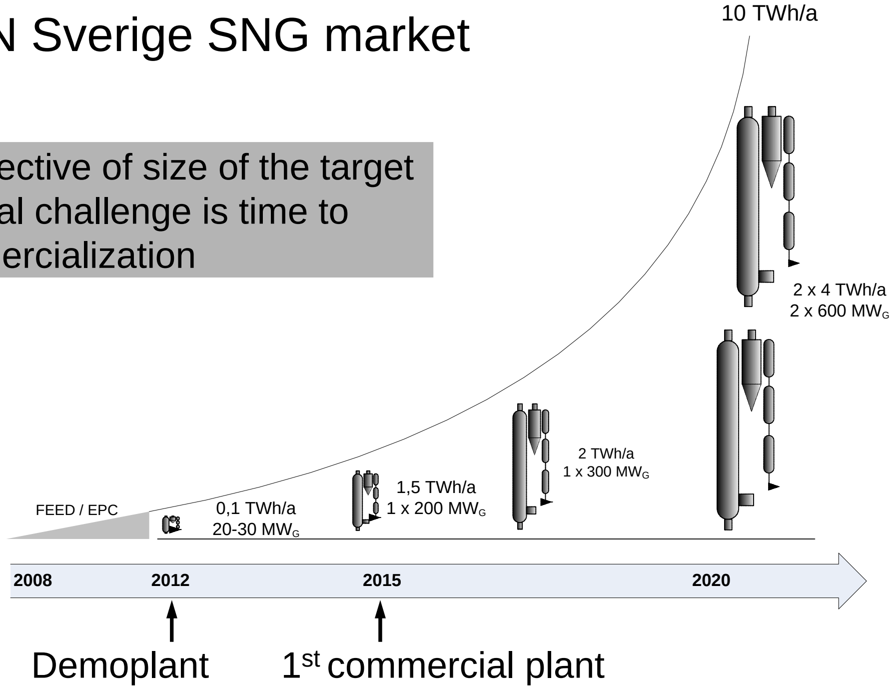


The rest will be

- 6 TWh to be fermentation
- 4 TWh to be Combinate

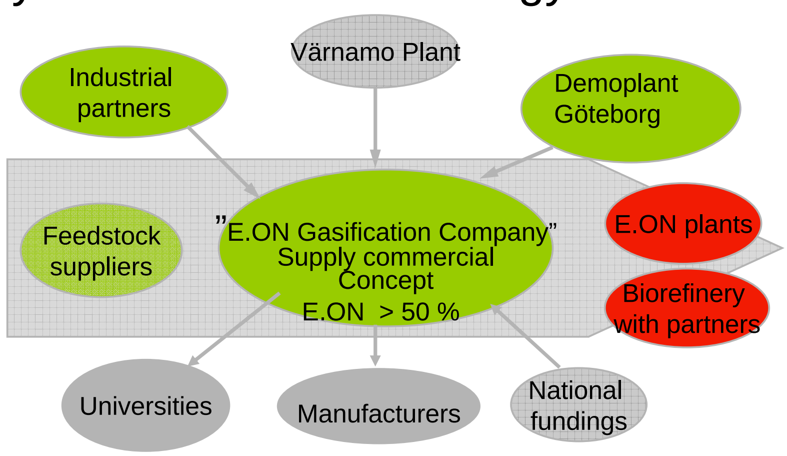
Commercialization route for Gasification E.ON Sverige SNG market

Irrespective of size of the target the real challenge is time to commercialization



Potential in Europe considerably bigger

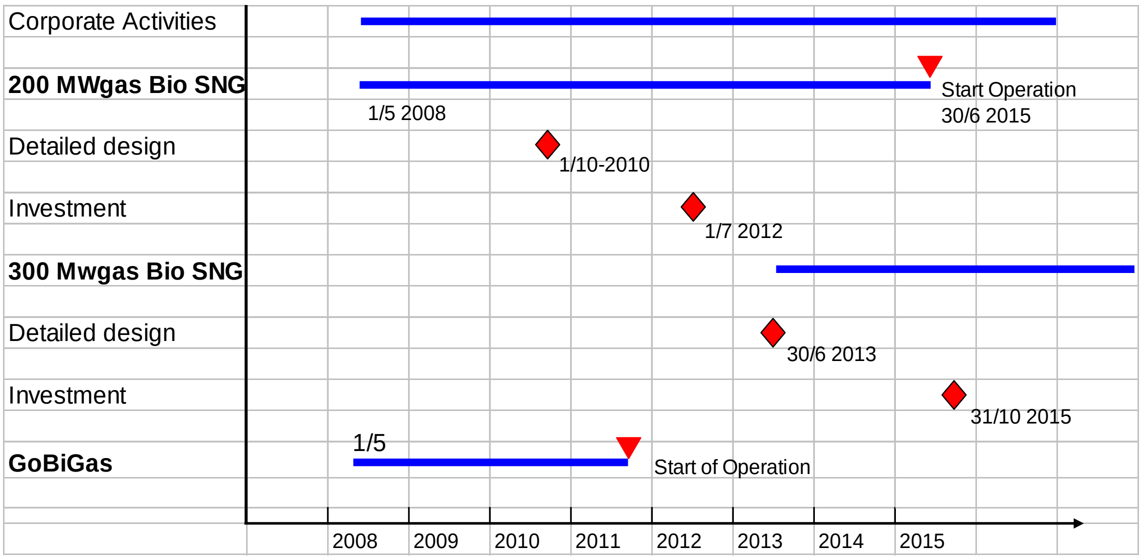
We have established E.ON Gasification Development Company to realize the technology



Purpose Gasification Development Company

- Know how build up by active participation in gasification projects
  - Partner in the Gothenburg project GoBiGas
- Industrial partners will be invited as shareholders
- Design and engineering of the first commercial plant – 200 MW_{gas}

E.ON Gasification Development Company - Time Schedule



Gasification is promising but requires big efforts to be commercial

The real challenge is not to get the technology working but to get

- Access to raw material at acceptable price level
- Develop a technology that make the technology competitive with alternatives

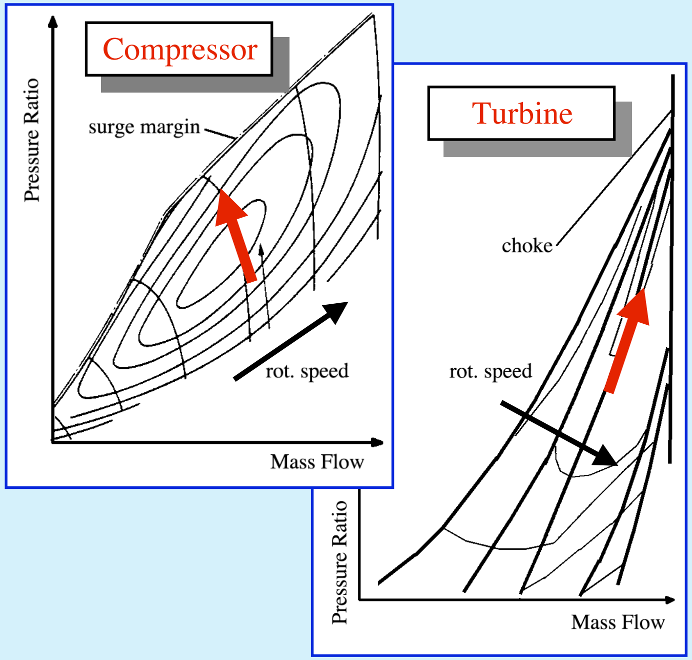
Therefore the

- Cost and risk for development needs Governmental support

E.ON are willing to take responsibility for the development but would welcome co-operation with industrial partners

Use of Biomass in Gas Turbines: Requirements and Challenges

International Gasification Seminar



October 9-10, 2008

Malmö, Sweden

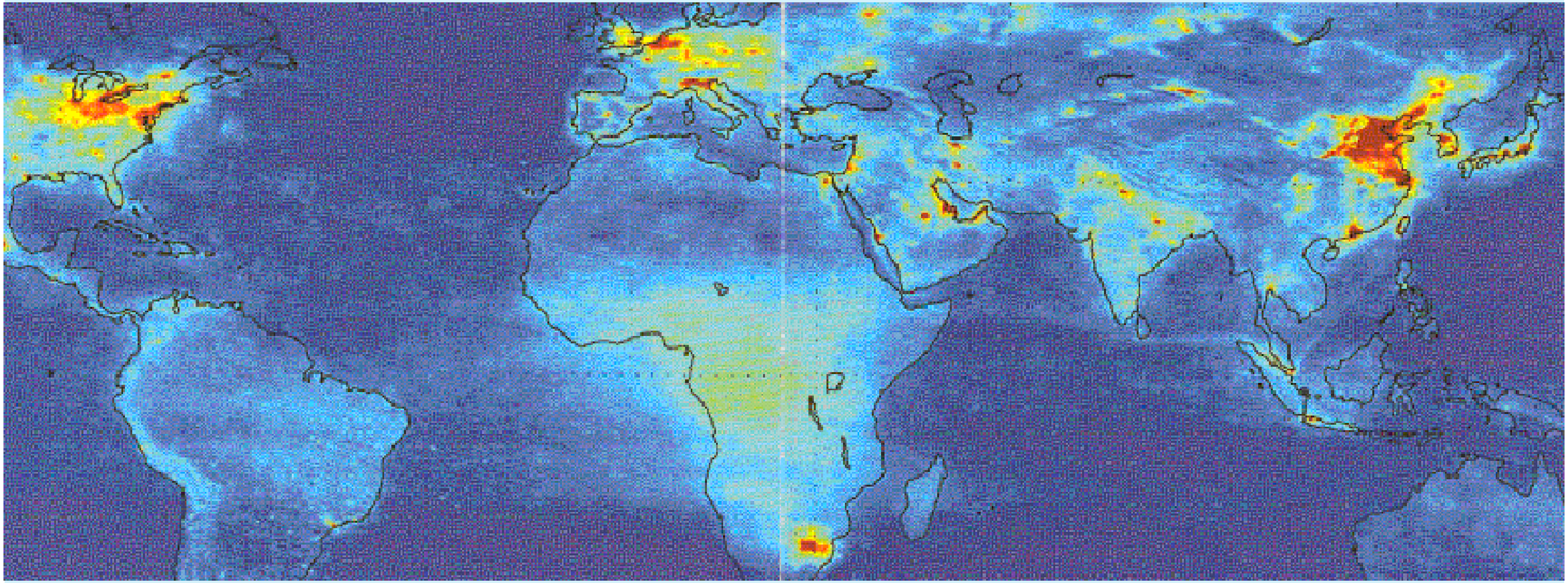
Univ.-Prof. Dr.-Ing. D. Bohn

Institute of Steam and Gas Turbines, RWTH Aachen University, Germany

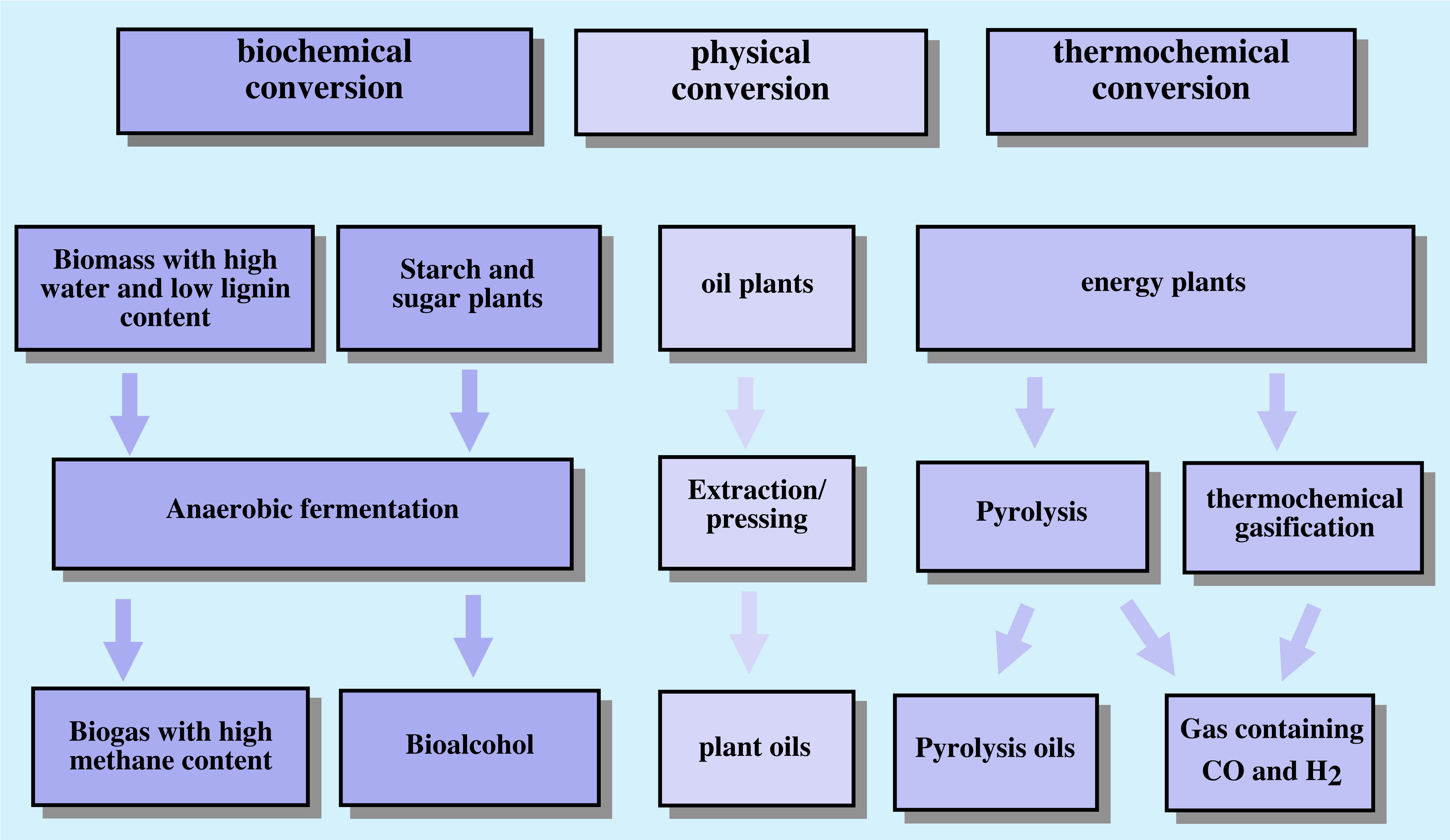
Outline

- Introduction
- Gas Turbines for Low-BTU Fuels
- Influence on Gas Turbine Components
  - Combustion Chamber
  - Compressor
  - Turbine
- Case Study: Micro Gas Turbine Operation
- Summary and Outlook

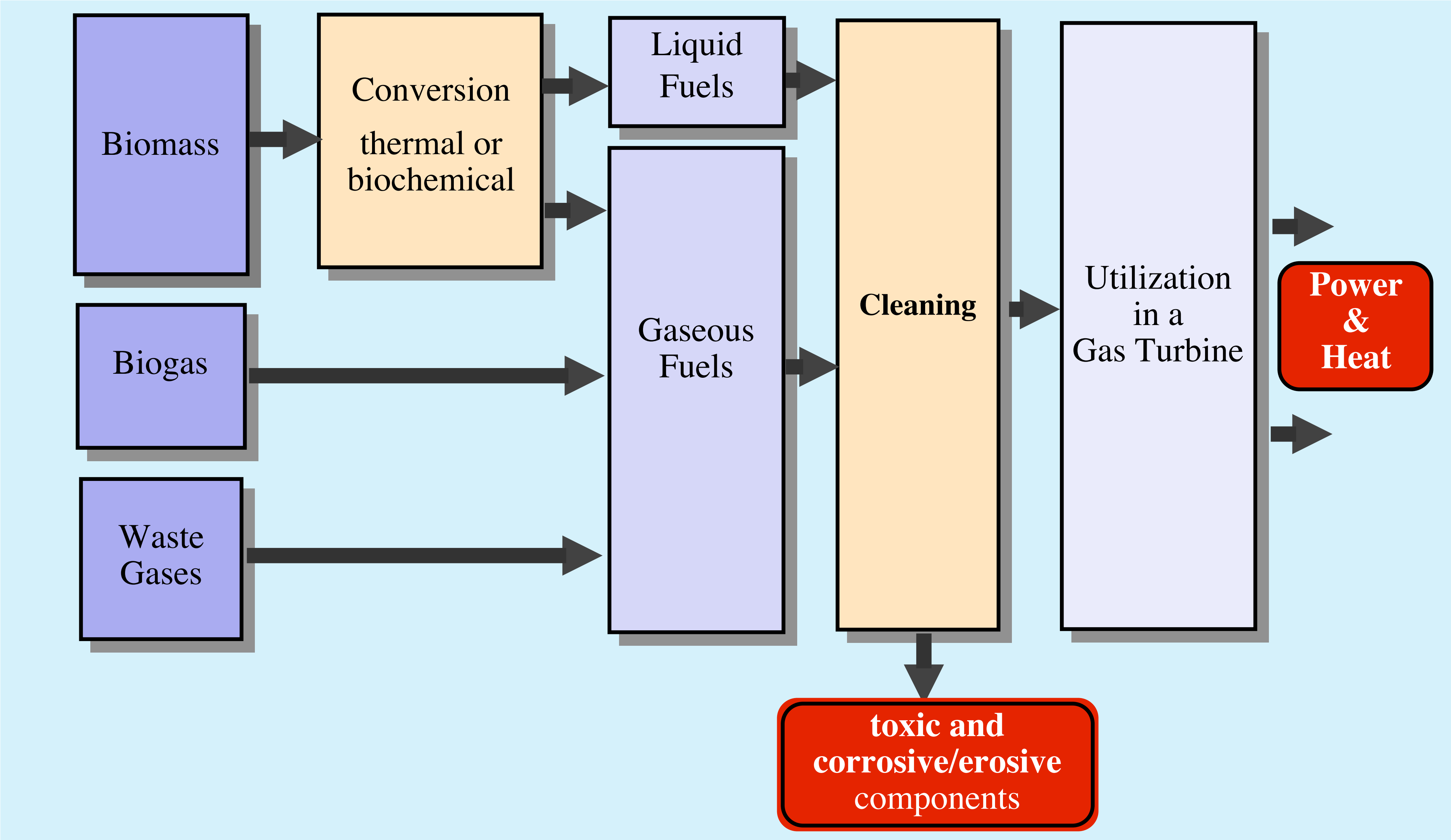
World Wide NO_x-Concentration



Biomass Conversion Methods



Utilization of Low-BTU Fuels in Gas Turbines



Application of gas turbines for the energetic use of low-BTU gases

Advantages:

- automatable
- low-maintenance
- high availability and reliabaility
- low emissions (esp. compared to gas engines)
- low investment costs
- high power density
- high fuel utilisation with cogeneration, high-quality waste heat (e.g. dehydration, process steam, district heating)

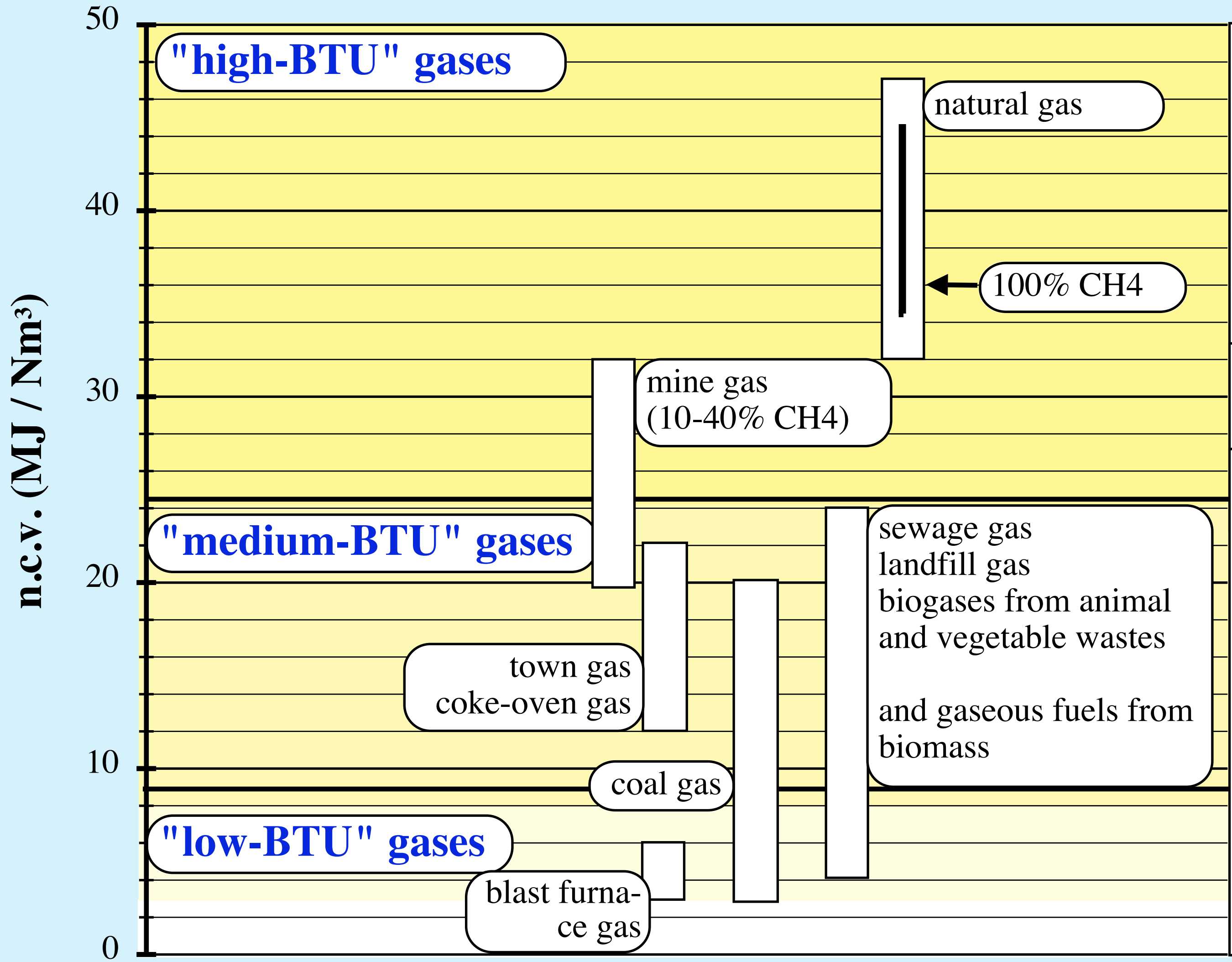
Disadvantages:

- low electrical efficiency compared to gas engines in single cycle (ca. 25% for power outputs below 10 MW), but high potential for efficiency increase by process optimisation (recuperation, intermediate cooling etc.)
- unfavourable part-load characteristic (single-shaft)

RWTH Aachen IDG LVS

Firing of Low- and Medium-BTU Gaseous Fuels in Gas Turbines

Gasification
October 9-10
Malmö, Sweden



applicability of standard gas turbines

Control adjustment

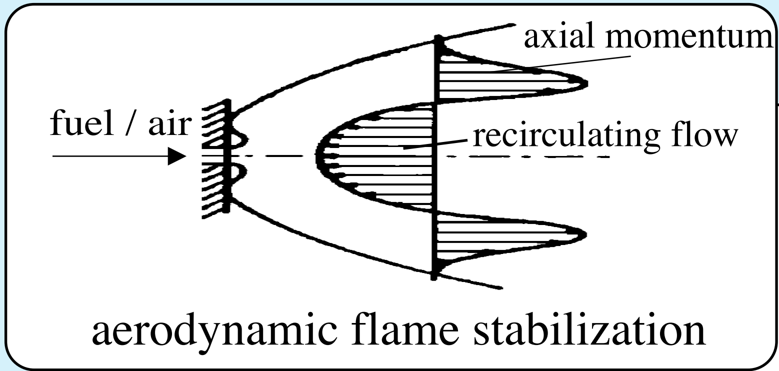
Modified combustor
New fuel injectors
New control

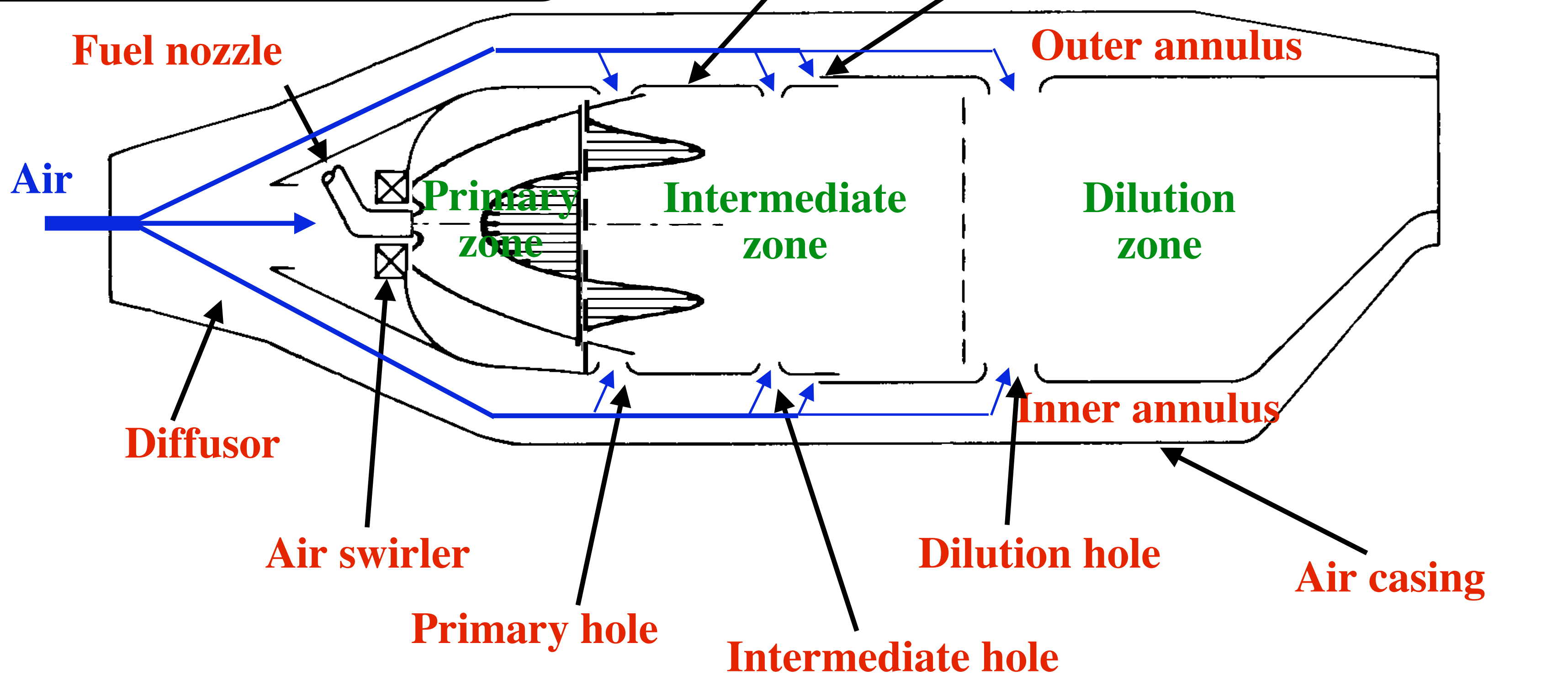
Start-Up and Shut-Down with "high-BTU" gases

Adaption of turbine and compressor to increased mass flow:

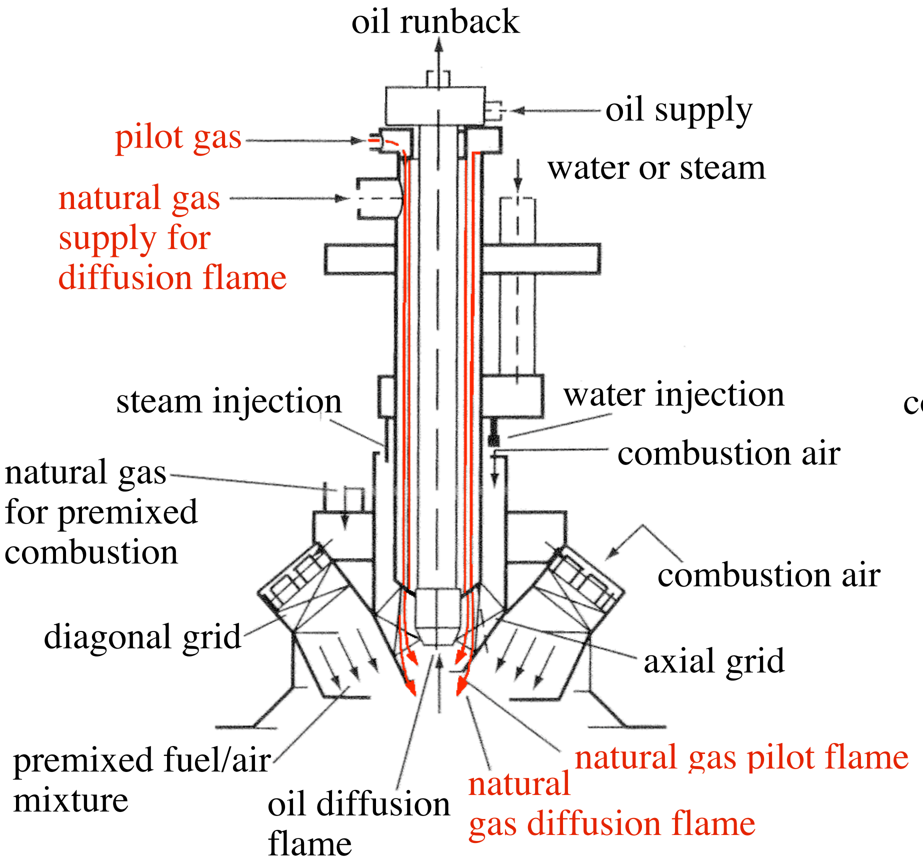
- **Opening of the first guide vane of the turbine**
- **Supply of the compressor with an inlet guide vane**

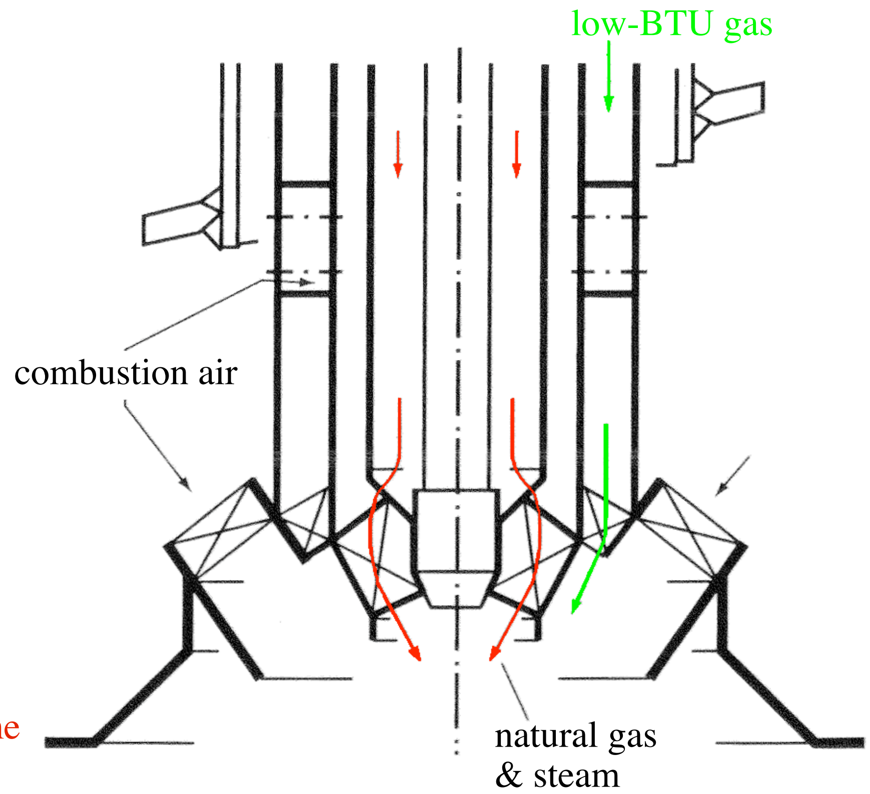
Basic Design of Gas Turbine Combustion Chamber





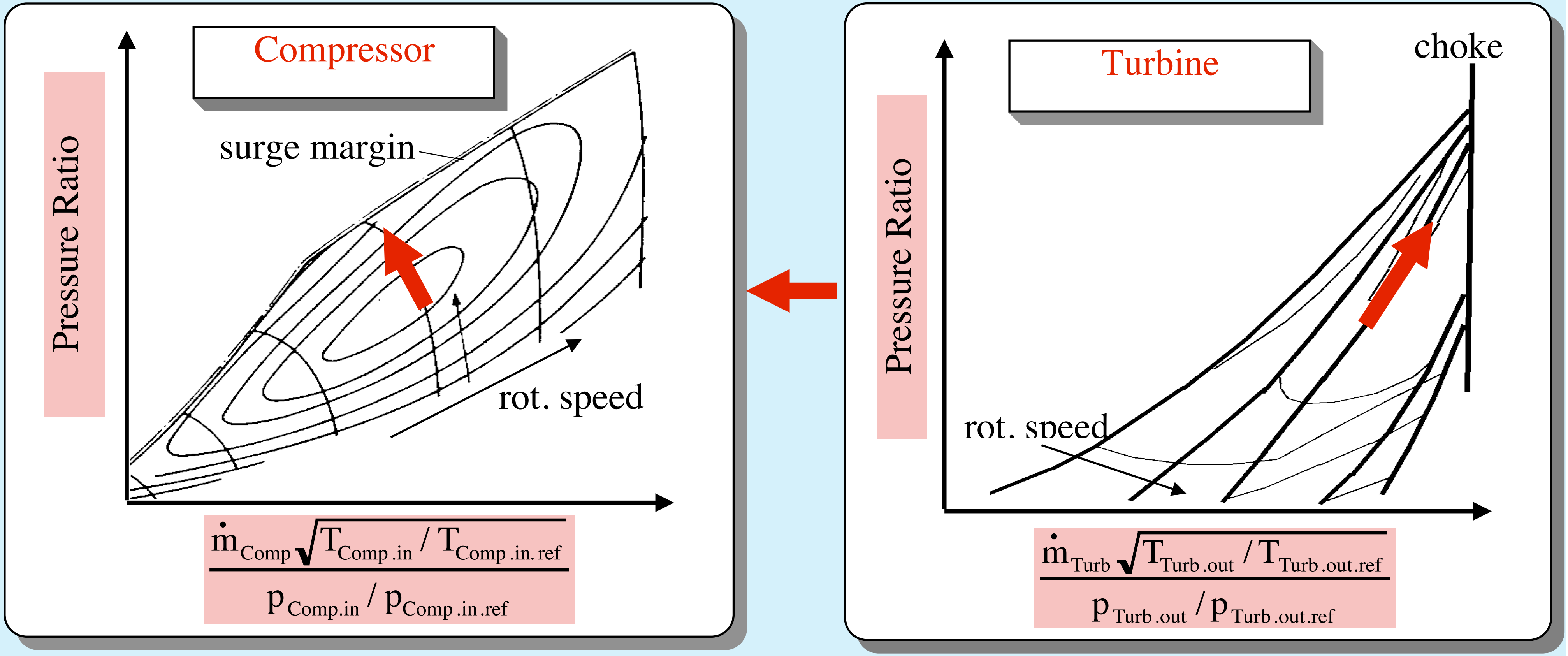
Influence of Use of Low-BTU Gases on the Burner





- No change of the fuel system required if Wobbe-Index $WI = \sqrt{\frac{\rho_{air}}{\rho_{fuel}}} \cdot H_u$ differs less than 10% from normal fuel
- Changes in viscosity and spray characteristics have to be taken into account

Influence of Low-BTU Gases on the Operating Characteristics of Compressor and Turbine



Reduction of pressure ratio for increased mass flows

- **Opening of turbine guide vane: increased swallowing capacity**
- **Adaption of compressor inlet guide vane: reduced air flow**

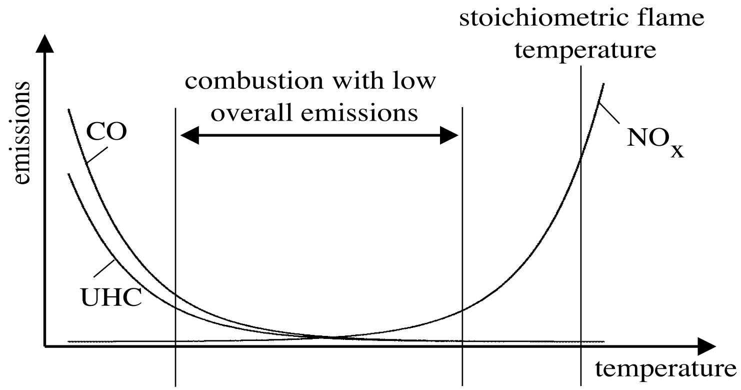
Emissions

Temperature dependent emissions:

NO_X: high temperature of combustion

CO: incomplete combustion due to inhomogeneous fuel/air mixture and/or low temperature of combustion

UHC: incomplete combustion due to inhomogeneous fuel/air mixture and/or low temperature of combustion



-> optimization of combustion process

Emissions due to fuel constituents:

SO_2: Formation from sulphur contents in the fuel

Fuel-NO_X: Formation from nitrogen contents in the fuel

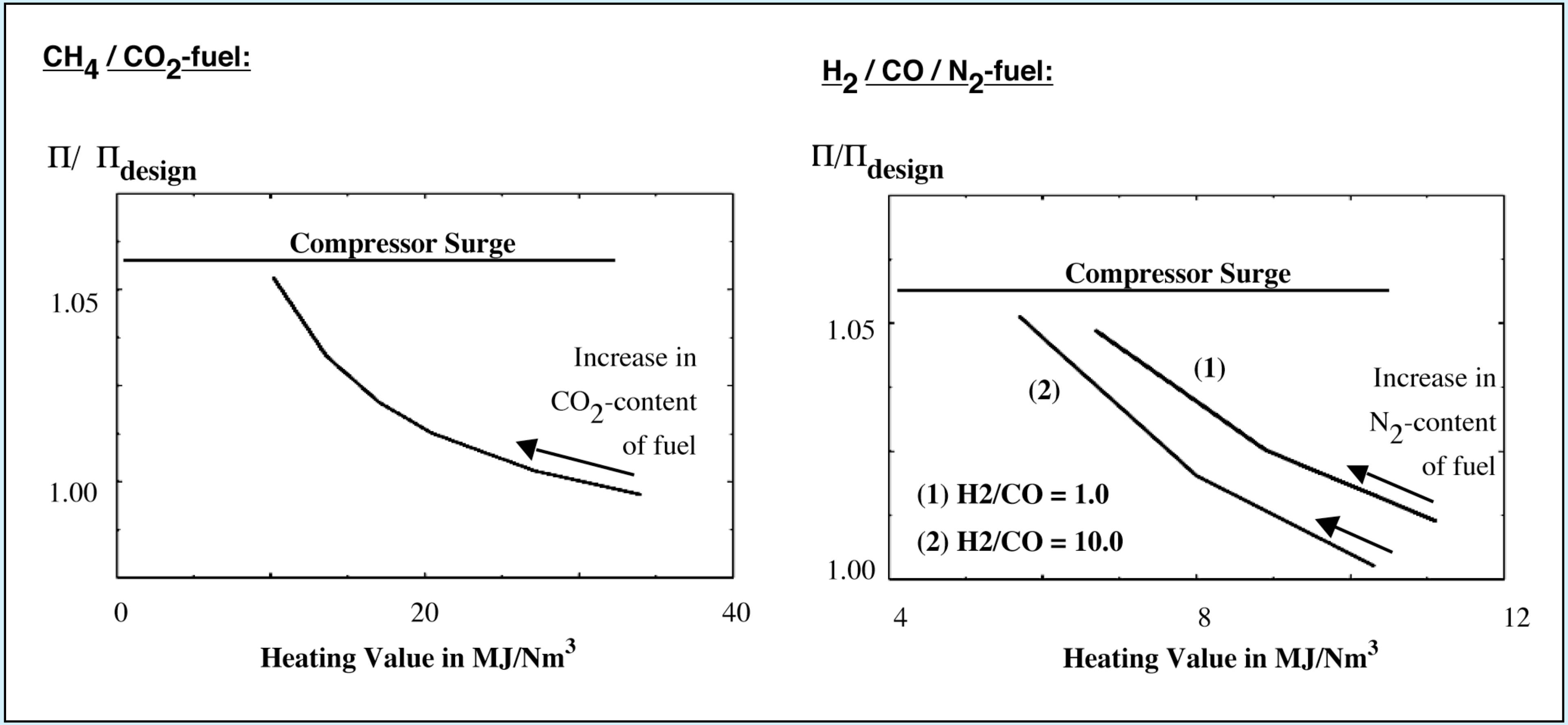
-> treatment of fuel prior to combustion

Further emissions:

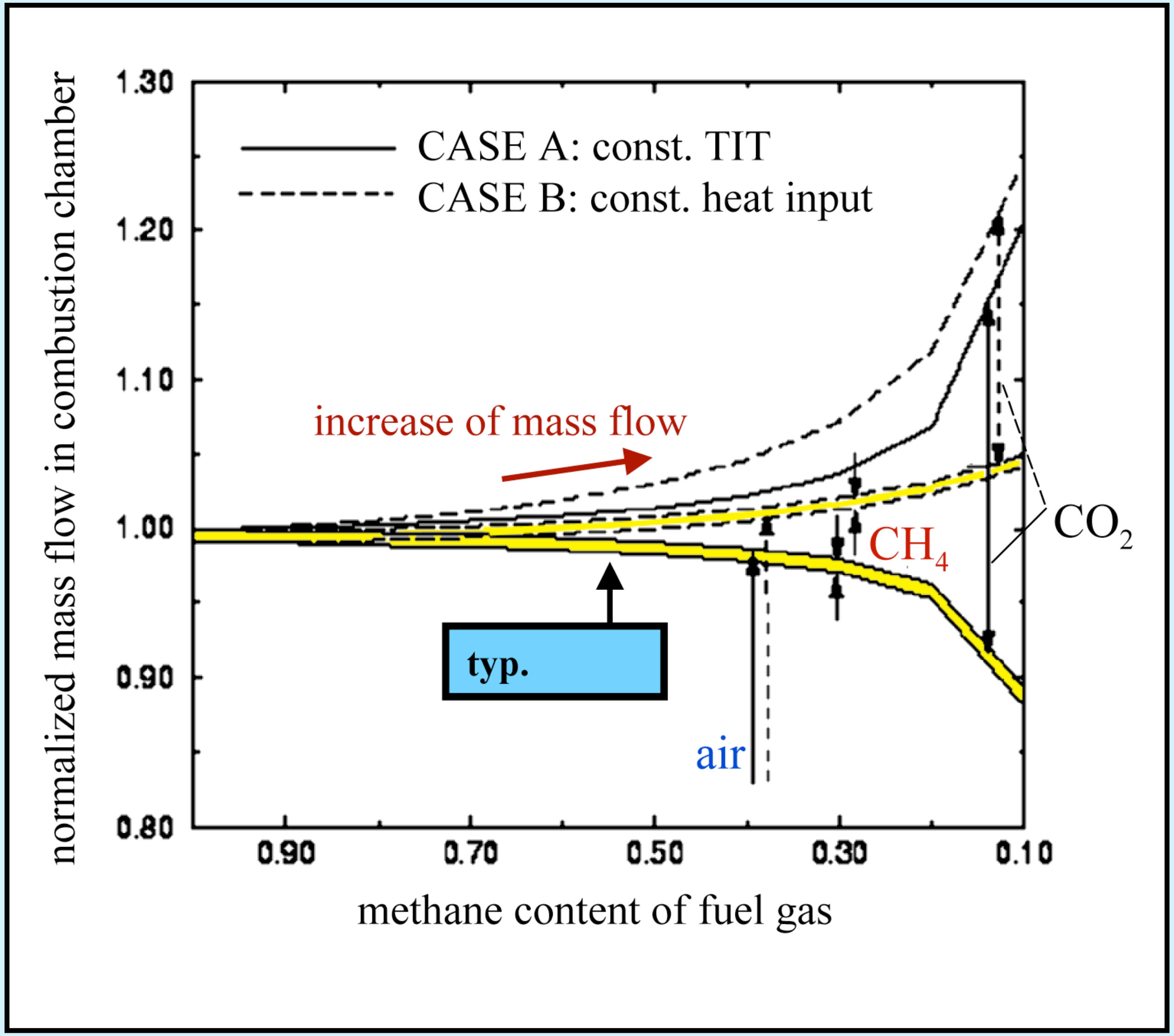
N_2O-NO_X: Formation of NO via the nitrous-oxide path at elevated pressures

Fuel constituents can corrode the turbine and have to be regarded when assessing the emissions.

Operation of a 850kW Gas Turbine on Low-BTU Fuels



Mass Flow Rates for Different Operating Strategies



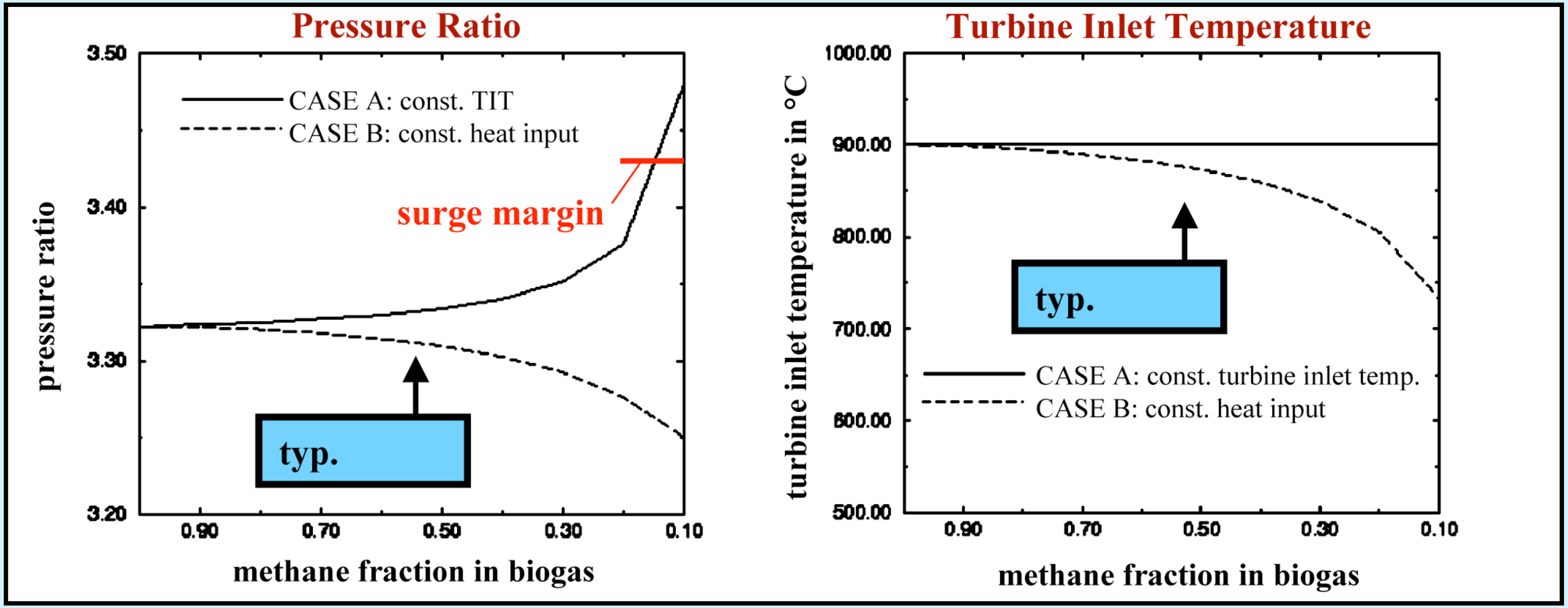
- **reduced CH_4 contents**

  and

- **increased CO_2 contents**

-> reduction of air mass flow in the combustor

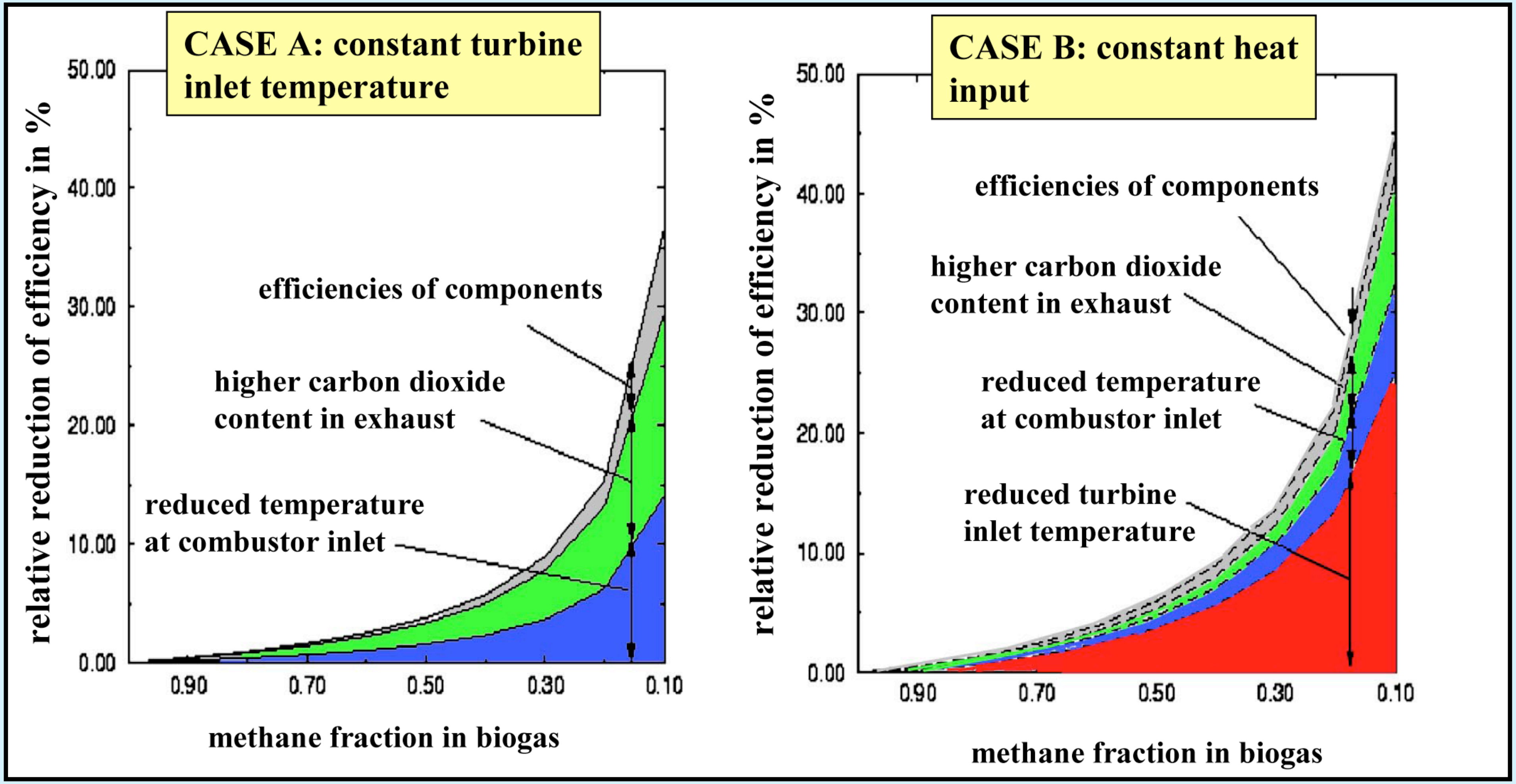
Pressure Ratio and Net Efficiency for a Micro Gas Turbine Firing Biogas



displacement of operating point:

1. **constant turbine inlet temperature: larger volumetric flow at turbine inlet**
   -> pressure ratio increases
2. **constant heat input: fi turbine inlet temperature decreases**
   -> reduced volumetric flow at turbine inlet
   -> pressure ratio decreases

Contributions to Efficiency Decrease in a Micro Gas Turbine



The efficiency reduction can be substantially reduced by preheating the fuel gas

Summary and Outlook

Reduction of CO_2-emissions by CO_2-neutral technologies

Use of low-BTU fuels requires extensive modifications of compressor, combustion chamber and turbine

Compressor operates closer to surge

Combustion chamber & turbine to modify for larger mass flow

Turbine corrosion risk through untreated gases

All required modifications technologically and economically possible

International Seminar on Gasification

9-10 of October 2008, Malmö, Sweden

WÄRTSILÄ

International Seminar on Gasification

9-10 of October 2008, Malmö, Sweden

Thomas Stenhede ***Master of Science***

Senior Application Manager

Combined Technologies

Wärtsilä Power Plants

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WÄRTSILÄ

Wärtsilä Green Solutions - Running Large Engines on Alternative Fuels

Presented at
International Seminar on Gasification
Malmö, Sweden Oct 10, 2008

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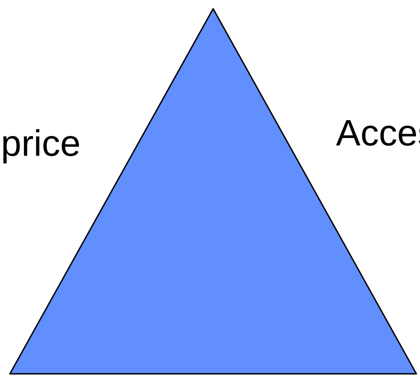
ENERGY
ENVIRONMENT & ECONOMY
Wärtsilä Power Plants

Fuel price

Access to fuel type



Emissions

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Spot fuel prices
Financial Times Commodity prices

24 September 2008		
Crude oil Brent	**94 $/bbl**	
Gas oil (LFO) NWE*	**993 $/ton**	**57 €/MWhf**
HFO NWE	**550 $/ton**	**33 €/MWhf**
LNG Zeebrugge	**10,4 $/MMBtu**	**24 €/MWhf**
Crude Palm Oil (Malaysia)	**768 $/ton**	**52 €/MWhf**
Coal	**145 $/ton**	**13 €/MWhf**

*North West Europe, MWhf f=fuel

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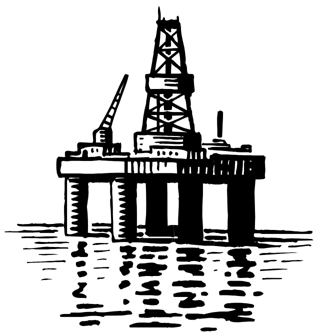
What fuels are the alternatives to oil?



- Natural gas
- Liquid biofuel
- Syngas
- Hydrogen
- Efficiency improvement

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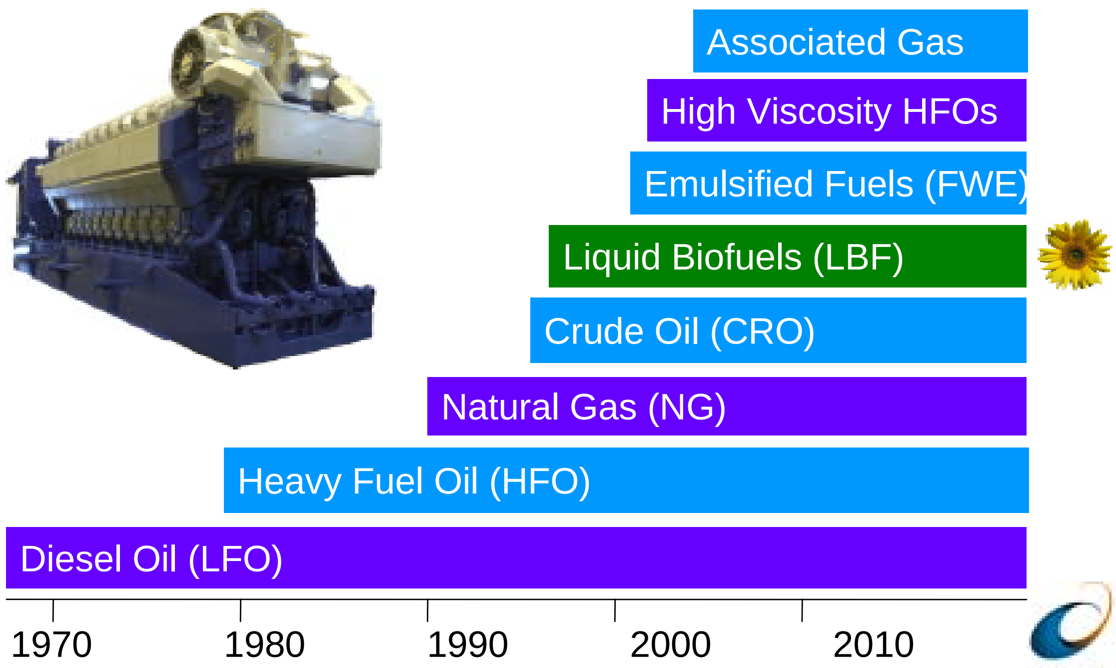
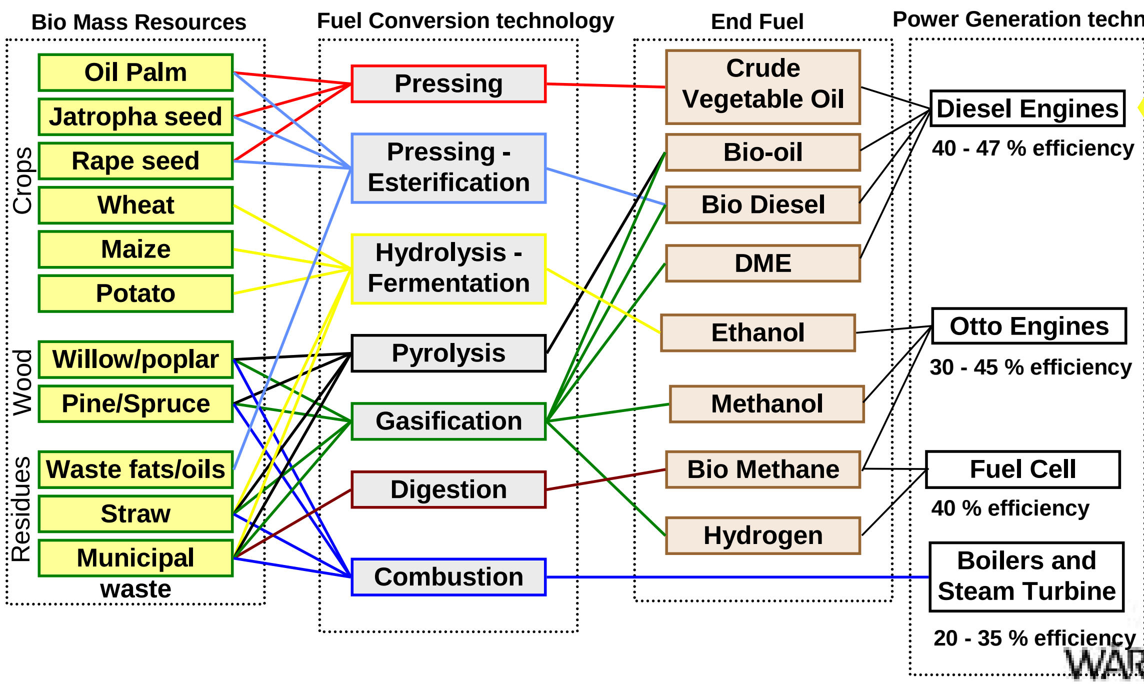
Wärtsilä Fuel Versatility

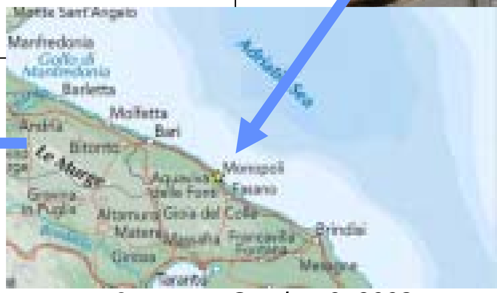


Biomass derived end fuels



Monopoli, Italy

- 3 Wärtsilä 18V32
- 24 MW
- Operational since 2004
- 30000 operating hours
- Crude Vegetable Oil as fuel
- CHP steam generation for oil factory



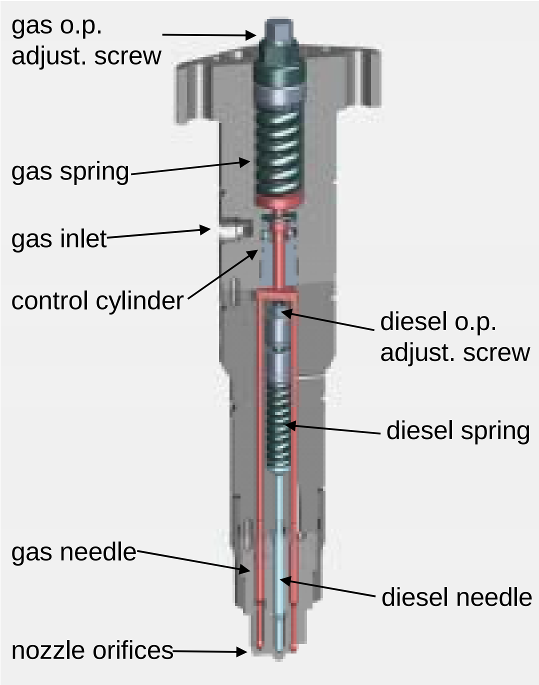
GAS ENGINE TECHNOLOGIES

GAS DIESEL	GD	- diesel principle - high pressure gas - “real” Dual Fuel
SPARK IGNITED LEAN BURN	SG	- otto principle - low pressure gas - mono fuel
PILOT FUEL IGNITED LEAN BURN	DF	- otto principle - low pressure gas - dual fuel

Gas Diesel Engine Concept

Multi-needle injection valve

- Combined diesel fuel and gas injection valve
- One centrally located diesel needle
- Full load capability on diesel fuel
- Pilot fuel injection during gas operation
- Three gas needles symmetrically around the diesel needle
- Hydraulic oil pressure used for gas needle control



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International Seminar on Gasification

9-10 of October 2008, Malmö, Sweden

Wärtsilä 20V32 Engine 9 MWe

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Glycerine (Glycerol)

- Last year raw Glycerine were made about 1 million tons, to produce 10 million tons of bio diesel
- 1 Million tons would be enough for 150 containerized gensets of W9L20 which generates 0.25 GW continuous power
- The net calorific value of glycerine is about 16 MJ/kg compared to ~36.5 MJ/kg for vegetable oil
- Glycerine has very poor ignition and combustion characteristics, does not ignite in a diesel engine
- The cost of Raw Glycerine is low
- Ongoing : Pilot fuel + glycerine, a test with modified Fuel Combustion Analyzer

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DME and Pyrolysis Oil

Dimethyl ether

- DME can be produced form biomass through gasification, a DME synthesis and different cleaning and purification processes
- Currently the EU is considering DME in its potential biofuel mix in 2030
- Main characteristics:
  - Must be stored under pressure to maintain a liquid state
  - Extremely low viscosity
  - \+ Very clean burning
- Engine tests made (mixed with HFO & fumigated into the intake manifold). Conclusion: Neither way was found to be appropriate

Pyrolysis oils

- A wide variety of pyrolysis oils are being offered (wood, tires, etc.)
- Typical characteristics:
  - Poor ignition
  - Can not be blended with diesel
  - Acidic
- Wood pyrolysis oil tested in mid-1990's and found to be too challenging
- Pyrolysis oil production technologies have developed and suitable oil qualities might become available in near future

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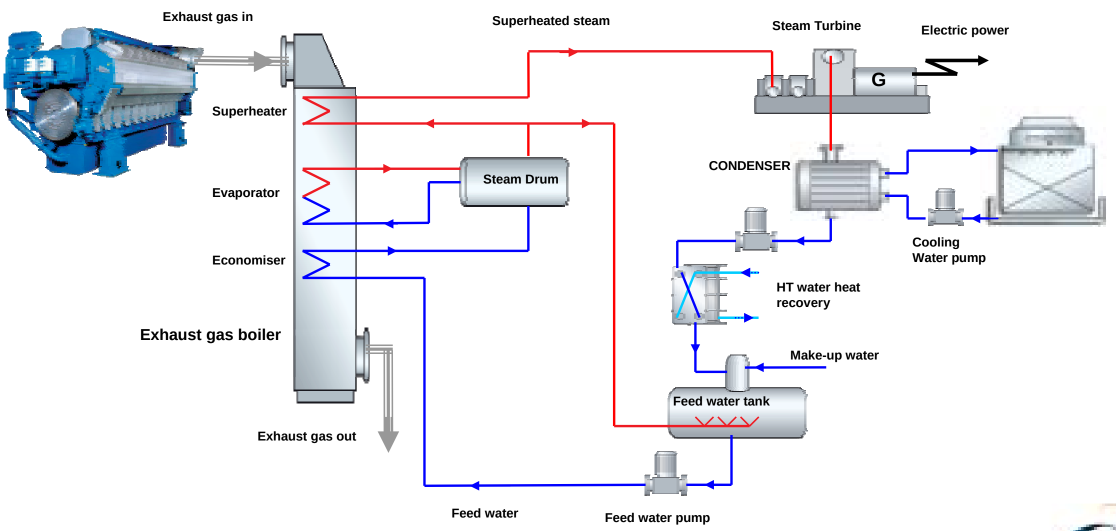
Fuel impact on performance of engines

Wärtsilä engine type	50DF	46	34SG
Fuel	LNG	HFO	NG
Sulfur content in fuel %S	-	1.5	-
Power kWm	17100	17550	9000
Shaft efficiency (η). ISO %	47.3	48.2	48.0
Exhaust gas temperature °C	399	360	390
Nitrogen oxides (NO_x) g/kWh	1.2	14.9	1.2
Carbon monoxide (CO) g/kWh	2.2	1.1	2.1
Sulfur (SO2) g/kWh	0.09	6.7	-
Particles g/kWh	0.07	0.46	0.07
Carbon dioxide (CO2) g/kWh	449	660	450

Engine combined cycle
10% more electric power, 50% efficiency



LNG/LBM references at sea

Petrojarl 1
FPSO
Petrojarl
2x 18V32DF
2x 27'000 running hours

Stril Pioner
DF-electric offshore supply vessel
Simon Møkster
Kleven Verft
4x 6R32DF
4x 11'000 running hours

Sendje Ceiba
FPSO
Bergesen
1x 18V32DF
12'800 running hours

Gass Avant / hull 29
DF-electric offshore supply vessel
Eidesvik
West Contractors
4x 6R32DF
Ship delivery 2007

Viking Energy
DF-electric offshore supply vessel
Eidesvik
Kleven Verft
4x 6R32DF
4x 13'500 running hours

15 engines with 164'800 running hours
(March 2006)

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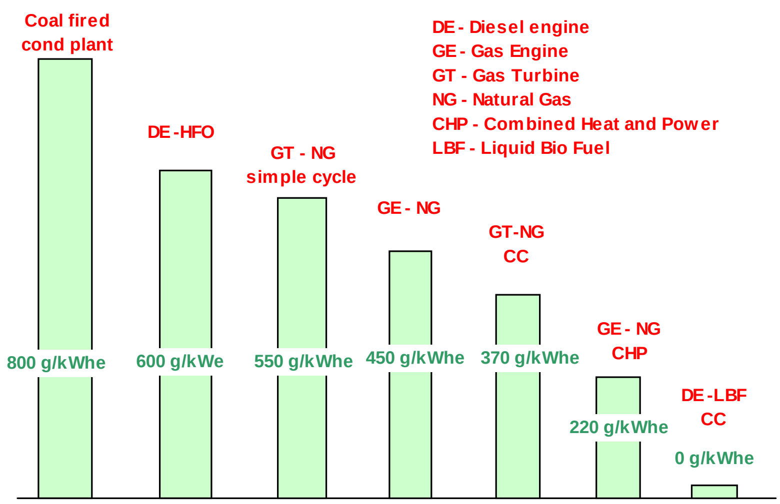
Specific CO2 emissions in g/kWhe



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Linate Airport Milan, Italy
3*20V34SG, 24 MWe

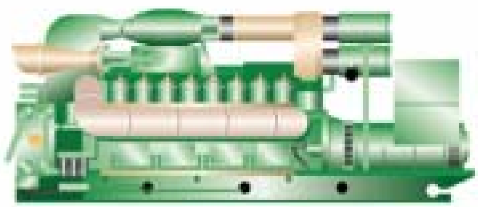
Experiences with Special Gases

- Requirements
- Applications

Martin Schneider

GE imagination at work

Fuel Gases for Jenbacher Gas Engines



- Natural gas
- Propane gas
- Gas LNG
- ...

- Biogas

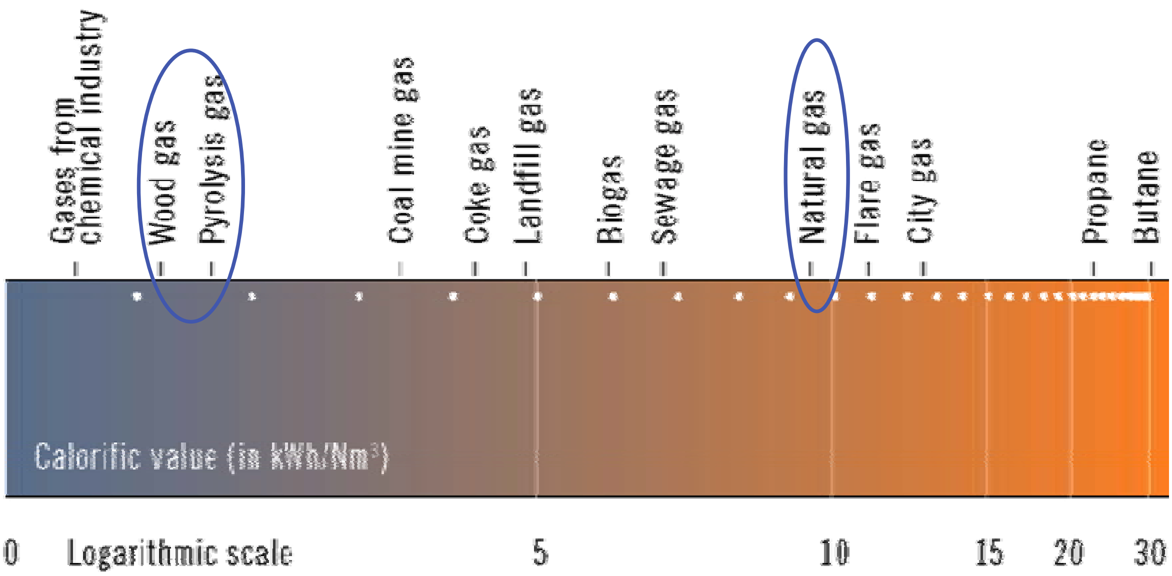
  (Landfill gas,
  gas from biomass,
  sewage gas)

- Synthetic gases

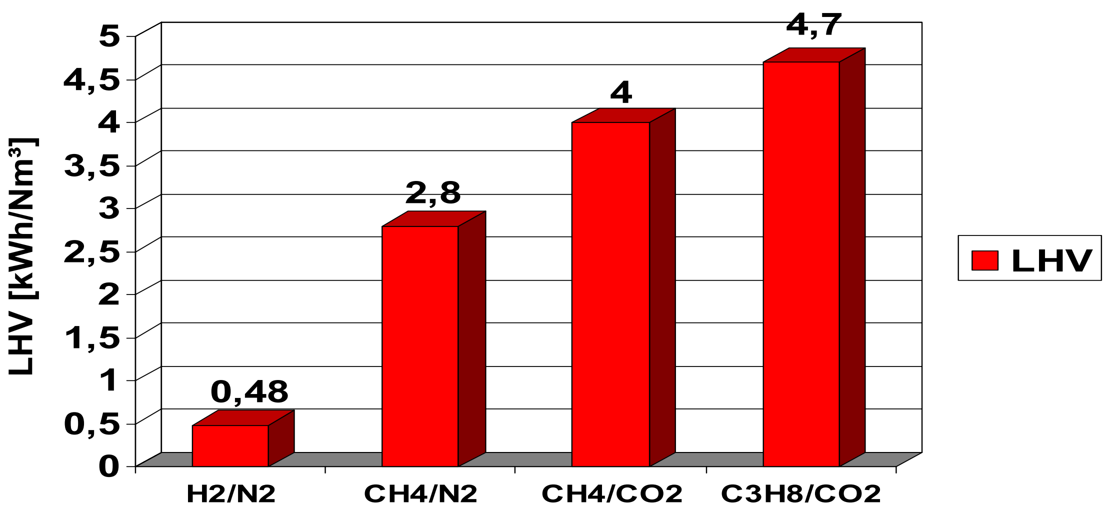
  (Wood gas, pyrolysis
  gas, coke gas, ...)

GE imagination at work

Lower Heating Value
range of gases used in Jenbacher gas engines

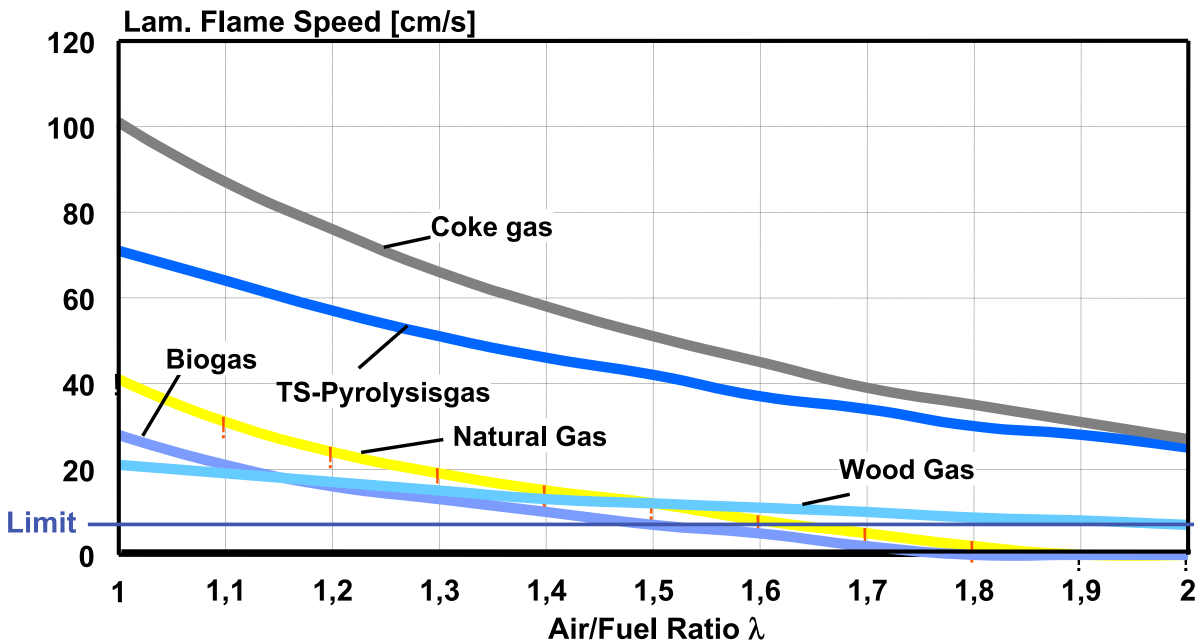


Combustion Limits/LHV



Mixture	H_2/N_2	CH_4/N_2	CH_4/CO_2	C_3H_8/CO_2
Volume [%]	16/84	28/72	40/60	18/82
LHV [kWh/Nm³]	0.48	2.8	4.0	4.7

Laminar Flame Speed



GE imagination at work

Utilization of Special Gases in Gas Engines - Examples

- Thermoselect/Italy/Japan
  Pyrolysis Gas from Waste; 20 - 40% H2; LHV 2.0 kWh/Nm³
- Krems Chemie/Austria
  Gas from Chemical Industry; 16 - 21% H_2; LHV 0.5 - 0.6 kWh/Nm³
- Profusa & SAMA / Spain
  Coke Gas; 55 - 60% H_2; LHV 4.8 kWh/m^3_N
- Aceralia / Spain
  Converter (LD) Gas; 60 - 75% CO; LHV 2.4 kWh/m^3_N
- Harboore / Denmark;
  Woodgas; H_2: 15-18%; CO: 25-28%; LHV = 1.9 kWh/Nm³
- Güssing / Austria
  Woodgas; H_2: 35 - 40%; CO: 20-25%; LHV = 2.5 kWh/Nm³

GE imagination at work

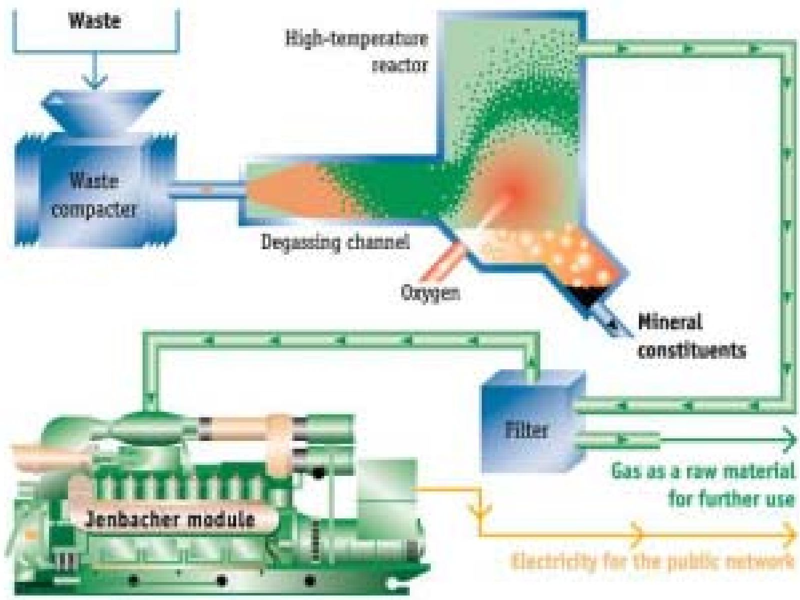
Waste to Energy

Thermoselect/Italy/Japan

Gas from Waste gasification
20 - 40% H2;
LHV 2.0 kWh/Nm³

GE imagination at work

Waste Gasification



Thermoselect/Italy
1 x JMS 612 GS SN.L

Pyrolysis gas:
H_2 20 - 40%
CO 35 - 40%
CO_2 25 - 35%
N_2 2 - 5%
LHV = 1.5 - 2 kWh/Nm³

GE imagination at work

Waste Gasification

Thermoselect/Italy
1 x JMS 612 GS SN.L

Pyrolysis gas:

H_2	20 - 40%
CO	35 - 40%
CO_2	25 - 35%
N_2	2 - 5%

LHV = 1.5 - 2 kWh/Nm³

GE imagination at work

Waste Gasification

Thermoselect/Italy
1 x JMS 612 GS SN.L

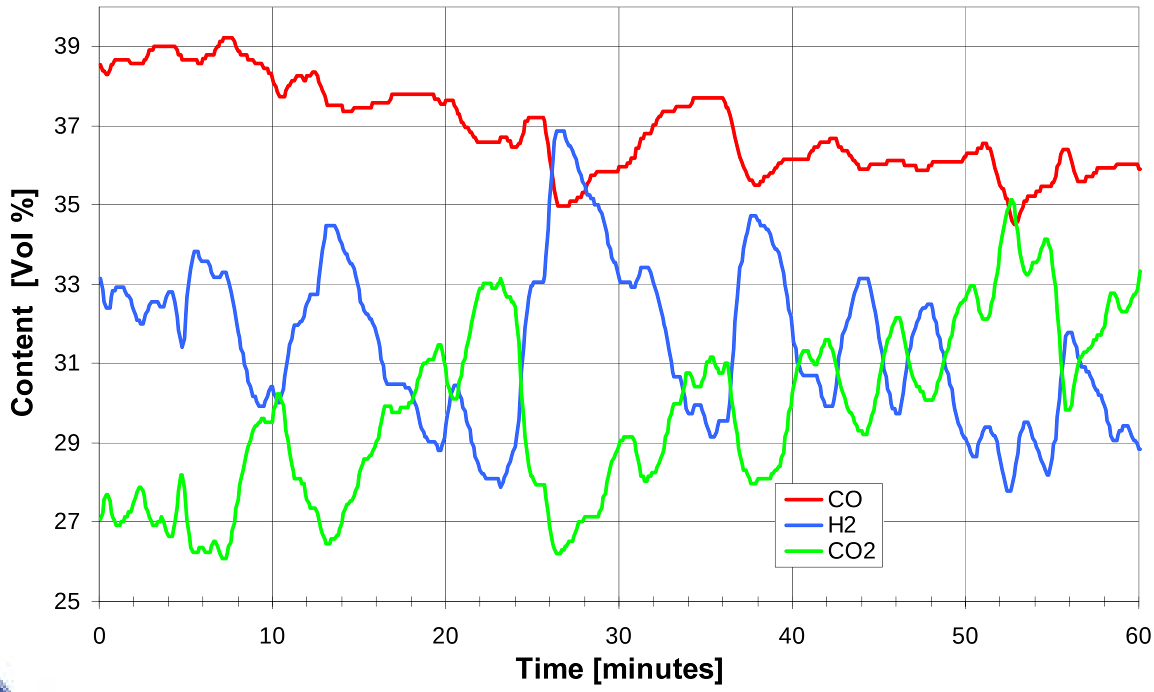
Pyrolysis gas:

H_2	20 - 40%
CO	35 - 40%
CO_2	25 - 35%
N_2	2 - 5%

LHV = 1.5 - 2 kWh/Nm³

GE imagination at work

Waste Gasification



Thermoselect Waste Gasification Chiba/JP

Thermoselect Chiba/JP
1 x JGS 620 GS SN.L

300 t/d public waste

Pyrolysis gas:

H_2	**20 - 40%**
CO	**35 - 40%**
CO_2	**25 - 35%**
N_2	**2 - 5%**

LHV = 1.5 - 2 kWh/Nm³

Commissioning:
10/2001

Thermoselect Waste Gasification Chiba/JP

Thermoselect Chiba/JP
1 x JGS 620 GS SN.L

300 t/d public waste

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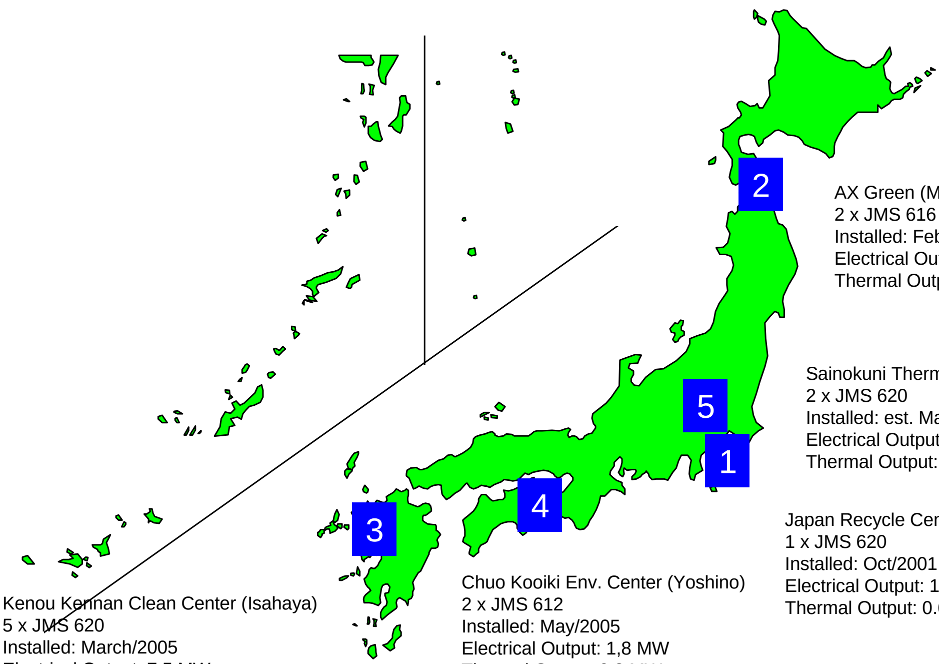
Commissioning: 10/2001

Thermoselect plants Japan



AX Green (Mutsu)
2 x JMS 616
Installed: Feb/2003
Electrical Output: 2,4 MW
Thermal Output: 1,5 MW

Sainokuni Thermal Recycle Facility (Sainokuni)
2 x JMS 620
Installed: est. March/2006
Electrical Output: 3,0 MW
Thermal Output: 0.9 MW

Japan Recycle Center (Chiba)
1 x JMS 620
Installed: Oct/2001
Electrical Output: 1,9 MW
Thermal Output: 0.6 MW

Chuo Kooiki Env. Center (Yoshino)
2 x JMS 612
Installed: May/2005
Electrical Output: 1,8 MW
Thermal Output: 0.8 MW

Kenou Kennan Clean Center (Isahaya)
5 x JMS 620
Installed: March/2005
Electrical Output: 7,5 MW
Thermal Output: 3.1 MW

Thermoselect Waste Gasification Mutsu/JP

Thermoselect Mutsu/JP
2 x JGS 616 GS SN.L

Pyrolysis gas:

H_2	20 - 40%
CO	35 - 40%
CO_2	25 - 35%
N_2	2 - 5%

LHV = 1.5 - 2 kWh/Nm³

Commissioning: 2/2003
> 40,000 oh (10/2008)

Utilisation of Pyrolysis gas Thermoselect Isahaya/JP & Joshino/Jp

Thermoselect Isahaya/JP
5 x JGS 620 GS SN.L
Commissioning: 3/2003
> 30,000 oh (10/2005)

Thermoselect Yoshino/JP
2 x JGS 612 GS SN.L

Commissioning: 10/2003
> 25,000 oh (5/2008)

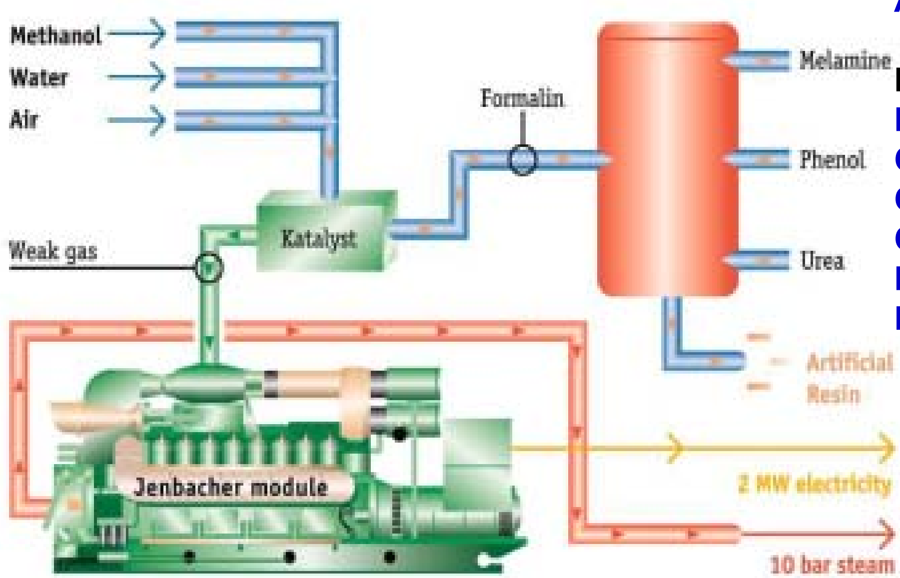
Gas from **Chemical Industry**

Krems Chemie/Austria

Gas from Chemical Industry;
16 - 21% H2;
LHV 0.5 - 0.6 kWh/Nm³

GE imagination at work

Gases from the Chemical Industry



Krems-Chemie, Austria

Process gas:

H_2	16 - 21%
CH_4	1.5%
CO	1.5%
CO_2	5%
N_2	71 - 76%

LHV = 0.5-0.6 kWh/m³$_N$

GE imagination at work

Gases from the Chemical Industry

Krems Chemie / A
4 x JGS 320 GS S.LC
Pel = 2,352 kW
1,400 kg/h sat. Steam
(11.5 bar/186°C)

Process gas:

H_2	**16 - 21%**
CH_4	**1.5%**
CO	**1.5%**
CO_2	**5%**
N_2	**71 - 76%**

LHV = 0.5-0.6 kWh/m^3_N

GE imagination at work

Gases from the Chemical Industry

Krems Chemie / A
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1,400 kg/h sat. Steam
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Process gas:

H_2	**16 - 21%**
CH_4	**1.5%**
CO	**1.5%**
CO_2	**5%**
N_2	**71 - 76%**

LHV = 0.5-0.6 kWh/m^3_N

In commercial operation since more than 100,000oh (10/2008)

GE imagination at work

Special Gases from Steel Industry

Coke Gas

Profusa & SAMA / Spain

55 - 70% H_2; LHV 4.8 kWh/m^3_N

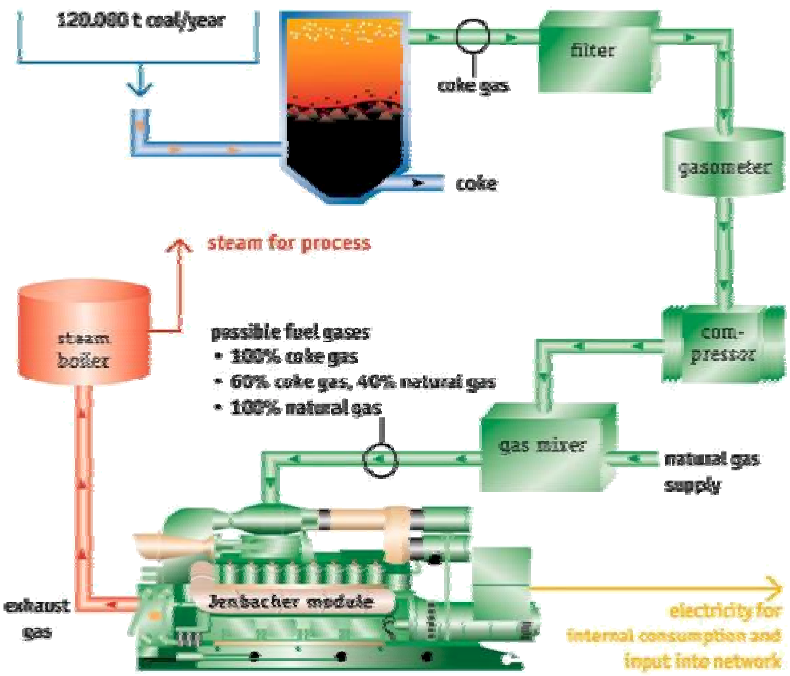
Converter (LD) Gas

Aceralia / Spain

60 - 75% CO; LHV 2.4 kWh/m^3_N

GE imagination at work

Coke Gas Utilization



Profusa / Spain
12 x JMS 316 GS-S/N.L

Electrical Output
7,164 kW

Coke gas:

H_2	55%
CH_4	30%
CO	5%
CO_2	5%
N_2	5%

LHV = 4.8 kWh/m^3_N

GE imagination at work

Coke Gas Utilization

Profusa / Spain
12 x JMS 316 GS-S/N.L

Electrical Output
7,164 kW

Coke gas:

H_2	55%
CH_4	30%
CO	5%
CO_2	5%
N_2	5%

LHV = 4.8 kWh/m³$_N$

In commercial operation since more than 95,000 oh (10/2008)

Converter Gas from LD-Steel Process

Gas

Electricity & Steam

Gas Engines:
Electricity & Heat

Steamboiler

Steam from Engine Exhaust

Plant Aceralia/Spain

Converter Gas from LD-Steel Process

Aceralia / Spain
12 x JMS 620 GS-S/N.L

Electrical Output
18,700 kW
12,140 kW therm

Converter (LD) gas:

CO	**60-75%**
H_2	**1%**
N2	**13%**
CO_2	**13,5%**

LHV = 2.4 kWh/m^3_N

Converter Gas from LD-Steel Process

Aceralia / Spain
12 x JMS 620 GS-S/N.L

Electrical Output
18,700 kW
12,140 kW therm

Converter (LD) gas:

CO	**60-75%**
H_2	**1%**
N2	**13%**
CO_2	**13,5%**

LHV = 2.4 kWh/m^3_N

Approx. 28,000 oh (10/2008)

Experiences with **Wood gasification (extract)**

•Harboore / Denmark;

Woodgas; H_2: 15-18%; CO: 25-28%; LHV = 1.9 kWh/Nm³

•Güssing / Austria

Woodgas; H_2: 35 - 40%; CO: 20-25%; LHV = 2.5 kWh/Nm³

•Spietz / Switzerland

Woodgas; H2: 15 - 18%; CO: 18-20%; LHV = 1.7 kWh/Nm³

•Kokemäki / Finnland

Woodgas; H2: 15 - 18%; CO: 18-20%; LHV = 1.7 kWh/Nm³

•Skive / Denmark

Woodgas; H2: 15 - 18%; CO: 18-20%; LHV = 1.7 kWh/Nm³

GE imagination at work

Installed wood gas plants with GE Jenbacher

~40 units sold/delivered in 8 countries (7 in Europe)

- 5 units AUT/4units CH/15units UK….2units Japan
- 9 different gasifier concepts

20 units already commissioned

- 11 units in commercial operation
- 5 units stand by due to optimization
- 4 failed due to gasifier system issues

More than 150k oph
Fleet leader Harboore >50k oph

Plant	Harbøøre/Dk	Spiez/Ch	Güssing/A
Gasifier Supplier	Babcock & Wilcox Vølund	Pyroforce	Repotec
Gasifier concept	Fixed bed - updraft	Fixed bed - downdraft	Fluidized bed steam gasifier
Engine	2 x JMS 320 GS	1 x JMS 208 GS	1 x JMS 620 GS
Electrical outut	2 x 764 kWe	1 x 200 kWe	1 x 1960 kWe
Commissioning	3/2000	4/2001	4/2002
operating hours *)	> 54,500 h (total)	> 15,000 h	> 42,000 h
Gas cleaning technology	wet-electrostatic filter + integrated scrubber	precoat filter; gas scrubber	precoat filter; gas scrubber (RME)

GE imagination at work

Biomass Gasification Harboore/Dk

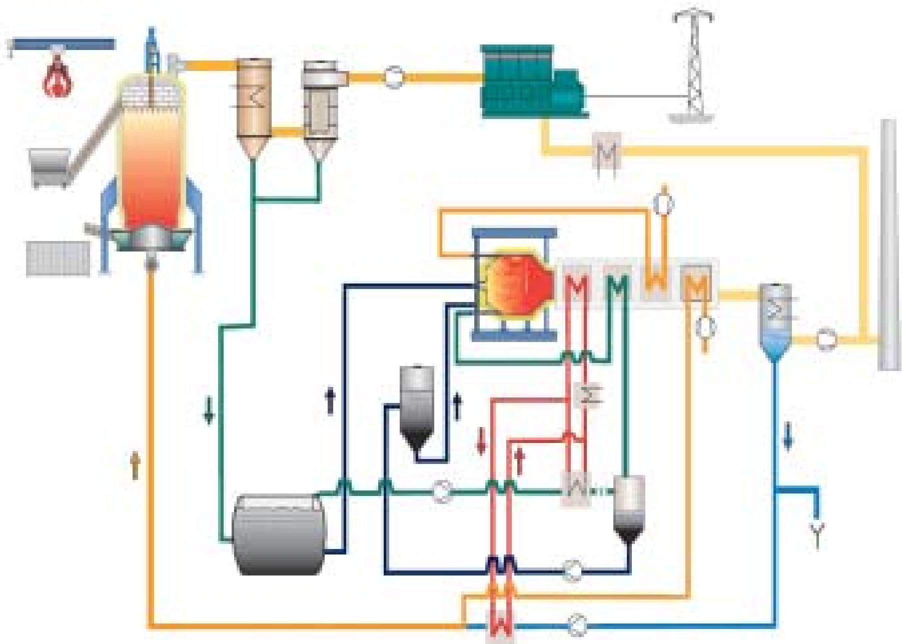
Harboore/Denmark
2 x JMS 320 GS S.L

electrical output
2 x 760 kW

wood gas:

H_2	**15 - 18%**
CH_4	**3 - 5%**
CO	**25 - 28%**
CO_2	**7 - 10%**
N_2	**50 - 55%**
LHV	**6.84 MJ/Nm³**

Biomass Gasification Harboore/Dk



Harboore/Dk
2 x JMS 320 GS S.L

Electrical Output
2 x 760 kW

Woodgas:

H_2	15-18%
CH_4	3-5%
CO	25-28%
CO_2	7-10%
N_2	50-55%

LHV = 1.9 kWh/Nm³

Biomass Gasification Harboore/Dk

Harboore/Dk
2 x JMS 320 GS S.L

Electrical Output
2 x 760 kW

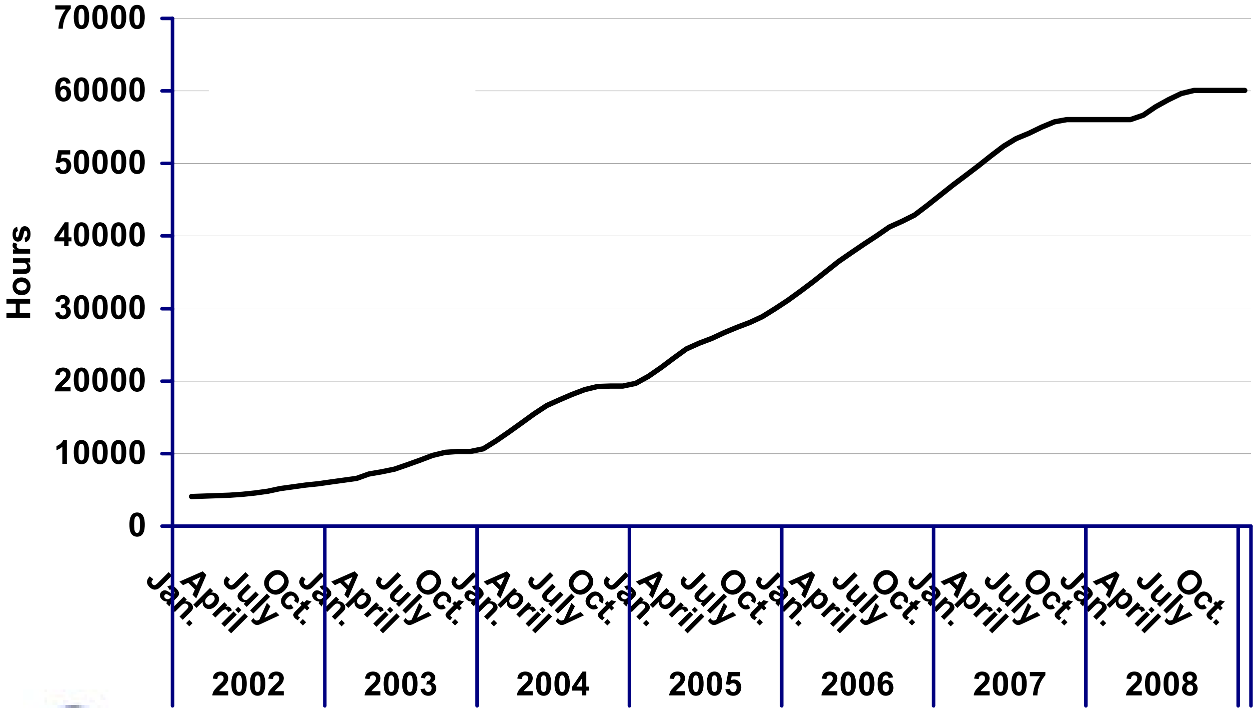
Woodgas:

H_2	15-18%
CH_4	3-5%
CO	25-28%
CO_2	7-10%
N_2	50-55%

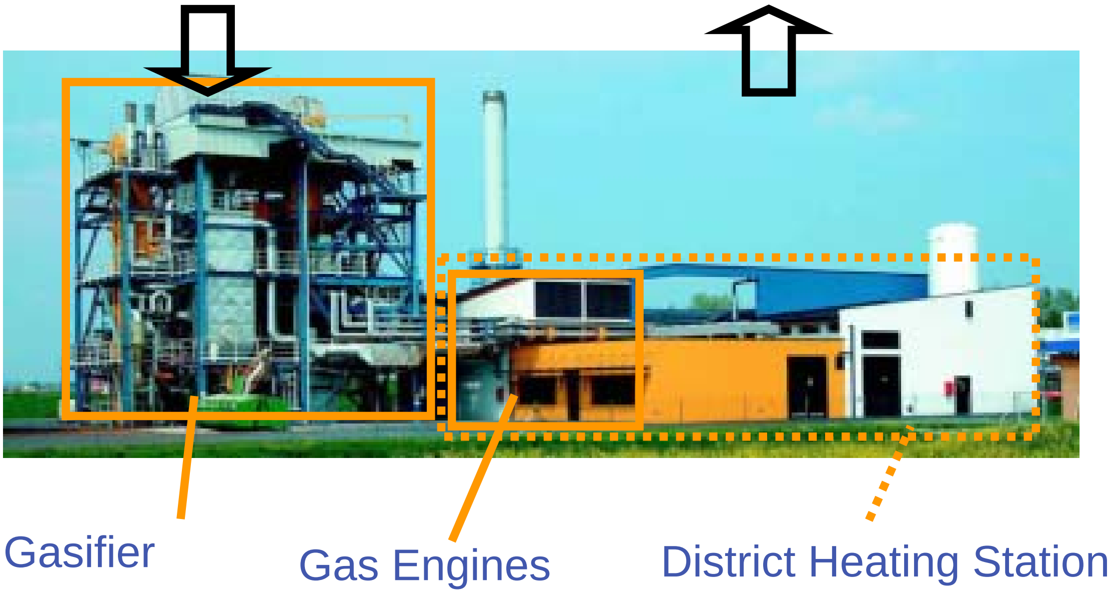
LHV = 1.9 kWh/Nm³

Engines: total approx. 54,000 oh (10/2008)
increased output (bmep = 13bar) since April 2001

Harboøre CHP – Gasengine operation



Biomass Gasification Güssing/A



Biomass Gasification Güssing/A

CFB steam - gasifier

Wood:	8 MW	
Wood gas:	O_2	0 %
	N_2	3 %
	CH_4	10 %
	CO_2	23 %
	H_2	40 %
	CO	24 %
LHV	10.95 MJ/sm^3	

J620GS ~ 1.97 MWe

commissioned 9/01

operating hours >42,000 (09/08)

Biomass Gasification Oberwart/A

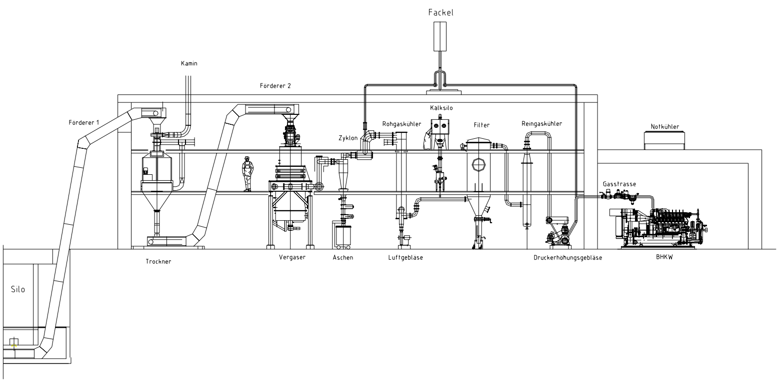
CFB steam - gasifier

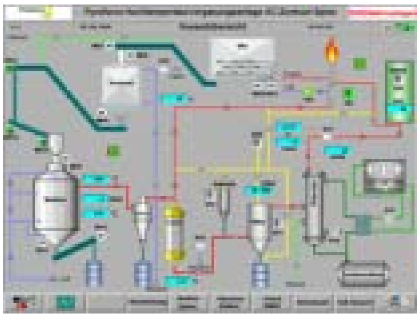
Electr. Output ~2.8 MWe

- **2 x J612GS ~ 1.2 MWe**
- **ORC ~400 kWe**

Thermal output ~4.1 MW

Biomass Gasification Spiez/Ch





PYROFORCE®
Industrial pilot plant
AC Lab Spiez
1 x JMS 208 GS S.L

Electr. output
1 x 200 kW

Conzept:
Fixed bed downdraft

Wood gas:

H2	**15 %**
CH4	**2 %**
CO	**18 %**
CO2	**12,1 %**
N2	**47,1 %**
H2O	**rest**
LHV	**1,25 kWh/Nm³**

Operating hours
Gas engine > 15,000 (08/2008)

Pyroforce® – further commercial projects

Holzverstromung Nidwalden/CH
2 x JMS 320 GS-S.L

Pel	1,176 kW
Pth	1,458 kW

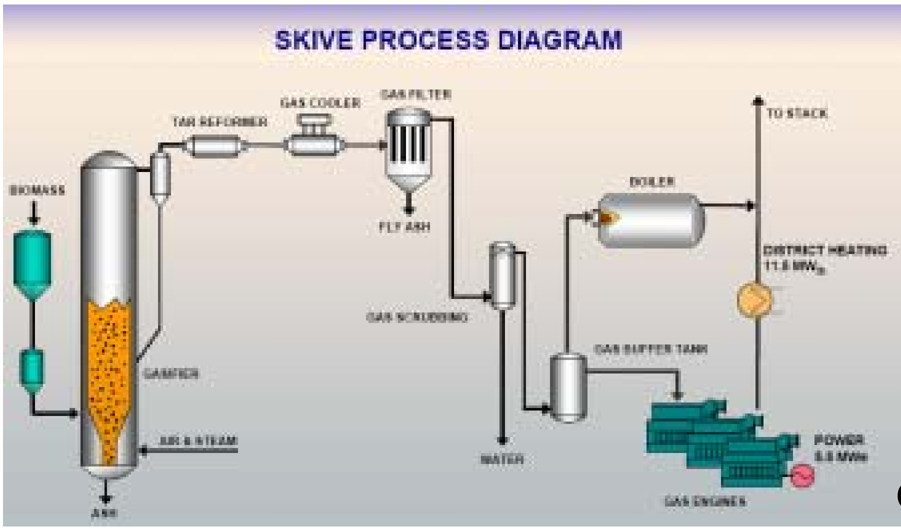
Comm. 12/07; ~2,000 oph/engine

Holzgas Güssing 2 /AT
1 x JMS 312 GS-S.LC

Pel	353 kW
Pth	430 kW

Comm. 02/08; ~1,000 oph

Woodgas Plant Skive/Denmark



3 x J620GS; 1.97 MWe
Commissioning 07/2008

Crucial points in the utilization of wood gas

- Gas cleaning technology

- Fulfillment of emissions

GE imagination at work

Condensate, deposits (water, tar, naphtalenes.....)



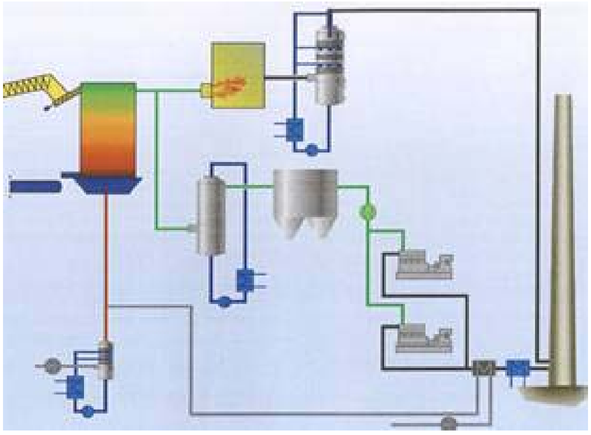



Gas cleaning is the key technology

GE imagination at work

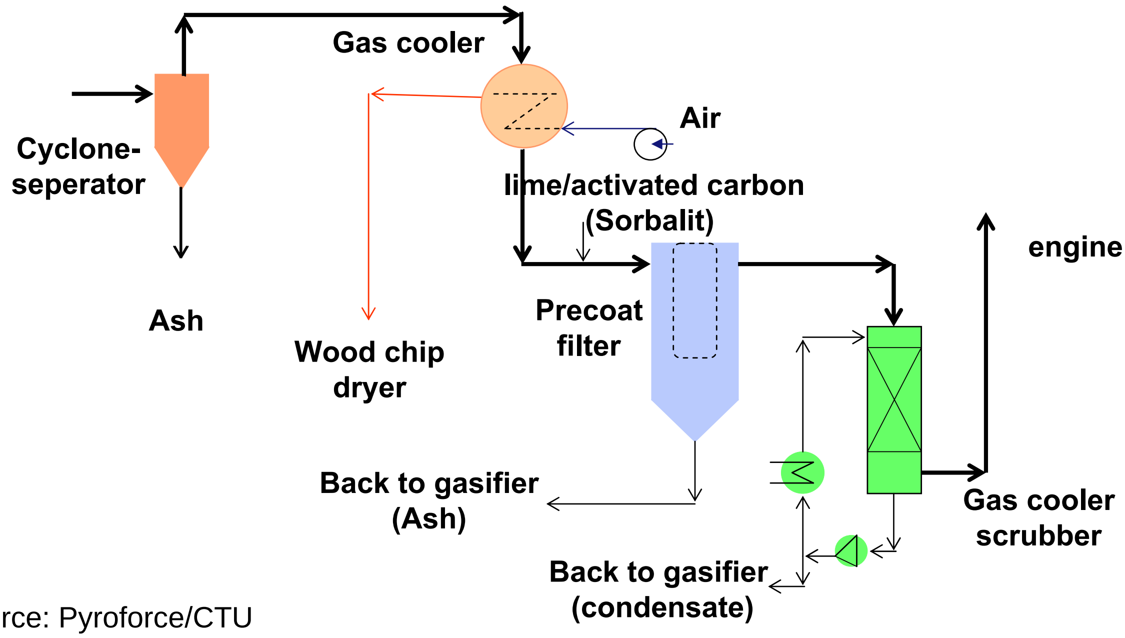
Gas cleaning Harboøre

Wet scrubber & wet electrostatic precipitator



Results: oxidation catalyst ok; relative high Cl content (feedstock?) initial and O&M costs high (High disposal/treatment cost for contaminated water)

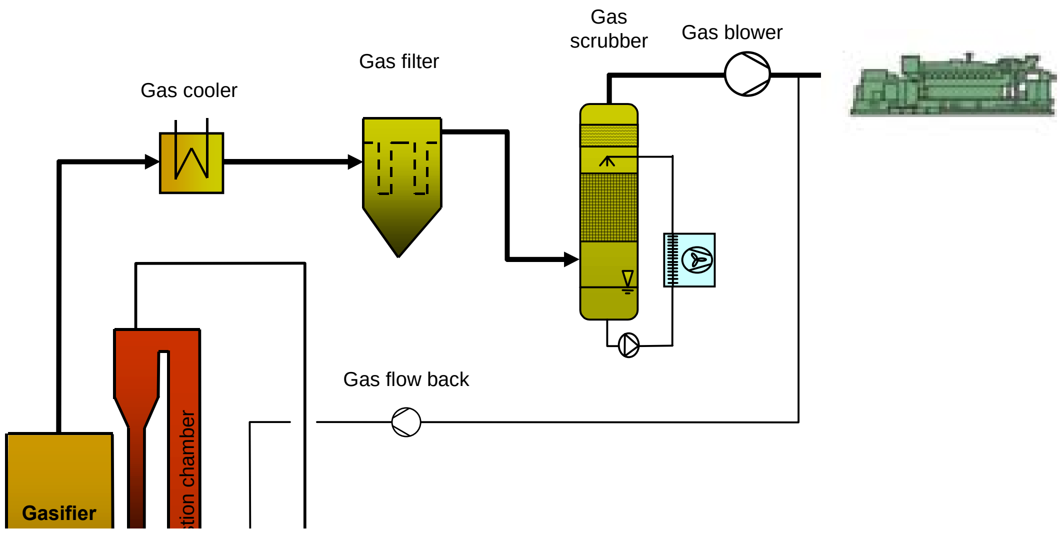
Gas cleaning Pyroforce®/CTU



Source: Pyroforce/CTU

Results: oxidation catalyst ok; relative high H2S content (feedstock); relative high NH3 content first and O&M cost acceptable

Gas cleaning repotec
Scrubber with RME & precoat filter



Results: oxidation catalyst ok; relative high NH3 content first and O&M cost acceptable (RME production on site)

Crucial Points/Technical Barriers

Emissions limits according e.g. “TA Luft”

NOx ≤ 500 mg/Nm³ ✓

CO ≤ 650 mg/Nm³

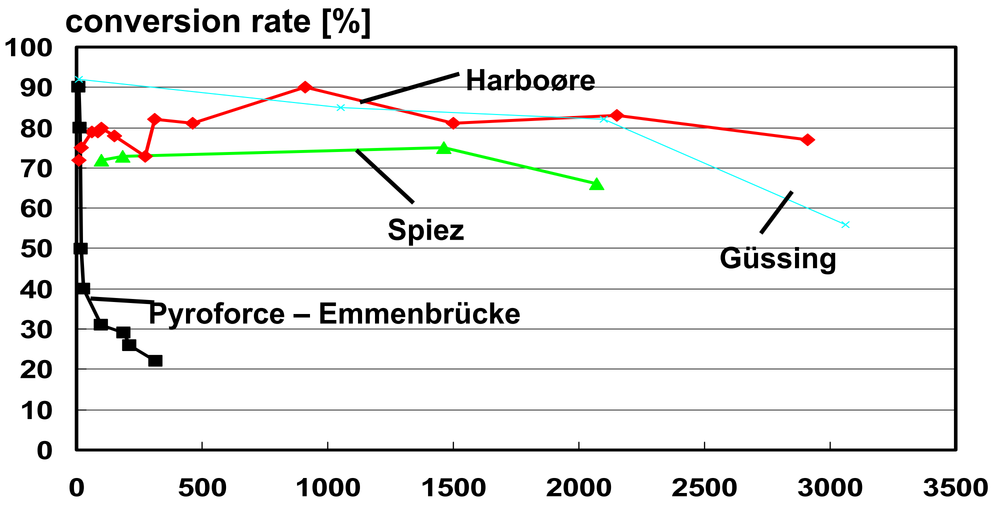
		Gas		Exhaust gas [mg/Nm³]	
Plant	Engine	H2 [%]	CO [%]	NOx	CO
WUT Wamsler	J 208 GS	9 - 12	20 - 26	50 - 150	2500 - 3500
Boizenburg	J 612 GS	13 - 15	16 - 20	200 - 250	3000 - 3500
Harboore	J 320 GS	18 - 20	20 - 30	200 - 400	2000 - 3500
Güssing	J 620 GS	30 - 45	20 - 30	450 - 500	3000 - 4500

unburned CO- content of pyrolysis gas

Emissions

unburned CO- content of wood gas requires exhaust gas after-treatment

=> first results of Catalytic reduction promising



Gas cleaning is also here the key technology

Biomass Gasification Güssing/A

CO- Reduction

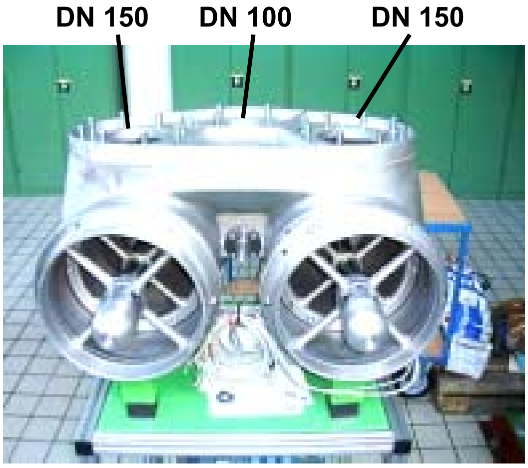
Catalytic Exhaust Gas Aftertreatment

Oxidation Catalyst test runs e.g. Güssing

Oxi catalyst after 3 060 oh:
Problem with condensates

- change of test catalyst and position
- in the meantime conversion rate >85% for more than **15.000 oh**

Advantages of Special Gas Mixer



Picture.: Special Gas Mixer; Air Intake

Benefits:

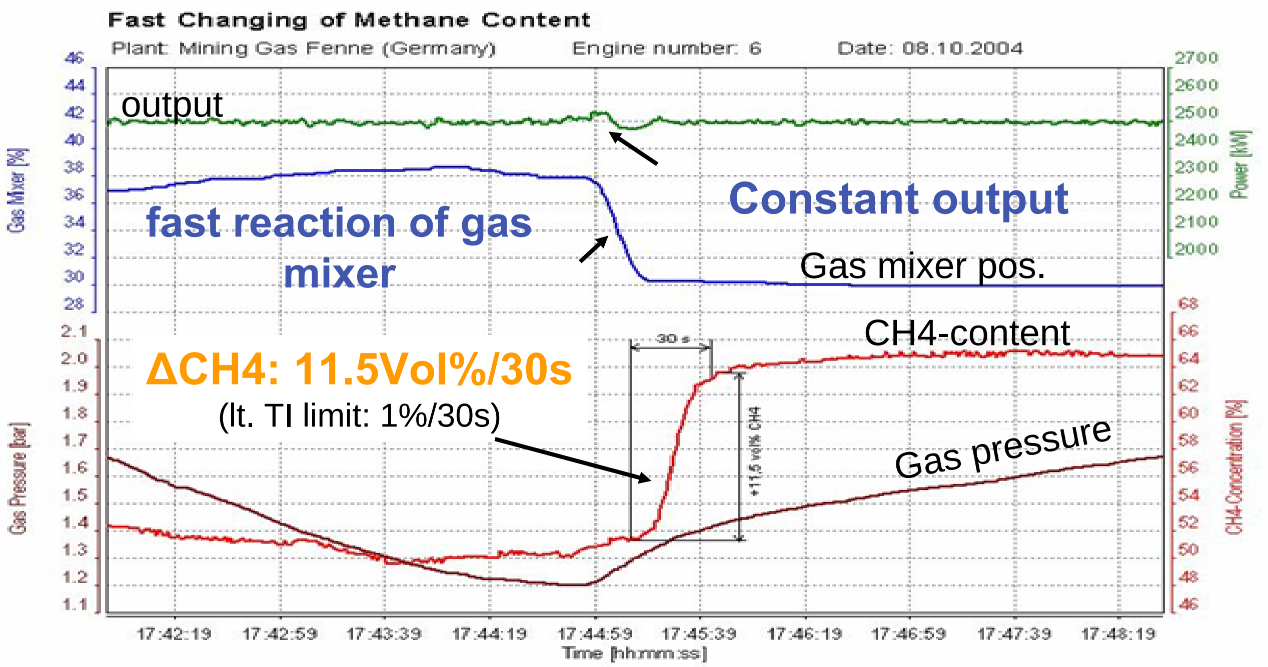
- 1 Special Gas Mixer instead of
- 4(6) Standard Gas Mixer
  (up to 4000ms3/h possible)

Further Benefits – Integrated Flanges:

- No additional Pipe Work necessary
- 1 x DN100 (high LCV), 2 x DN150 (low LCV)
- Gas Mixing possible (not controlled)

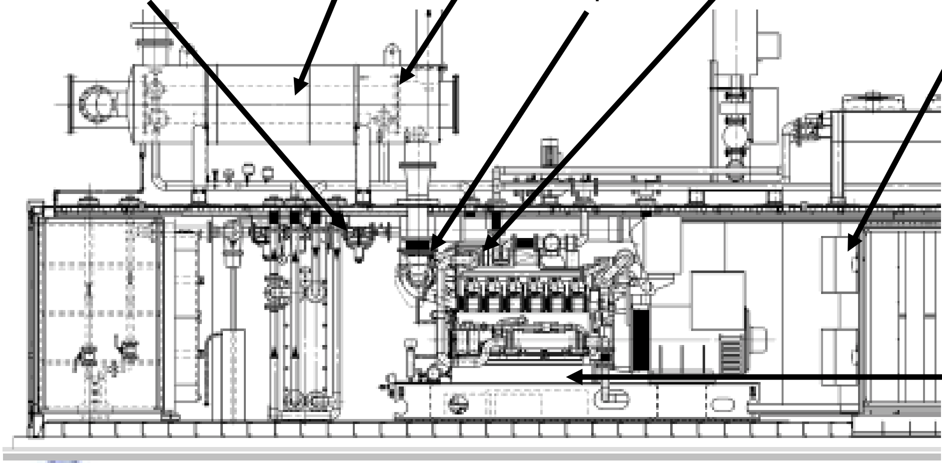

Picture: Special Gas Mixer applied in Güssing

CMG – Experience
LHV – fluctuations => GE Jenbacher gas mixing system



To keep Emissions within Limits comply to GEJ TI 1000-0300 value of 1%/30s.

Critical issues at Wood Gas CHP`s



Summary

- wide range of H_2 gases can be used in gas engines
- key factor is laminare flame speed
- main technical challenges:
  - gas contaminations (tars, humidity....)
  - CO- emissions

Thank You for Your Attention

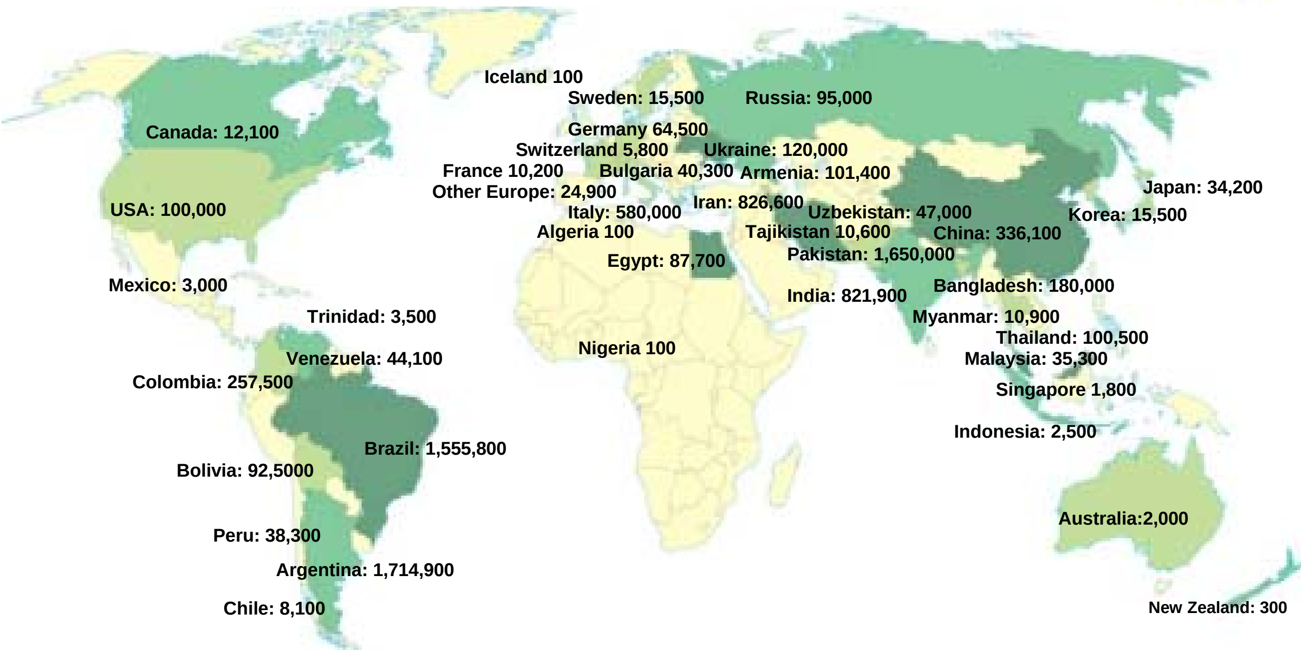
GE imagination at work

The future role of biomethane as a vehicle fuel

Peter Boisen
Chairman of NGVA Europe … for sustainable mobility

peter.boisen@ngvaeurope.eu

9.1 MILLION NGVs WORLDWIDE IN SEPT, 2008
(4 million at the end of 2004)



Source: The GVR, Sept 2008, adjusted

7,686,400 cars, 179,700 buses, 143,000 trucks, and 1,033,400 other vehicles now running on natural gas and biomethane, using 25,4 billion Nm3 of methane annually (21.8 Mtoe). A total of 13,000 filling stations worldwide.

NGVs as % of all cars, trucks, and buses

- Iran 75.0 % (no NGVs five years ago!)
- Pakistan 58.7 %
- Armenia 30.4 %
- Argentina 22.5 %
- Bolivia 19.4 %
- Bangladesh 19.3 %
- Colombia 16.1 %
- Malaysia 9.3 % (?)
- Tajikistan 6.5 %
- Brazil 4.4 %
- Peru 3.2 %
- Myanmar 3.1 %
- Kyrgyzstan 2.9 %
- Egypt 2.8 %
- Uzbekistan 2.8 %
- India 2.3 %
- Moldova 2.1 %
- Bulgaria 1.92 %
- Venezuela 1.56 %
- Italy 1.48 %
- Ukraine 1.35 %
- Trinidad & Tobago 1.22 %
- Georgia 0.60 %
- Belarus 0.44 %
- Thailand 0.40 % (?)
- China 0.39 %
- Chile 0.35 %
- Sweden 0.33 %
- Singapore 0.28 %
- Lichtenstein 0.20 %
- Russia 0.19 %
- Switzerland 0.15 %
- Korea 0.14 %
- Germany 0.13 %

Please note that the fuel market share is often larger than the vehicle market share
NGVs can no longer be dismissed as niche vehicles only

How well known are gas powered cars?

NGVs per 1000 inhabitants

- Argentina 41
- Armenia 33
- Iran 13
- Bolivia 10
- Italy 10
- Pakistan 10
- Brazil 8
- Bulgaria 6
- Colombia 4
- Trinidad & Tobago 3
- Sweden 2
- Venezuela 2

Present NG bus fleets

- China 45,300
- Ukraine 30,500
- Korea 15,100
- Colombia 13,800
- India 12,000
- USA 11,000
- Armenia 9,800
- Russia 8,000
- Myanmar 6,400
- Egypt 5,400
- Thailand 4,500
- Iran 2,600
- Italy 2,300
- France 2,000
- Bangladesh 1,600
- Germany 1,400
- Japan 1,400
- Australia 1,300
- Spain 800
- Sweden 800 (15 of 19 cities with gas buses completely depend on biomethane)

Present NG truck fleets

- Russia 35,000
- Ukraine 29,500
- Armenia 19,600
- Japan 18,500
- Thailand 11,000
- Colombia 9,700
- Bangladesh 8,400
- Egypt 3,400
- USA 2,500
- Italy 1,200
- Spain 800
- India 700
- France 700,
- Poland 400
- Sweden 400
- UK 300
- Korea 300
- Indonesia 200
- Latvia 200
- Australia 100
- China 100

HD potential in all of Europe

- Totally some 800 million people
- About 1200 HD buses per million people -> total fleet around 1 million, meaning up to 100,000 new buses every year (10 year life time)
- About 6000 HD trucks per million people -> total fleet around 5 million, up to 600,000 new trucks every year (8 year life time)
- Present HD NGV fleet about 60,000 buses and 90,000 trucks
- About one million buses and five million trucks annually use some 250 million tonnes of diesel oil, thus emitting close to 800 million tonnes of CO2.
- Dual fuel vehicles using natural gas could save some 160 million tonnes of CO2 emissions – or more than 600 million tonnes if instead using biomethane.

Average annual deliveries (million Nm3) per fuelling station

- China 4.1
- Egypt 2.6
- Chile 2.6
- Ukraine 2.5
- Malaysia 2.2
- Bolivia 2.0
- India 1.9
- Colombia 1.7
- Argentina 1.7
- Brazil 1.6
- Bulgaria 1.5
- Belarus 1.4
- Armenia 1.4
- Peru 1.3
- Russia 1.3
- Bangladesh 12
- Lichtenstein 1.2
- Kyrgyzstan 1.2
- Uzbekistan 1.2
- Slovak Republic 1.1
- Thailand 1.0
- Italy 1.0
- Trinidad & Tobago 1.0
- Tajikistan 0.94
- Moldova 0-86
- Turkey 0.80
- Spain 0.69
- Venezuela 0.66
- USA 0.60
- Sweden 0.47
- Finland 0.47
- UK 0,39
- Iceland 0.36
- Poland 0.33
- Japan 0.27
- Canada 0.27
- Macedonia 0.24
- Luxembourg 0.17
- Germany 0.17
- Czech Republic 0,13
- Croatia 0.08
- Switzerland 0.08
- Mexico 0.08
- Serbia 0.03
- Austria 0.02
- Average 1.4

Rumours that all future new models from Volkswagen,Seat, Skoda and Aud will have a basic design allowing the introduction of NG/biomethane versions

Tuesday, December 18, 2007

VW Will Offer Turbo CNG Passat

By Brendan Moore

12.18.2007

Quick, what's the most popular fleet car in Germany?

You are very smart to guess the Volkswagen Passat. And according to an article in *Automotive News Europe*, Volkswagen is being very smart by planning to offer a version of the Passat that will run on either gasoline or compressed natural gas (CNG). CNG is currently selling at .90 euro a liter while gasoline is priced at 1.35 euro a liter.

The Passat will offer the world's first turbocharged engine that will run on either gasoline or CNG. The engine is reputed to be a version of VW's 1.4 liter turbocharged engine and is expected to produce a minimum of 150 hp.

Fiat, Opel and Peugeot are reportedly all working on similar powerplants.

Combi as well as sedan, manuals and automatics, less than 130 g/km CO_2, 420 km range on gas

Germany will have 1000 CNG filling stations by 2009…..this vehicle can be expected to sell in very large numbers.

Germany and Austria committed to the 2020 target 20 % biomethane share in all methane used for transports.

Do you remember how turbo diesel sales took off in the mid 80s?

Confirmed Fiat policy October 2008

All new car models from now on developed by Fiat will have a basic design allowing the introduction of NG versions

NGV product news
light duty passenger cars and vans

- **Fiat Panda Aria concept car, 2-cyl turbo, start/stop micro-hybrid, 0.9 litre, 80 hp, 69 g/km CO2 on a blend of 70 % NG and 30 % hydrogen**
- **Hyndai i10 Blue CNG concept car, 3-cyl turbo, start/stop micro-hybrid, 0.8 litre, 97 hp, 65 g/km CO2**
- **Audi 2.0 litre TSFI engine (with power ratings between 170 and 220 hp) may be offered with soft hybrid solution including start/stop and also recovery of braking energy, and also available in NG version. This engine is also conisdered for a NG version with an underfloor CNG cylinder installation..**
- **IFP study of Smart NG version reaching CO2 emissions of 80 g/km**
- **Opel Corsa and Skoda Octavia NG concept cars have been shown**
- **Peugeot has launched plans to build two new engine factories for 3-cylinder turbo engines (which would be ideal for NG applications)**
- **MagnaSteyer has shown concept offroad (all wheel drive with 45 % climbing power) hybrid NG concept car Mila Alpin with CO2 emissions below 100 g/km**
- **Brazilian Obvio trifuel (NG/E85/gasline) plug-in hybrid concept car with CVT transmission and 1.6 litre engine with 200 hp**
- **Rumours that all future Volkswagen, Skoda, Seat, and Audi models will be engineered to allow underfloor CNG cylinder installations, more firm rumours that also the Touran from early 2009 will be available with the NG compressor/turbo engine soon available in Volkswagen Passat**
- **New MB B-class 170 NGT already on the market**
- **Fiat Punto Grande, Opel Zafira turbo, and Volkswagen Passat (both sedan and wagon) with compressor/turbo charged engines soon on the market**

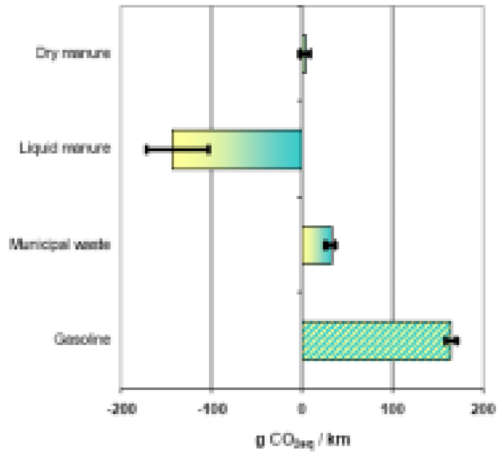
2009 likely to become a year with a fast expansion of the fleets of European NG passenger cars – higher performance engines, improved range, further reduced CO2 emissions, and a real potential for fast substitution of oil based fuels.

A modern gas car (MB B-class 170 NGT), a modern filling station, a modern fuel

picture supplied by Fordonsgas Sverige AB) – photography Nils-Olof Sjödén

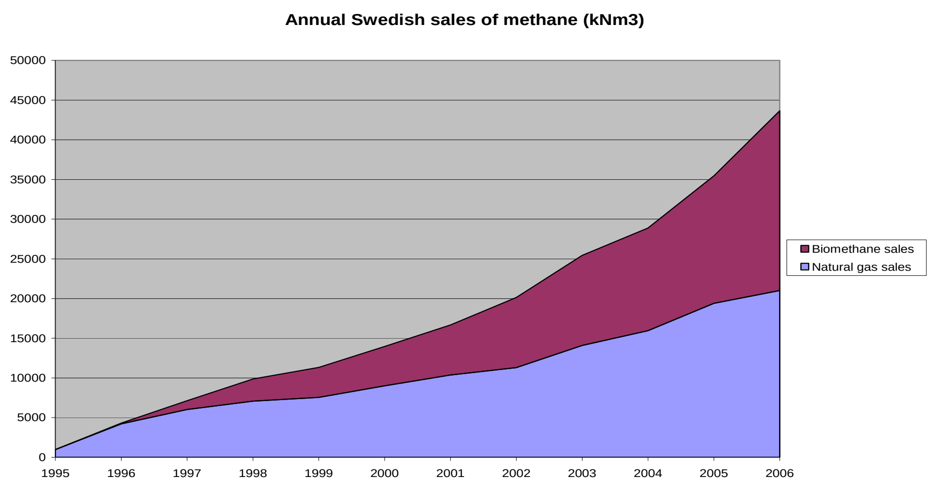
Lidköping

Biomethane GHG performance



Data from Concawe/Eucar/JRC study

BIOMETHANE MARKET GROWTH IN SWEDEN (kNm3)



Methane now accounts for 0,50 % of the Swedish road fuels. With an annual growth of 35 % the market share will reach 2 % by 2010. Biomethane already accounts for more than 50 % of all methane sold.

Commercial vehicles

- Dedicated HD spark ignited NG engines continue to offer the largest reductions of air pollution in urban areas. First examples of hybrid technology in HD NG vehicles now coming onto the market.
- Dual fuel engines a very attractive choice in long haulage goods traffic. Offers the same fuel efficiency as diesel engines meaning very large reductions of CO2 emissions and very low fuelling costs. Some concepts offer capability to run on diesel only (in areas without access to natural gas), other concepts can only run in dual fuel mode.
- Use of onboard LNG fuel storage offers opportunities for increased operating range.

PROPOSED SWEDISH L-CMG INFRASTRUCTURE
(2- 300 km between stations)

Infrastructure for 200,000 ton annual diesel substitution (3 % of Sweden's transportation fuel requirements)

LMG production*	€ 12 million
20 LMG trailers	€ 6 million
24 L-CMG stations	€ 10 million
Total investment	€ 28 million

Specific investment costs € 0,01/Nm^3

*Both liquefied biomethane and liquefied NG

From a study made by Vattenfall Power Consultants

Biomethane potentials

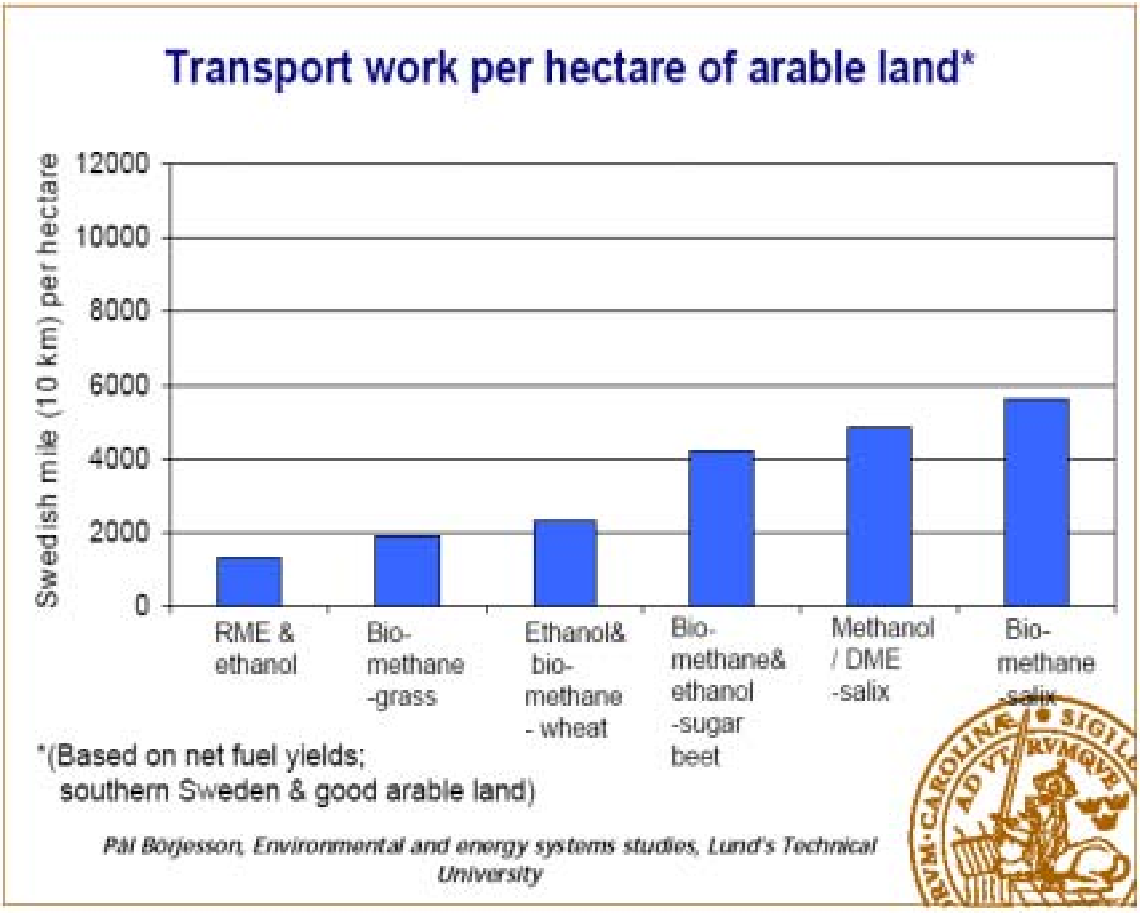
Waste based fuels

- Some 15 % of the European fuel needs in the transportation sector could be covered by biomethane derived from *anerobic digestion* all kinds of biodegradable waste

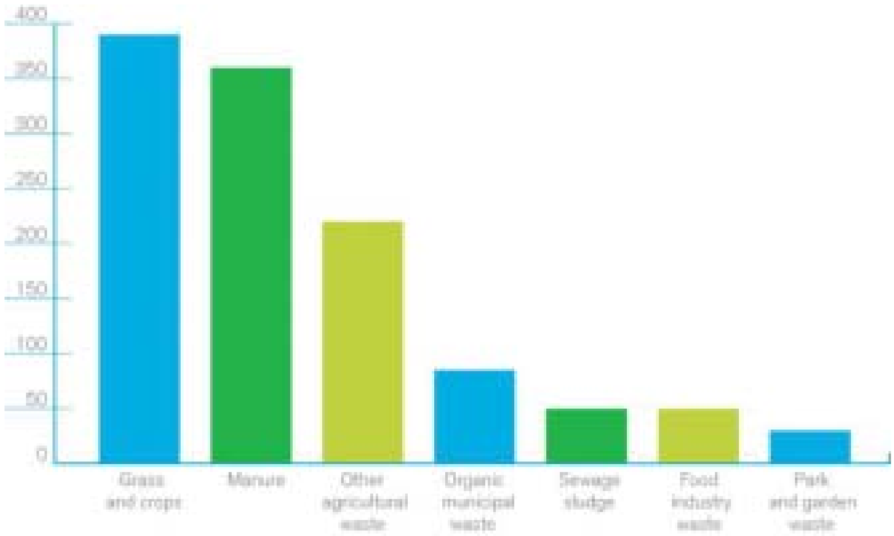
- In countries with an established forest industry the residuals and waste products can be processed via *gasification* to produce biomethane. The potential, of cause, varies from one country to another.In Sweden a recent estimate states a potential corresponding with not less than 75-105 % of the present total Swedish demand of fuels for road transports.

Crop based fuels

- To the extent that crops will be used for production of fuels, biomethane offers much higher fuel yields per hectare of land than other alternatives.



EU-15 *THEORETICAL* BIOGAS POTENTIAL 1200 TWH
(THE TOTAL USE OF ROAD FUELS IS ABOUT 3200 TWH OR 275 MTOE)



The German Wuppertal institute in January 2006 released an estimate that up to 20 % of all road fuels could be replaced by biomethane

Synthetic fuel potentials

- Using forest industry waste to make biomethane net energy conversion yields of 56-65 % have been demonstrated, and above 70 % targeted
- For various competing wood based options like DME, methanol, or FT diesel net yields of 55 % are targeted, for ethanol perhaps only 40 %. Why settle for 40 or 55 %, if you could get 70%?

Countries with ongoing commercial projects for supply of biomethane as a vehicle fuel

- Korea
- China
- India
- Pakistan
- Spain
- France
- Switzerland
- Austria
- Germany
- The UK
- The Netherlands
- Sweden
- Norway
- Iceland
- Brazil
- The USA

Production of raw biogas which is flared, or used to generate electric power and/or heat, already occurs in most countries. Biogas production technologies are thus well known, but upgrading of the gas to a quality on par with, or better than pipeline gas, and thus fit for use in vehicles, is new.

Strong European Parliament support for injection of biomethane into NG grid. Gas injection safeguards efficient use when required.

Biomethane from waste – potentials

- One million people will directly or indirectly generate enough organic waste to annually produce at least 100 million Nm3 of methane gas, and simultaneously large volumes of good fertilizer.
- 100 million cubic metres would cover the fuel needs in 100,000 cars. The required investment would, excluding facilities for waste handling and pre-treatment, be around € 100 million.
- Each AD plant would typically produce between 2 and 5 million cubic metres annually - say 30 plants for every 1 million human population. The capital costs would be in the order of € 0.1 per Nm3 delivered pure methane gas and total costs on average around € 0.6 per Nm3.
- Gas from old landfills could be purified with cryogenic technology to produce pure LMG which can be transported using tank trucks. The gas could be supplied at a cost below today's natural gas price.

Liquefied biomethane



•Cryogenic technology used for up-grading and purification of biogas or landfill gas

•Two products, liquefied biomethane (-160°C) and liquefied CO2 (-78° C)

•Cost and energy efficiency in transportation of liquefied methane

•Refueling stations with both compressed and liquid methane, and 2/3 saving on maintenance and operational costs.

Sweden is not the only country in the world without an NG pipeline network reaching all parts of the country

Three words of warning

1. Since the late 90s the efforts to promote the use of NGVs have been met by promises of future much more efficient H2/FC vehicles. Ten years later these vehicles are equally far from a commercial reality. Promises offer no help today.

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2. The gradual realization that liquid biofuels made from crops may, in fact, not at all, or only marginally, contribute to GHG avoidance, now leads to the promotion of "2nd generation liquid biofuels" made from ligno-cellulosic biomass. That these fuels are less efficient than biomethane made from the same resource is a fact ignored by the defenders of the status quo. Vehicles should, in their opinion, use liquid fuels. Well, use LNG, if you like.

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3. The third defense against really changing vehicles and refuelling infrastructure is the promise of "plug-in hybrids". A plug-in passenger car, however, needs some 2 kg of batteries per/km range. "Refuelling" takes hours, not minutes. If we assume that a minimum range of 150 kms is required to meet a broad consumer demand this means a vehicle with 300 kgs of battery weight. Please show me the true energy balance for this vehicle, and for a comparable vehicle fuelled by NG/biomethane!

Conclusion

We cannot always find a new excuse not to take action.

In countries with limited financial resources, and with huge pollution problems, the solution has already been found – in the short to mid term natural gas, but at the same time a gradually increasing share of biomethane.

NGVs will also very substantially reduce GHG emissions

Also, there is no conflict between the use of methane, and the use of hybrid technology.

No vehicle will benefit more than an NGV from the use of this technology.

Stored electric power should be used to power the vehicle at low engine loads when a spark ignited NG engine is not as efficient as a diesel engine.

Fuel savings will also reduce the need for required comparatively costly gas cylinders.

The future

A WWF report in April 2007 introduced the discussion of sustainable and non sustainable biofuels. The same report recommended increased use of NG as a vehicle fuel in a short and mid term perspective – for a more sustainable future.

The EP review of the draft EU directive (Jan 23, 2008) on renewable energy and biofuels now highlights three resources – all kinds of organic waste, aqua cultures (algae), and grass or crops only from 'degraded' agricultural land

Even if it would be possible to maintain crude oils supplies, meeting the world demand at a reasonable price, we cannot continue to increase the CO2 emissions.

Sunshine, wind, and water can be used to generate electric power, but not fuels. Let us prioritize the use of available biomass resources for use as fuels, and let us choose the biofuel alternatives that will maximize oil substitution.

No other biofuel can compete with biomethane in terms of fuel per tonne of waste, or per hectare of cultivated land.


"Towards a clean and sustainable mobility"
International Conference & Exhibition
GNV2009
madrid, españa
June 17-19, 2009
Madrid Fair, Pavilion 1 - Spain
www.gnv2009madrid.com
info@gnv2009madrid.com
hosted by
NGVA
europe
organizer
NGV
communications group

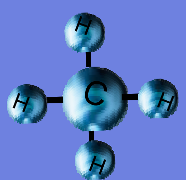
Biomethane as a Vehicle Fuel

International Conference on Gasification
Presented by: T L Fletcher, BSc
10th October 2008

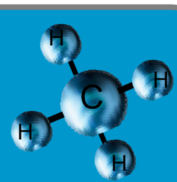
Motivating Forces

The move to Natural Gas is not solely driven by reduced operating costs:

The economic and environmental climate is the greatest motivating factor

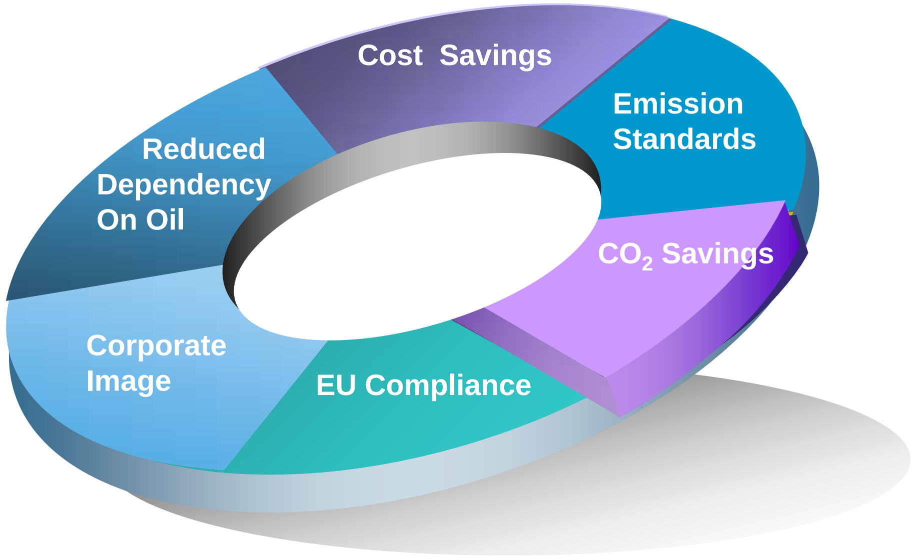


Escalating fuel costs and possible disruption in supply of imports from politically unstable countries accelerated the demand for alternative fuelled vehicles



Government initiatives

Advantages



EU Limit Values

	Unit	**EURO 3** Diesel/Gas	**EURO 4** Diesel/Gas	**EURO 5** Diesel/Gas
CO		5.45	4.0	4.0
HC		-	-	-
NMHC	g/kWh	0.78	0.55	0.55
CH_4		1.6	1.1	1.1
NO_X		5.0	3.5	2.0
PM		0.16/0.21 [1] [3]	0.03 [2]	0.03 [2]
SMOKE	M^{-1}	-	-	-

[1] For engines having a swept volume of less than 0.75 dm3 per cylinder and a rated power speed of more than 3000 min^{-1}

[2] For natural gas engines only

[3] Not applicable for gas engines – Euro 3 stage

CO_2 Emission Reduction

Substitution Rate %	CO2 reduction%	Saving per vehicle per Year (Kg)
50%	13.75%	16315
55%	15.08%	17893
60%	16.42%	19483
65%	17.83%	21156
70%	19.17%	22746
75%	20.58%	24419
80%	21.92%	26009
85%	23.33%	27682
90%	24.67%	29272

Long Haul Vehicle: based on 75,000 miles per year and 7.5 mpg
Note: 1 litre of diesel emits 2.61Kg CO2

Storage

LNG Tank

Cryogenic, -160°C, 100psi

or

CNG Tank

High pressure ambient temperature 3600psi

Fuel

	Bio-CNG (CBG)	Liquefied Bio-Methane (LBG)
PROS	•Ambient temperature •Security of supply	•Higher methane content •Summer gas price for winter use
CONS	•Moisture content •Gas price fluctuation (summer/winter)	•Cannot be odourised •Cryogenic •Limited shelf life •Transport by road

Vehicle Storage

	Bio-CNG (CBG)	Liquefied Bio-Methane (LBG)
PROS	•User friendly – easy to fill •Accurate metering •Accurate dash board ‘fuel gauge’ •Ambient temperature •Long cylinder life (20-years) •Well established Standards & Code of Practice •Over 7 million vehicles worldwide using CNG	•Better range availability •Less chassis space required
CONS	•Cylinder inspections required every 3 years •Heavier containment •Requires extra chassis space	•Not easy to part fill •Varied driver acceptance •Limited shelf life •No written standards (currently in progress) •Additional driver training •LNG tanks require re-vacuuming (between 3-5 years)

Station

	Bio-CNG (CBG)	Liquefied Bio-Methane (LBG)
PROS	•Established technology •Low site inventories (no bulk storage)	•Low power consumption (approx. 152 kWh) •Lower capital cost (approx. £0.75m) •No oil carry over •Bio-methane option •Mobility – no pipeline •Modular design •LNG dispensing option
CONS	•High capital cost (approx. £1.6 million) •Higher maintenance cost •Susceptible to oil carry over •High power consumption (approx. 1220kWh) •Specialist engineers required	•Cryogenic bulk storage

Umbilical Trailer

- The umbilical design allows the vehicle to fully jack knife and contains safety break away units for operational safety
- Allows a 6x2 tractor configurations to use CNG as fuel source or as an alternative or addition to LNG

Designed in answer to poor refuelling infrastructure in UK

Infrastructure

HARDSTAFF OIGI® Dual Fuel

LNG Storage & Dispensing

Gas storage facility capable of storing 12-tons of LNG, designed to support outbased fleet operations

Infrastructure

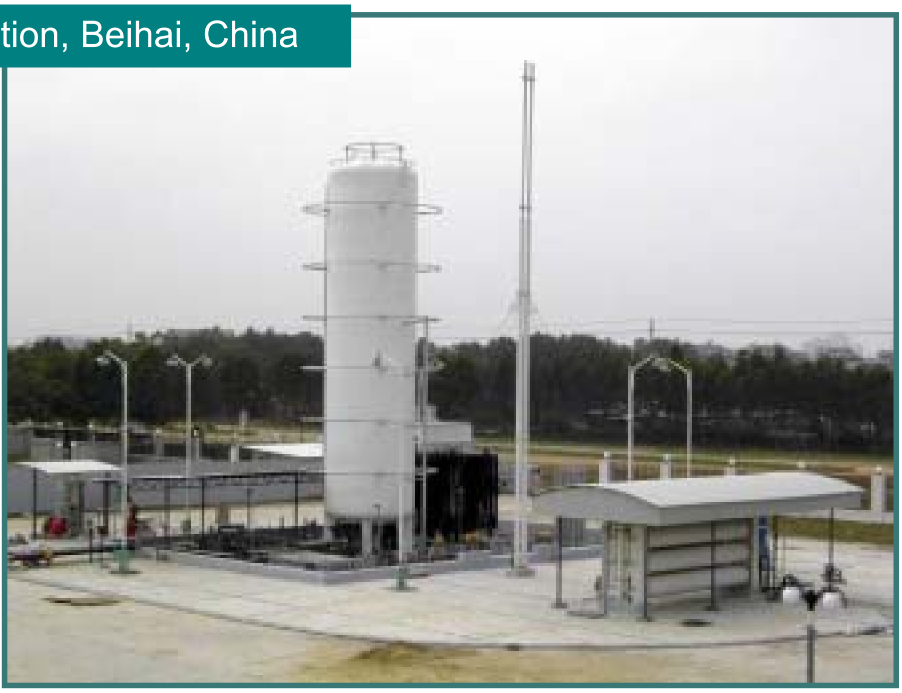
HARDSTAFF OIGI® Dual Fuel

LCNG Station

Infrastructure

Liquid Bio-fuel from Landfill

LCNG Station, Beihai, China



Proposal Overview

Turn-key Project incorporating:

- LCNG Station
- Hardstaff OIGI® Dual Fuel Technologies
- Fuel Supply (LNG & **Bio LNG**)
- After Sales Support
- Warranty
- Health & Safety
- Training Programme

Warranty Parts

- Hardstaff warranty covers all dual fuel components
- Warranty procedure (training and support)
- Manufacturer warranty unaffected (implied warranty agreement)

Marketing Strategy

- Identify key end-users
- Demonstration programme
- Provision of data for governmental and institutional bodies
- Joint marketing strategy

BENEFITS TO END-USER:

- **Retains existing diesel engine (transitional step from 100% diesel)**
- **Not infrastructure dependent**
- **Environmental compliance with significant reductions in greenhouse gases and other pollutants, with highest CO_2 gains**
- **Economic benefits**

Economic Viability

ESTIMATED PAYBACK TIME

- Cost of Natural Gas against diesel
- Fuel economy
- Grant incentives
- Value of CO_2 credits
- **Exemption from congestion charging**

Market Opportunities

OIGI® Dual Fuel technologies can be adapted to any fully electronically controlled fuel injection system, including: -

- Euro 2,3,4 and 5 light and heavy duty vehicles
- Refuse Collection Vehicles (RCV)
- Buses and Coaches
- OIGI® technologies can also be adapted to passenger vehicles

Summary

- Fuel Supply
- Gas Stations
- Technology
- Vehicles
- After Sales

Parallel Paths Process and Integrated Strategies

(collaboration behaviour removing barriers to optimal performance)

Why Hardstaff?

Turn-key concept incorporating:

- LCNG Station
- Hardstaff OIGI® Dual Fuel Technologies
- Fuel Supply (Biogas option)
- After Sales Support
- Warranty
- Health & Safety
- Training Programme

As the leading authorities in this field, let us help you

Biomethane as a Vehicle Fuel

The Hardstaff Group
Hillside, Gotham Road, Kingston-on-Soar, Nottingham, NG11 0DF, UK
Tel: 0044 (0)115 983 2300 Fax: 0044 (0)115 983 1075

The use of gases in metallurgical processes – applications and requirements

Lena Sundqvist Ökvist
MEFOS
- Metallurgical Research Institute AB,
Luleå, Sweden

Content

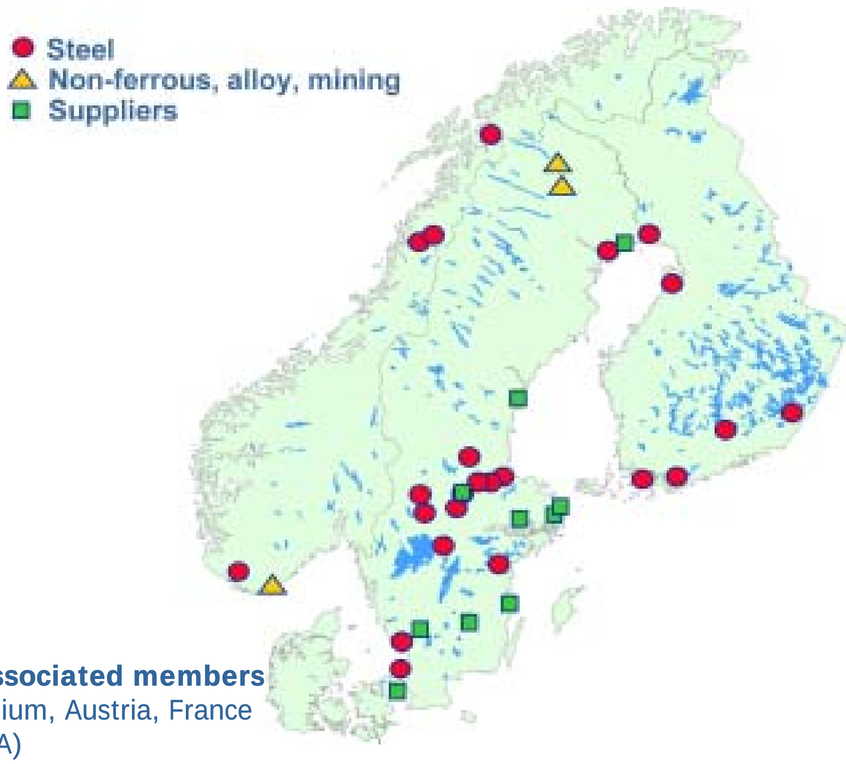
- **MEFOS**
  - a short presentation
- **The integrated steel plant - an example of metallurgical industry**
  - An example of layout
  - Production and use of gas
  - Use of gases and required properties
    - *Heat*
    - *Reduction*
    - *Oxidation*
- **Experience at MEFOS from research in gasification and use of metallurgical gases**
  - CO_2 removal and recycling of blast furnace gas
  - Use of LCV BF gas in heating furnaces
  - Gasification in hot metal bath
- **Conclusions**

MEFOS
- Metallurgical Research Institute AB

MEFOS

MEFOS-
Metallurgical Research Institute AB

Member companies, total 44



Five associated members
(in Belgium, Austria, France and USA)

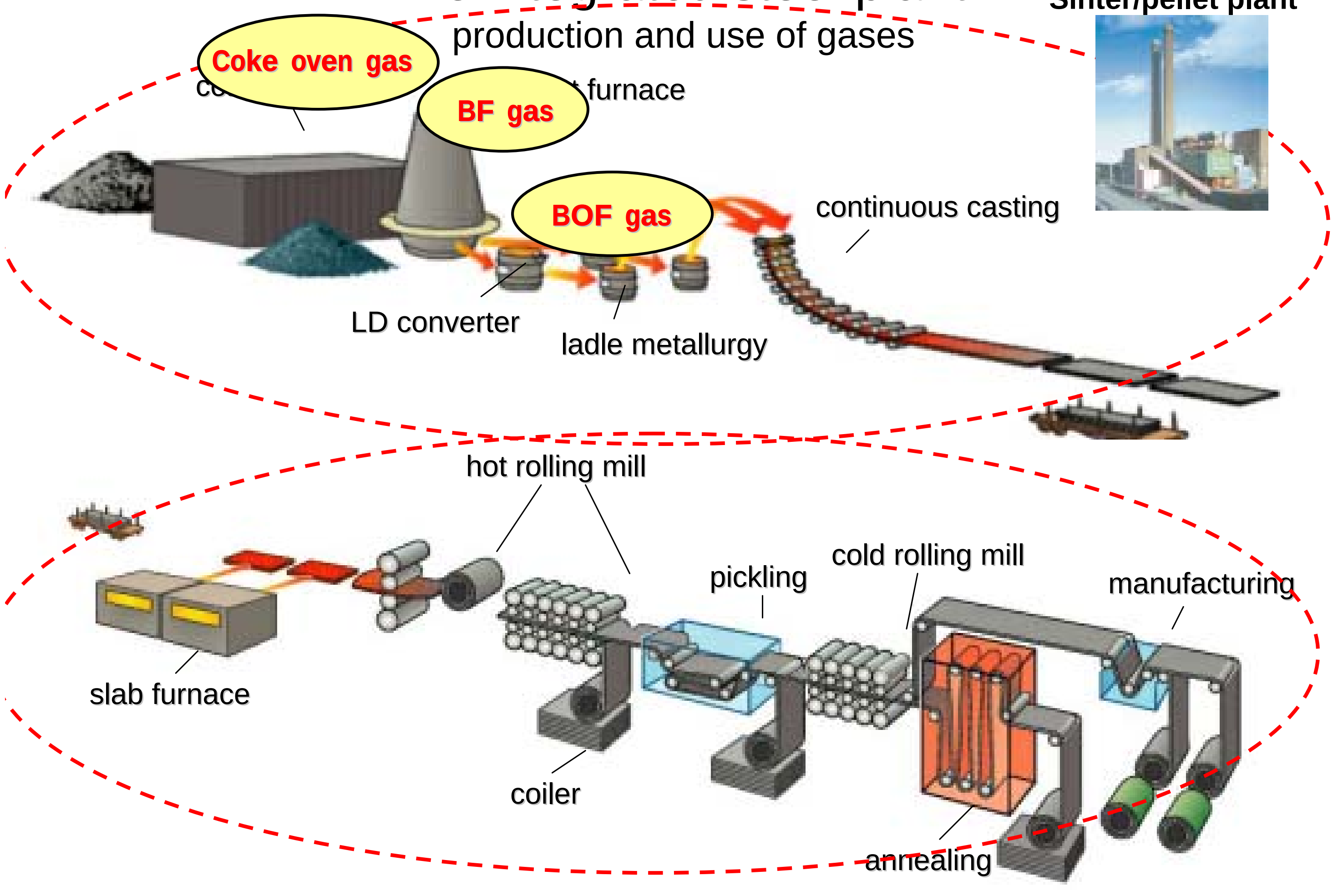
MEFOS

MEFOS
- Metallurgical Research Institute AB

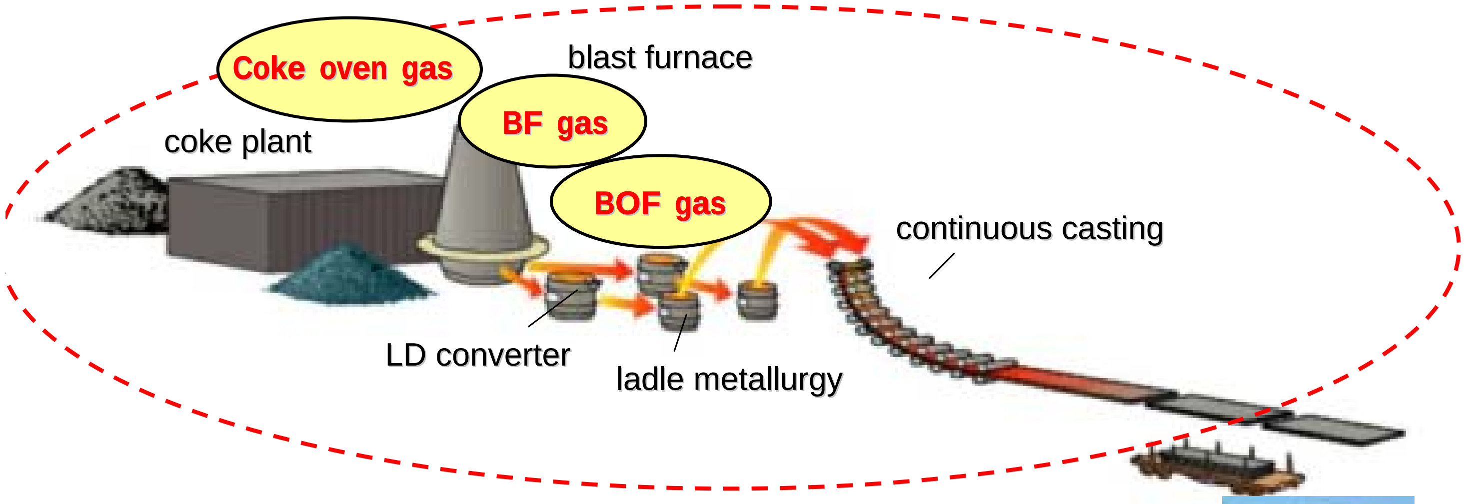
A Nordic institute within the metallurgical area with
- a yearly turnover of 124 Mkr (~12.7 MEuro)
- **industrial-related research**
- *60 % industrial contracts, 40 % collaborative research*
- *77 % is financed by companies*
- project size 0,01-20 Mkr, around 150 projects per year
- international R&D financing amounting to 25-30 %
- large scale pilot-plant equipment
- large network in collaborative research
  (ca 25 institutes/universities, 55 companies)
- large European R&D (**EU, RFCS**)

MEFOS

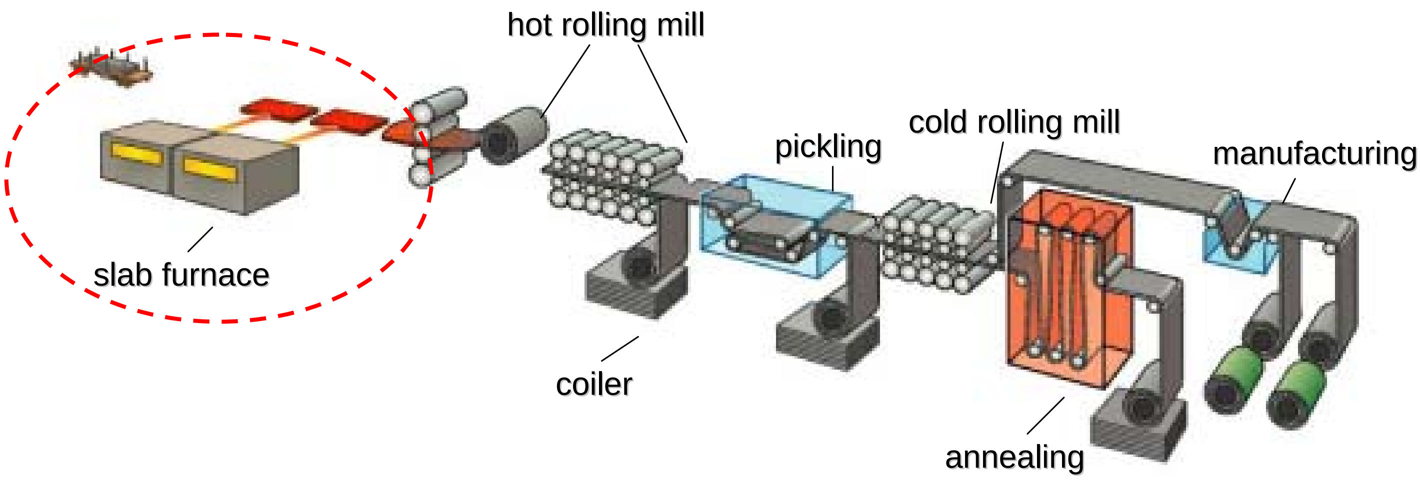
The integrated steel plant-



The integrated steel plant facilities e.g. in Luleå



The integrated steel plant e.g SSAB site in Borlänge



Properties of gas to consider

- **Gas can be used for**
  - **Reduction**- *e.g. BF, gas based direct reduction*
  - **Heating/melting** – *e.g. slabs before hot rolling, melting of lead scrap in BF, melting of iron in cupola furnace*
  - **Oxidation/sintering** - *e.g. in pelletizing plant*
- **Heat supply to the process**
  - **Heat value**
    - decomposition of hydrocarbons
    - combustion to CO_2
  - **Reduction gas**
    - ***partial combustion*** and generation of a gas containing $\mathbf{H_2}$ **and CO**
- **Content of impurities as e.g**
  - Na, K
  - Cl, F
  - S
  - Heavy metals
  - Alloying elements

Some examples of gases and their composition

- **Heat value of gas of importance for application**
  - *Calorific value varies significantly*
- **Impurities**
  - Cl, F, Na, K, heavy metals
- **Available amount, need e.g in a BF**
  - *Injection rate **50-100 kg/tHM** with a density of 0.8 kg/Nm³ approximately 60-120 Nm³/tHM (gas with high Q_n)*

		NG	COG	COG/BOF	BF gas (ind*./EBF**)	TGR	Anaerobic digester biogas*	Biogas (wood)	LPG⁺⁺
H_2	Vol%		65	4.5	4/3	17		30-60	
Hydro-carbons	Vol%	100	23	0.5			55-70	<1	~100
CO	Vol%		5	57	25/25	74		8-20	
CO_2	Vol%		1.5	20	20/21	1	30-45	22-20	
Qn	MJ/Nm³	**42**	**17.3**	**7.8**	**3/3**	**11.2**	**20-25**	**4-10**	**105**

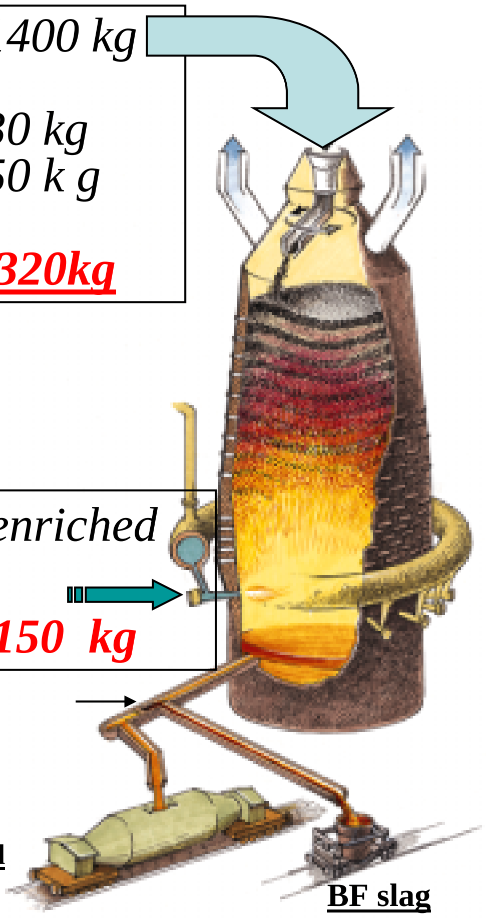
* SSAB Luleå 2007, ** EBF ref sept 2007, ⁺⁺ Shell LPG mix with approx. 55% butane

The BF

Pellets 1400 kg

Limestone 30 kg
BOF slag 50 k g

Coke 320kg



Top gas,
1450 Nm3, 120-150 °C
25% CO_2
20% CO
4% H_2
HV 3MJ/Nm^3

Blast *1000 Nm^3 O_2 enriched air, 1100-1150°C*
Coal injection 140-150 kg

The use of gas injection into the BF

reduction / heat

- **Possibilities and limitations with gas injection**
  - \+ Decreased coke rate
  - \+ Decreased CO_2 emission
  - \+ Possible to operate at a lower temperature, raceway adiabatic flame temperature (RAFT)
  - – Partial combustion to CO may cause local energy deficiency
    - less coke savings
    - accretions due to incomplete combustion may be formed
  - – Fires in BF top

Tapping at the LKAB EBF

The use of gas injection into the BF

- **Industrial applications**
  - Natural gas injection (**NG**)
  - Coke oven gas (**COG**) injection
  - Industrial trials with **COG/BOF** gas injection
- **Experimental trials** at LKAB EBF with recycling of hot top gas after CO_2 removal carried out in a European project (ULCOS) (**TGR**) (a possible composition)

		NG	COG*	COG/BOF*	BF gas	TGR
H_2	Vol%		63	47	4	17
H_2O	Vol%		0.8	1,4		
Hydrocarbons	Vol%	100	25	18		
CO	Vol%		6.9	20	23	74
CO_2	Vol%		1	6	22	1
N_2	Vol%		3	9	51	8
Qn	MJ/Nm^3	41.6	17.3	14.5	3-4	11.2

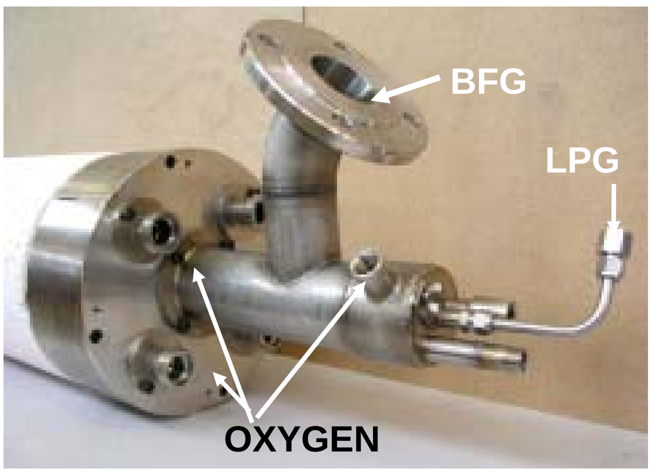
*Tests and operation at Voestalpine Linz

Reheating Steel Firing LCV Gases with Oxyfuel Technology

Linde Gas


MEFOS Chamber furnace used for testing a new BFG-oxyfuel burner


Installation of type S oxyfuel burner



Low-NOx version of oxyfuel burner was developed for BFG combustion based on based on the REBOX® concept at AGA-Linde

BFG-oxyfuel technology
J. Niska* A Rensgard*, T. Ekman**
***MEFOS and **AGA-Linde with EU-RFCS support**

Large Pipelines for LCV Blast Furnace Gas

Linde Gas

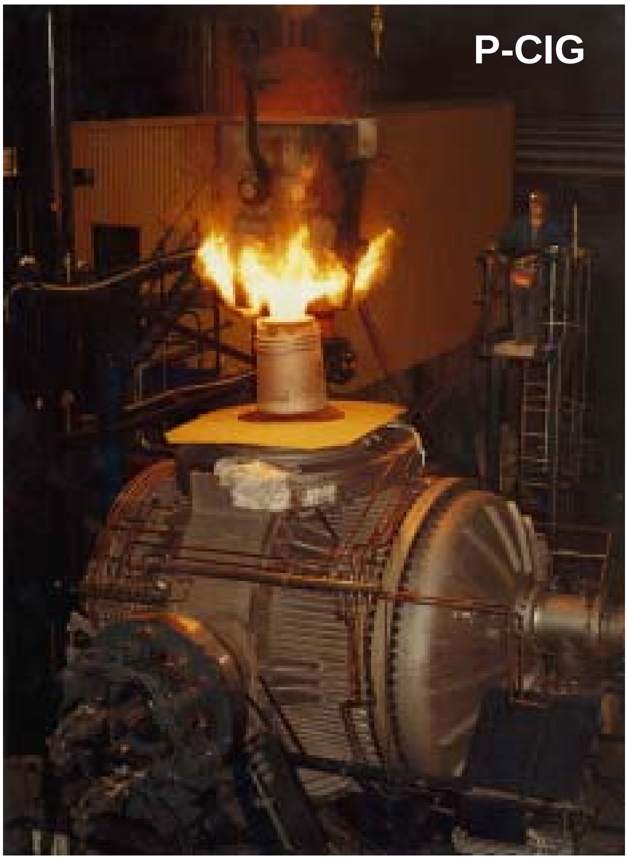
Summary
Potential Use of Low Calorific Value (CV) Gases in Steel Reheating Furnaces

- **Coke oven gas** is already an important fuel for reheating furnaces with conventional air combustion
- **Biogas** from anaerobic digesters has a high enough CV for use without upgrading the CH_4 content
- **BFG** has the lowest CV of steelmaking process gases, but it can be used with oxyfuel technology
  – Pure **BFG- oxyfuel** combustion requires a higher energy input than conventional LPG-air combustion
  – **LPG enrichment of BFG** with oxyfuel combustion can improve the reheating performance

MEFOS

Gasification of coal by injection into molten iron bath

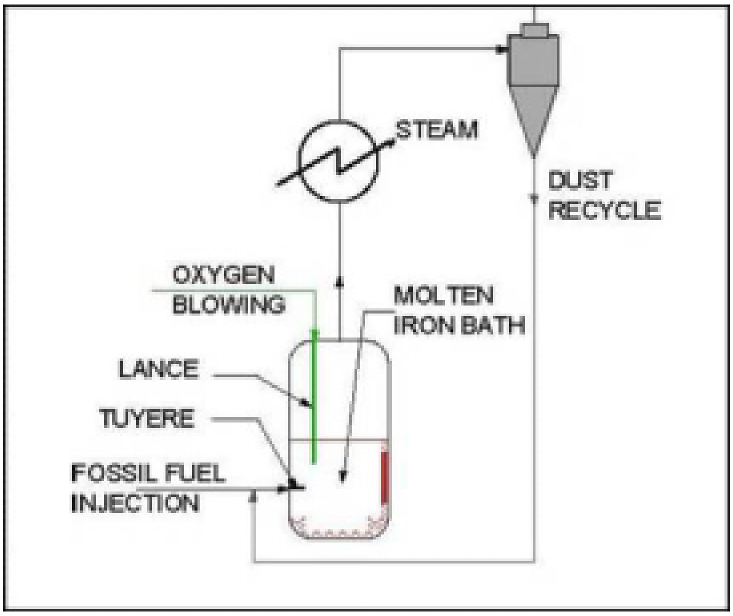
- General characteristics
  - CO and H_2
  - Hot metal bath absorbs impurities, ash forms a molten slag
  - Commercialization planned but not realized
- P-CIG – Pressurized Coal Iron Gasification (1984-85)
  - – Nippon Steel, Interproject Service AB
  - – Full-scale plant designed
- MIP- Molten iron pure gas (1985-1986)
  - – Sumitomo Metals, KHD



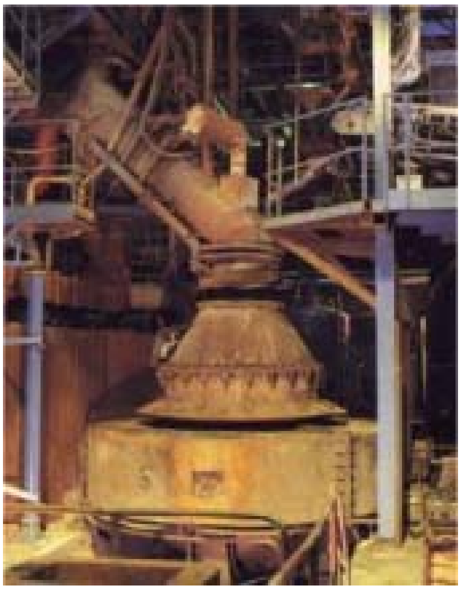
MEFOS

Gasification of coal by injection into molten iron bath

- HYMELT (2003)
  - –EnviROES, DOE (US)
  - –Production of ultra clean fuels
  - –Two gasification steps
    - O_2 blowing $\rightarrow$ CO
    - Coal injection $\rightarrow$ H_2 and carburization of HM
  - – Plan to build 1.1 m in diameter commercial plant (250-300 t/day) in Ashland, Kentucky



The operation of Hymelt



Left, the universal converter at Mefos. Right, charging the tilted converter with the molten metal

Conclusions

- The use of gases in metallurgical processes are widely spread.
- It may be possible to partly replace coke, coal, and oil with gas.
- Use of gas from external supply is highly influenced by
  - Local situation
  - Requirements for actual application and properties of available gas
    - Heat value
    - Impurities

Perstorp
WINNING FORMULAS

SGC Gasification conference

Malmö October 9-10 2008

Perstorp BioProducts AB

Biomethane based production of liquid Fuel components

Lars Lind
Perstorp
VP Business Development

Perstorp
WINNING FORMULAS

Perstorp in brief

The Perstorp Group

- World leader in several sectors of the specialty chemicals market
- 125 years of winning formulas
- Rich performance culture
- Annual turnover of 8.5 billion SEK (2007) Now at run rate 15 BSEK
- Ownership held by PAI partners, a leading European private equity company

Global presence

- Approximately 2600 employees in ten countries
- Production plants in Asia, Europe, North and South America
- Sales offices in all major markets

125 years of winning formulas

- Perstorp in the South of Sweden was formed in 1881 and was a family owned company for over 100 years
- Pioneer in formalin chemistry, plastics and surface materials
- The “new” Perstorp was formed in 2001 when Perstorp merged with Neste Oxo
- PAI partners, a French private equity company, has controlled Perstorp since December 2005
- Owned by a Scandinavian private equity company, Industri Kapital from 2001 until 2005
- Strategy of focused leadership in specialist segments of global markets for specialty chemicals
- Continued development into a world-class company

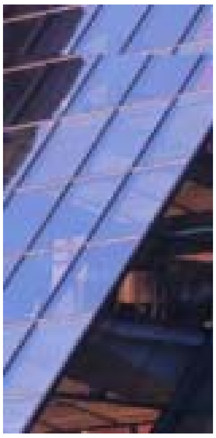
Our owners – PAI partners

PAI partners is an independent investment firm owned by its partners

- PAI is a leading private equity company in Continental Europe with more than €7 billion of funds under management
- PAI has offices in Paris, London, Madrid and Milan
- PAI has a Europe-wide team of 45 highly experienced professionals with diverse backgrounds

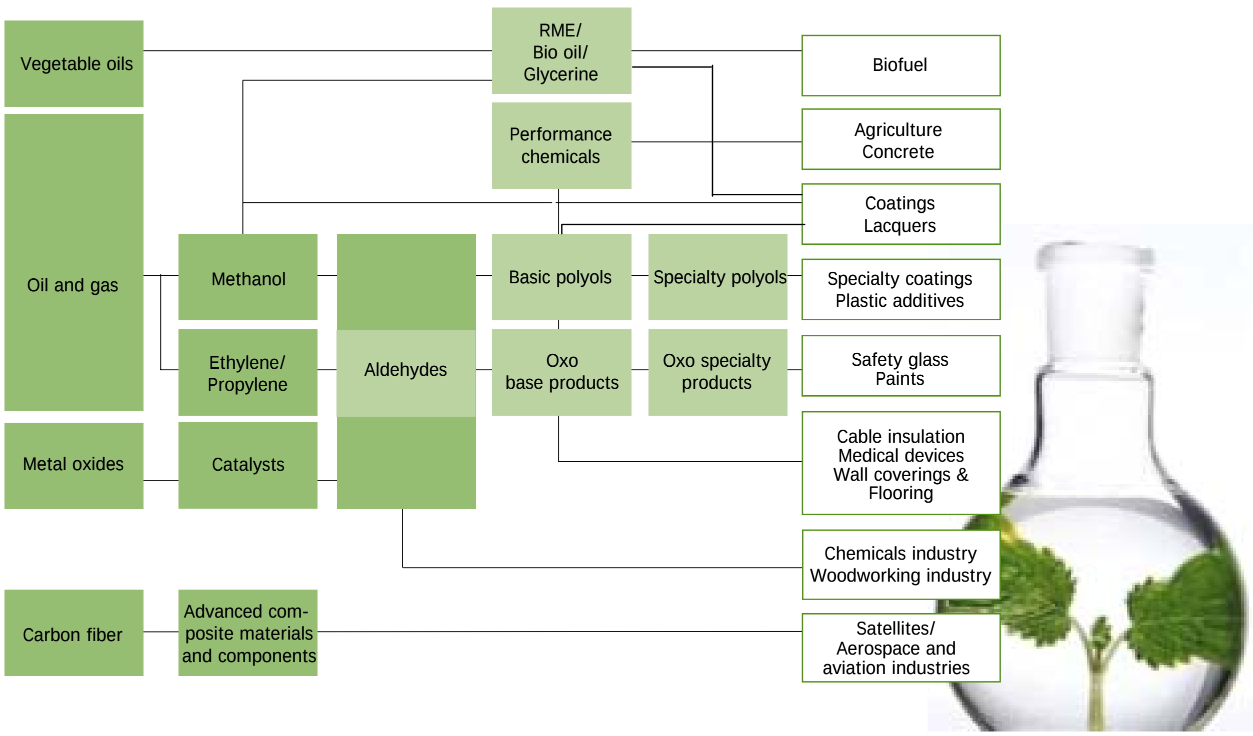
PAI is one of the most active and successful private equity investors in Continental Europe

- PAI is one of the oldest and most experienced European equity sponsors originating from the historical principal investment activity of Paribas
- Dominant sponsor of private equity investments in France
- Large portfolio of investments in the UK, Spain, Italy, Germany, Denmark and the Benelux



Truly global footprint!

Perstorp in the value chain



Perstorp
WINNING FORMULAS

A winning formula for you

The three essential elements of our winning formula

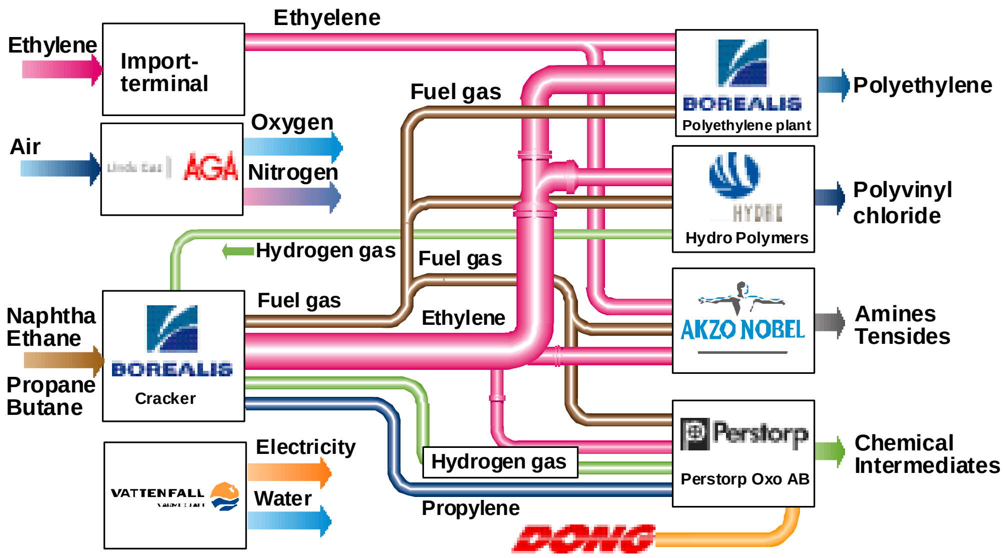
- FOCUSED INNOVATION
- RELIABILITY
- RESPONSIBILITY

Innovation & dedication
delivered globally

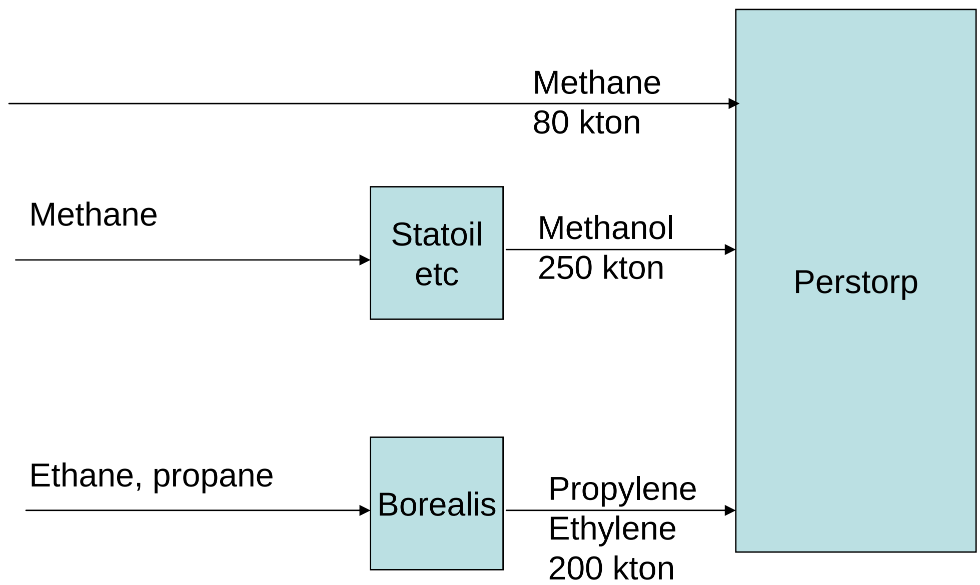
Perstorp
WINNING FORMULAS

Site Stenungsund – Perstorp Oxo AB

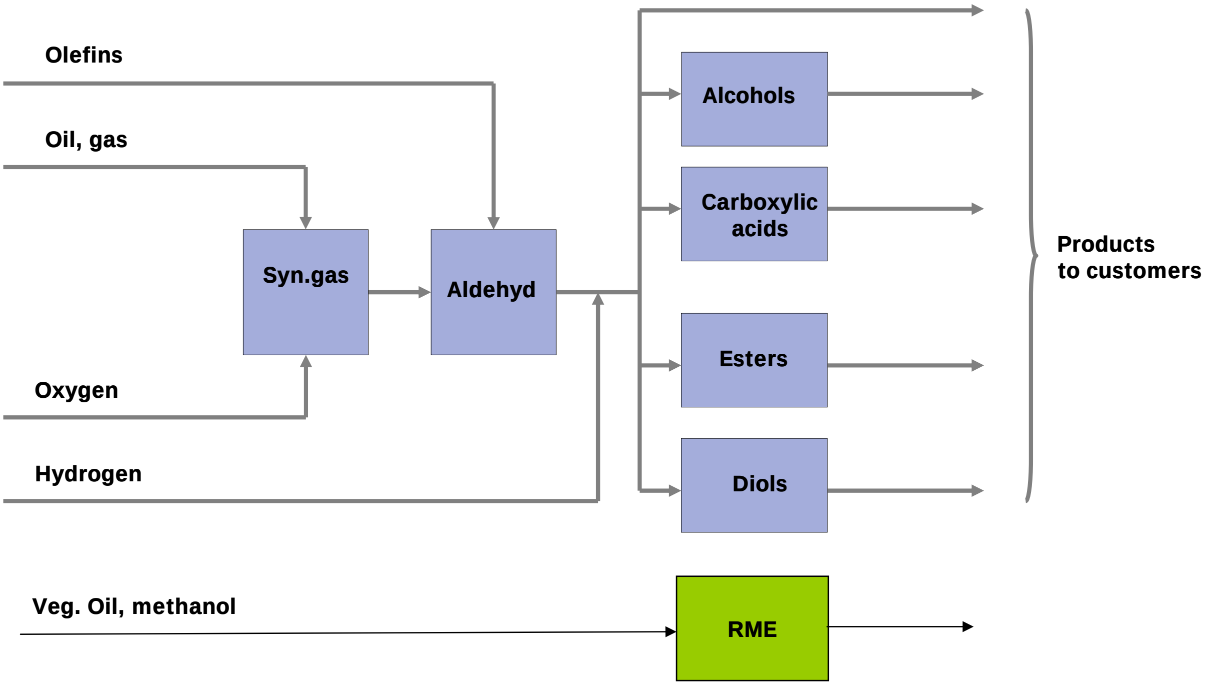
The Petrochemical complex- integration



North Sea Gas consumption by Perstorp



Process Perstorp Stenungsund



Conclusion

- Perstorp uses 750 kton of hydrocarbons as raw material
- The dominating source now, and in the future, is North Sea Gas
- Biological raw materials are emerging, we need to pay close attention to the development
- Synthesis gas is a key route that Perstorp applies already today
- Ethanol to Oxo is the historical route

Perstorp BioProducts

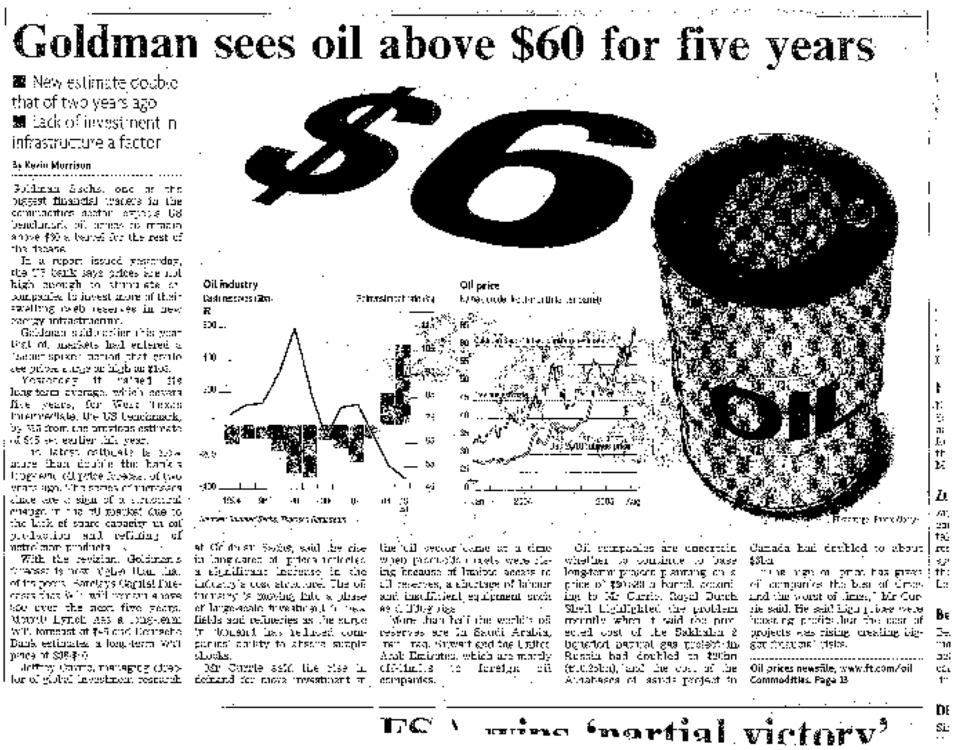
A company within the Perstorp group

New entity including:

-Existing RME
-Bio-Oils
-Glycerol

-Development projects

Lars Lind
Perstorp
VP Business Development



Goldman sees oil above $60 for five years

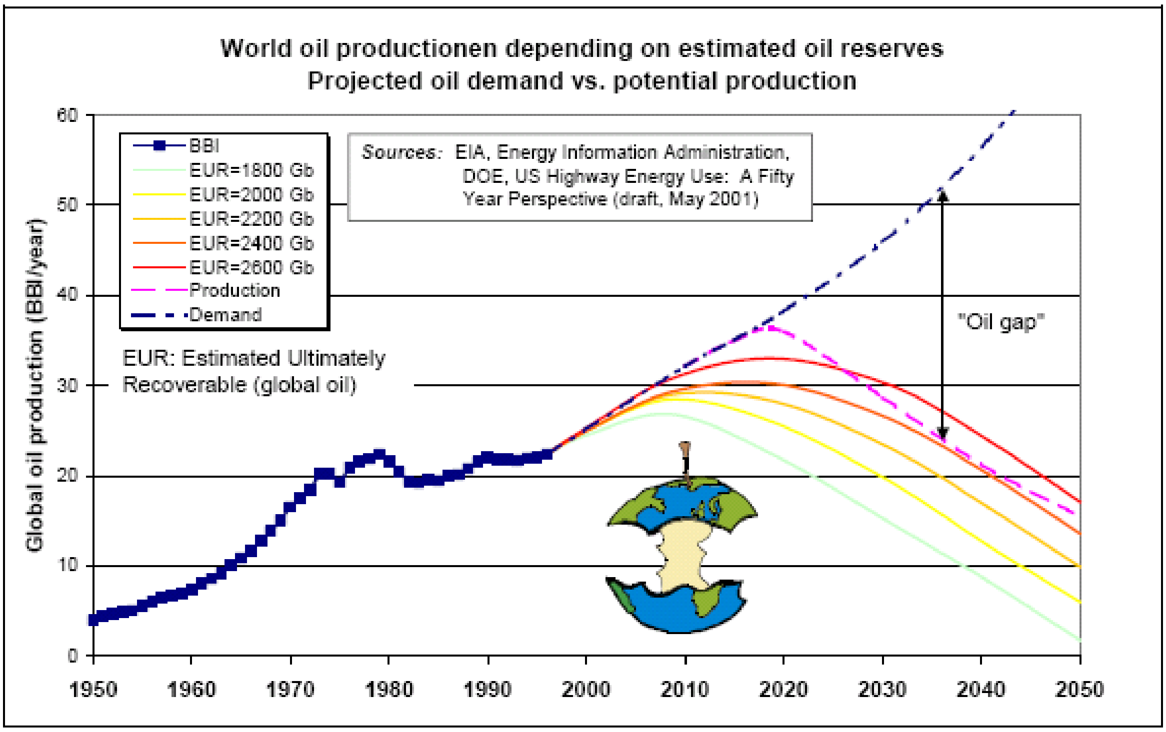
- New estimate double that of two years ago
- Lack of investment in infrastructure a factor

By Kevin Morrison

Oil industry

Oil price

Oil prices newsfile, www.ft.com/oil
Commodities, Page 13



Perstorp - historic roots

- •1880:ies wood dry distillation in Perstorp to oblain MeOH, FH etc
- •1940:ies sulphite liquids fermentation to EtOH and Oxo by MoDo

Perstorp's Biodiesel plant

Non-fossil routes to chemicals

- **Gasification, biogas of any origin converted to syn.gas**
- Fermentation: e.g. ethanol from sugar, starch or cellulose
- Esterification; i.e. chemical conversion of fatty acids
- Hydrogenation; conversion of vegetable oils with hydrogen

Synthesis gas

- Steam reforming or partial oxidation

$CH_4 + H_2O = 3\ H_2 + CO$
$CH_4 + 0.5\ O_2 = 2\ H_2 + CO$

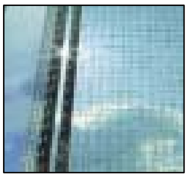
- Direct oxidation

$CH_4 + 0.5\ O_2 = CH_3OH$

Synthesis gas based products

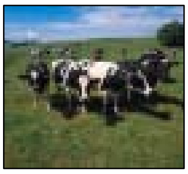
Hydrogen	**Kemira, Eka**	**hydrogenperoxide, fats**
Methanol	**Statoil**	**formaldehyde, plasticsplaster**
Ammonia	**Yara**	**fertilizers**
Oxo	**Perstorp**	**acids, alcohols, esters**
Diesel fuels	**Sasol**	**DME/GTL**

Perstorp Oxo – Examples of products



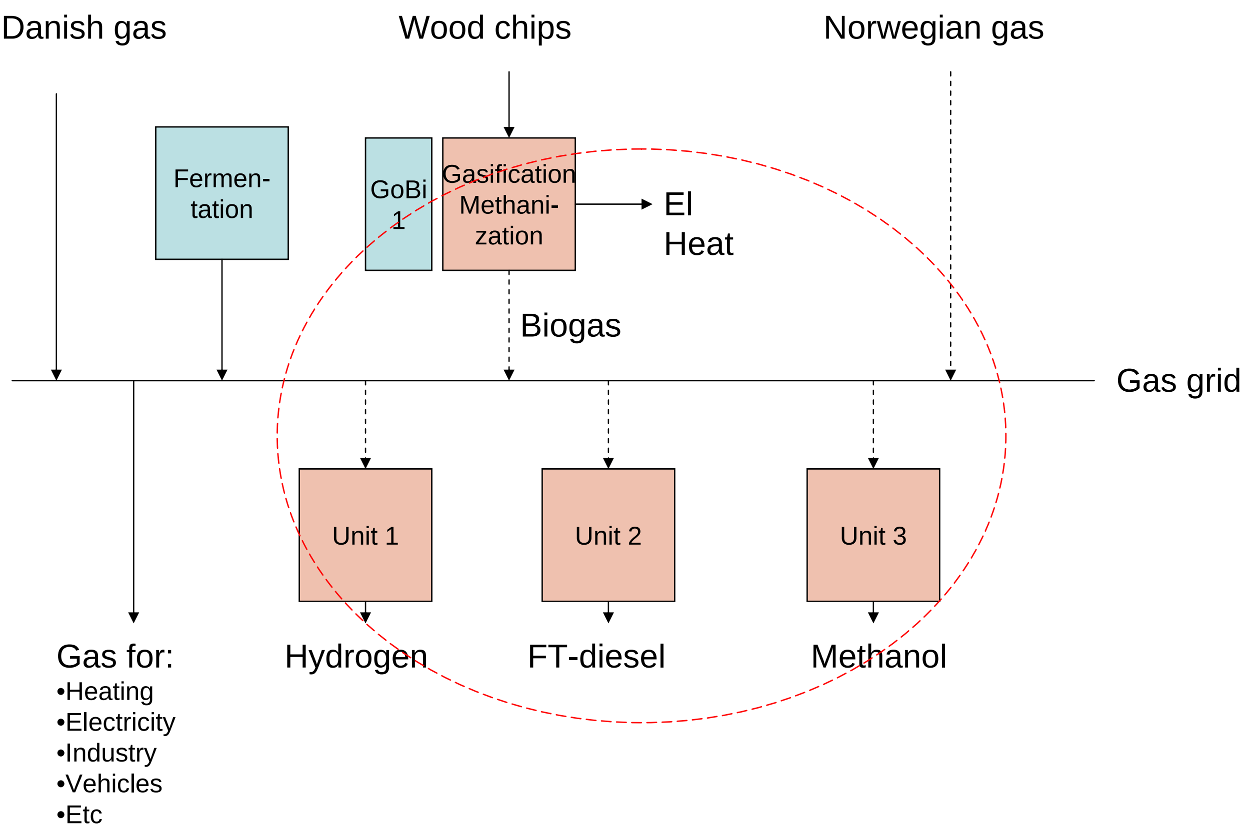
- 2-Ethylhexanoic acid
  - safety glass
  - synthetic lubricants
  - pharmaceuticals

- Butanols and Aldehydes
  - water borne paint
  - powder coating
  - film formers



- Propionic acid
  - animal feed
  - crop prescervatives
  - flavour agents

The ”Green Gas Principle” System



Project Bio-Metanol 09 Scope of work

Target:

To understand the fundamentals of commecial production methanol at the Perstorp Stenungsund site, based on pipeline delivered natural gas/biogas

Sub-targets

- **Specification of optimal commecially available technology**
- **Understand how specified methanol process best is integrated into the existing infrastructure**
- **To obtain relevant variable and fixed costs for choosen process**
- **To have a first indication of CAPEX needed**
- **Develop an implementation plan**

Design basis:

100 kton/år; 12 ton/h
ASTM standard specifikation for chemical grade methanol

Thank You !

Directorate-General for Energy and Transport

Overview of the *Biomass Gasification* Projects co-financed within the Framework Programmes (FPs)

*Gasification – production technologies and applications, **Malmö*** 9-10 October 2008

Anthi CHARALAMBOUS
DG TREN, D2 Technology and Innovation in Energy

EUROPEAN COMMISSION

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1. **Background (energy in figures)**
2. **The Energy & Climate Package January 2008**
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6. **Conclusions**

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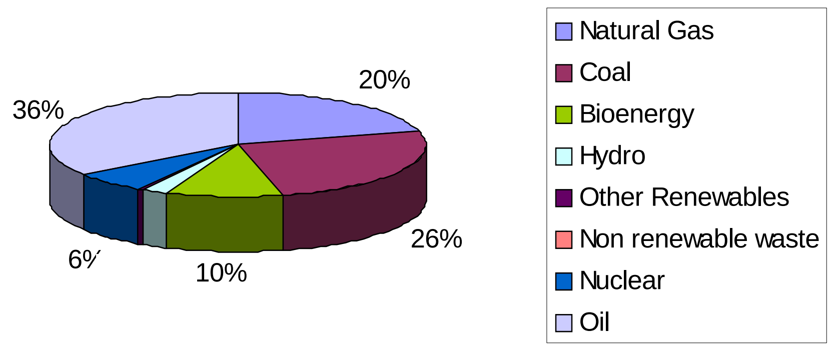
Bioenergy in the Global scene

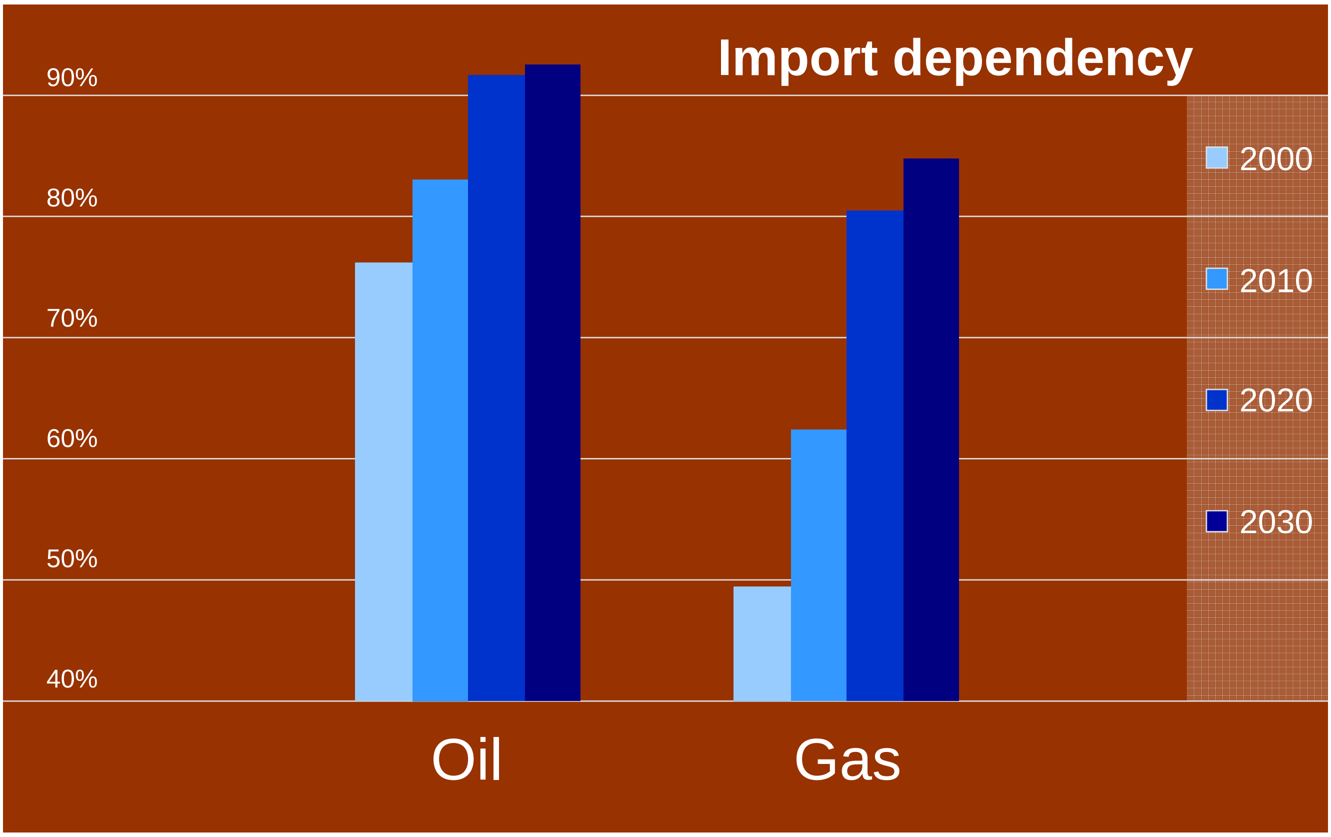
already plays a major role supplying ~10% of world primary energy supplies

Fuel Shares in World Total Primary Energy Supply 2005

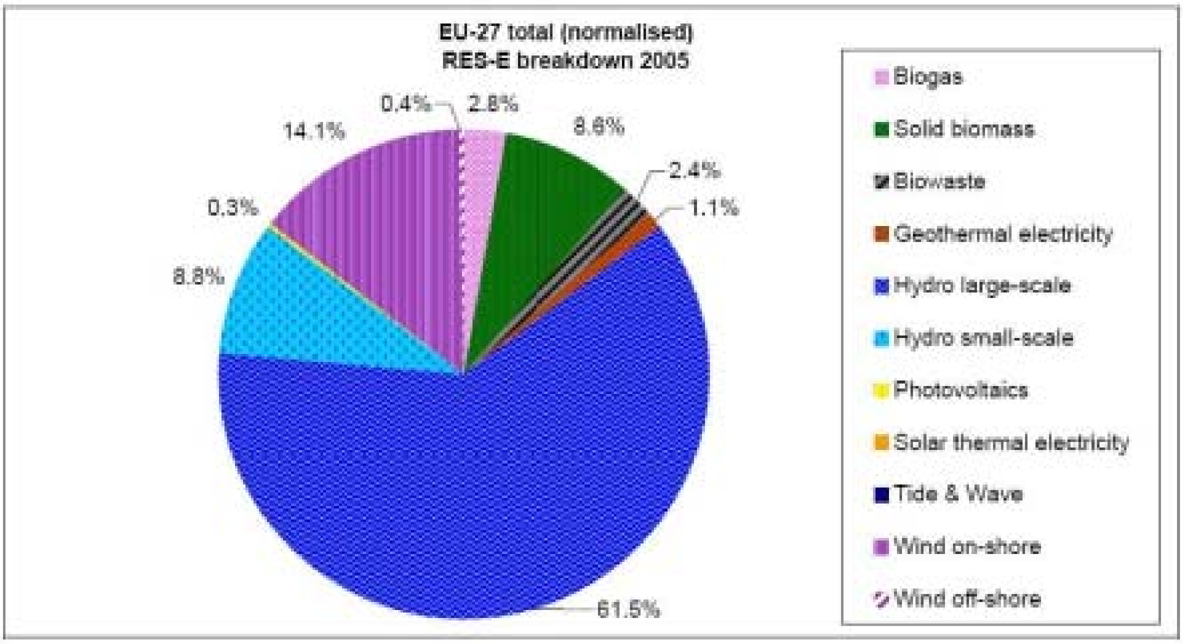


IEA Renewables Information 2007

EU-27 Baseline projection



Breakdown of renewable electricity in 2005 (normalised) for the EU-27



Source: OPTRES, 2007

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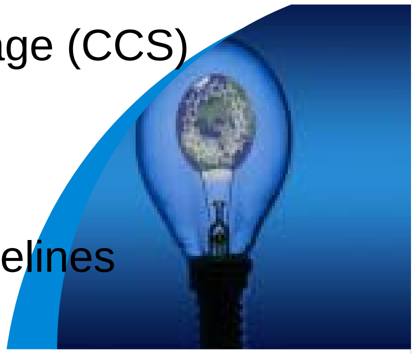
Package of energy and climate measures (January 2008)

- Reform of emissions trading scheme (ETS)
- National targets for greenhouse gas emissions in non-ETS sectors (buildings, transport, agriculture)
- Directive on Carbon Capture and Storage (CCS)
- Renewable Energy Directive
- Reform of environmental state aid guidelines



The RES Directive (1)

1. **Sets mandatory national targets for RES shares, including 10% biofuels share, in 2020 (***Art.3 and 5)*
2. **Requires national action plans** *(Art. 4)*
3. **Standardises "guarantees of origin" (certifying the RES origin of electricity or heat)** *(Art. 6, 7, 8 & 10)*
4. **Enables the transfer of guarantees of origin to give Member States flexibility to meet their targets by developing cheaper non domestic renewable energy** *(Art. 9)*

The RES Directive (2)

5. Reforms, or requires reforms of administrative and regulatory barriers to the growth of RES *(Art. 12)*

6. Requires improvements in provision of information and training regarding renewable energy *(Art. 13)*

7. Improves renewables' access to the electricity grid *(Art. 14)*

8. Creates a sustainability regime for biofuels *(Art. 15-18)*

Promotion of Biofuels (1)

Sustainability criteria for biofuels

GHG savings – minimum of 35%

No raw material from undisturbed forests, biodiverse grassland, nature protection areas (unless taken harmlessly)

No conversion of wetlands and continuously forested areas for biofuel production (to protect carbon stocks)

All EU biofuels must meet "cross compliance" environmental rules

Contents

Directorate-General for Energy and Transport

22 November 'package'

- COM(2007)723 – SET-Plan Communication

Supporting documents:

- SEC(2007)1510 – Technology Map
- SEC(2007)1511 – Capacities Map

Impact assessment:

- SEC(2007)1508 & SEC(2007)1509

http://ec.europa.eu/energy/res/setplan/communication_2007_en.htm

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EUROPEAN COMMISSION

The SET-Plan

Some key technological challenges

- First and foremost, **energy efficient** buildings, appliances, equipment, industrial processes and transport
- Developing **2nd generation biofuels**
- Getting large scale **offshore wind** competitive within the short term
- Getting **photovoltaic** electricity competitive to harness solar energy
- Creating a European **smart, bi-directional, RES friendly grid**
- **Fuel cell and hydrogen** technologies
- **Sustainable coal** and gas technologies
- **Fourth generation fission nuclear** reactors and future fusion technology
- …

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The SET-Plan

Proposals

- **Joint strategic planning** – Steering group + Information System
- **Effective implementation**:
  - **European Industrial Initiatives:** strategic technology alliances.
  - **European Energy Research Alliance**
  - **Trans-European Energy Networks and Systems of the Future –** Transition planning
- **Increase in resources**, both financial and human.
- Reinforce **international cooperation**

Directorate-General for Energy and Transport

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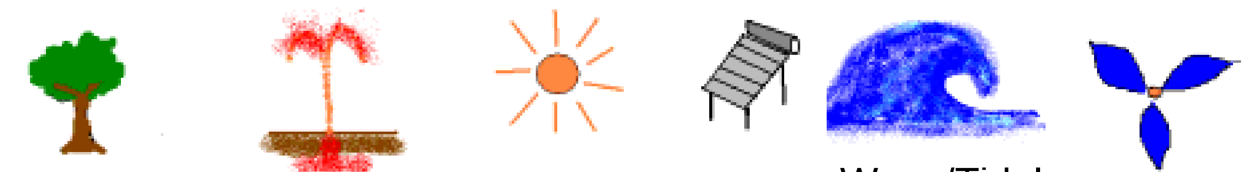
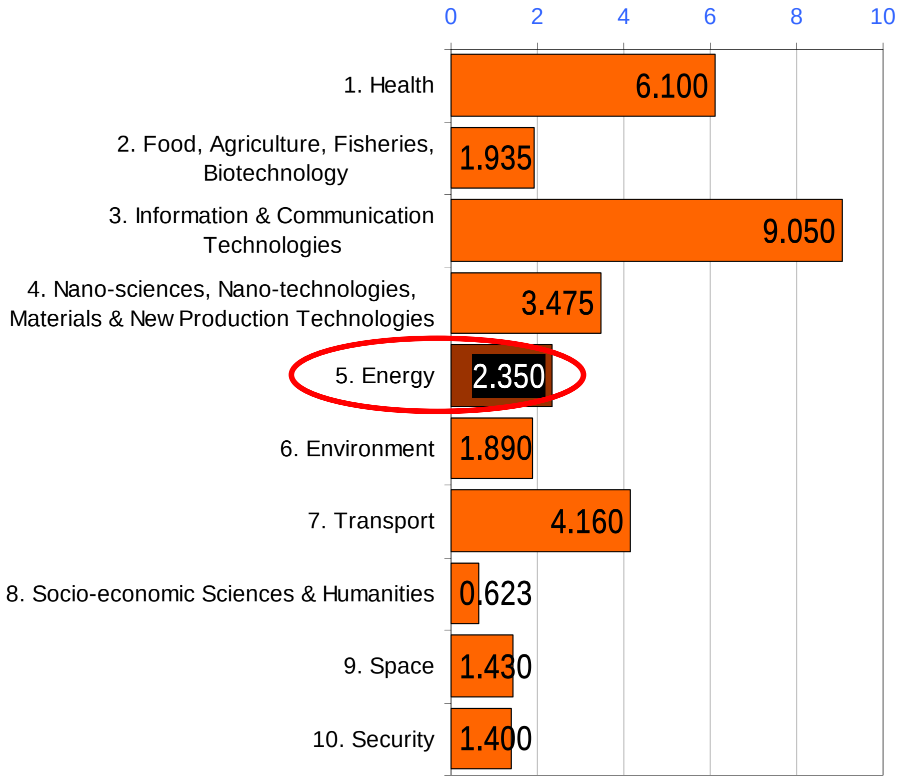
Community Funding Instruments

- **EU Programmes (2007-2013)**
  - » **7th Framework Programme (2.3 bln €)**
  - » **Competitiveness and Innovation Programme (CIP) (730 mln €)**



Bioenergy Geothermal Solar Wave/Tidal Wind

COOPERATION 2007 – 2013 (€32,4 Billion)



2009 Call for proposals: *8 topics are open*

1. **Photovoltaics** (thin film)
2. **Wind-Grid integration**
3. Bio-refineries (led by DG RTD)
4. **Solar thermal** (for industrial process heat)
5. **Solar thermal/biomass/geothermal** (Hybrid systems)
6. **Energy Efficiency in energy intensive industry**
7. **Clean Coal** (with a view to CCS)
8. **SET-Plan Think Tank**

<u>ACTIVITY ENERGY 2</u>: Renewable Electricity Generation

Area Energy 2.2: Biomass

- **<u>Topic ENERGY.2009.2.2.1: Biomass to electricity from energy crops and recovered fuels</u>**
- ***Content/scope:*** Innovative demonstration of the close linkage and complete supply chain of energy crop plantations (incl short rotation coppice and forestry) and waste recovered fuels in the medium to large scale (> 10 MW) cogeneration plants aiming to the efficient use of natural resources. Only projects that address CHP applications (or other projects addressing additional energy services to the community other than electricity only), will be considered. These should be based on close-coupled energy crop plantations (including sustainable methods, machinery development, drying technologies, efficient conversion technologies etc) and waste separation plants with optimised production processes for energy efficiency.
- ***Expected impact:*** Cost reduction through innovations in technology and plant efficiency. Technological improvements and developments in the overall supply chain of non-traditional biomass and recovered fuels leading to cost and GHG efficient electricity and heat generation.
- ***Other information:*** Up to two projects may be funded.
- ***Open in call:*** FP7-ENERGY-2009-2

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Call 2009 Timing of demonstration **(one-stage evaluation)**

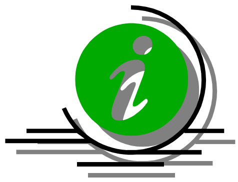
Call launched	**3 Sept 2008**
Info Day in Brussels	**24-25 Sept 2008**
Deadline for submission	**29 April 2009**
Evaluation	**June 2009**
Info to proposers	**Summer 2009**
Start of negotiation	**After summer 2009**
Start of contracts	**End 2009**

Directorate-General for Energy and Transport

More information

- **Homepage DG Energy and Transport** http://ec.europa.eu/dgs/energy_transport/index_en.html

- **FP7 Cordis homepage**: www.cordis.europa.eu



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5th Framework Programme (1998-2002)

2 projects co-financed under the FP5

- **BGGE - 13 MW CHP Plant Based on Biomass Gasifier with Gas Engines**
- **PROJECT CO-ORDINATOR : Carbona Inc**
- **DURATION : 79 Months**
- **Total Cost: 6.000.000 €**
- **EC contribution: 2.100.000 €**

Ended 31-12-2007

5th Framework Programme (1998-2002)

2 projects co-financed under the FP5

- **Lift-off : Multi agricultural fuelled staged gasifier with dry gas cleaning**
- **PROJECT CO-ORDINATOR : Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)**
- **DURATION : 55 Months**
- **Total Cost: 3.903.788 €**
- **EC contribution: 1.522.311 €**

Ended 31-8-2007

Biomass projects in FP6

DG Research (DG RTD) and DG Energy and Transport (DG TREN)

- **More than 160 M€ of EC Contribution**
- **More than 400 partners**
- **More than 40 projects (excluding CONCERTO and CIVITAS projects)**

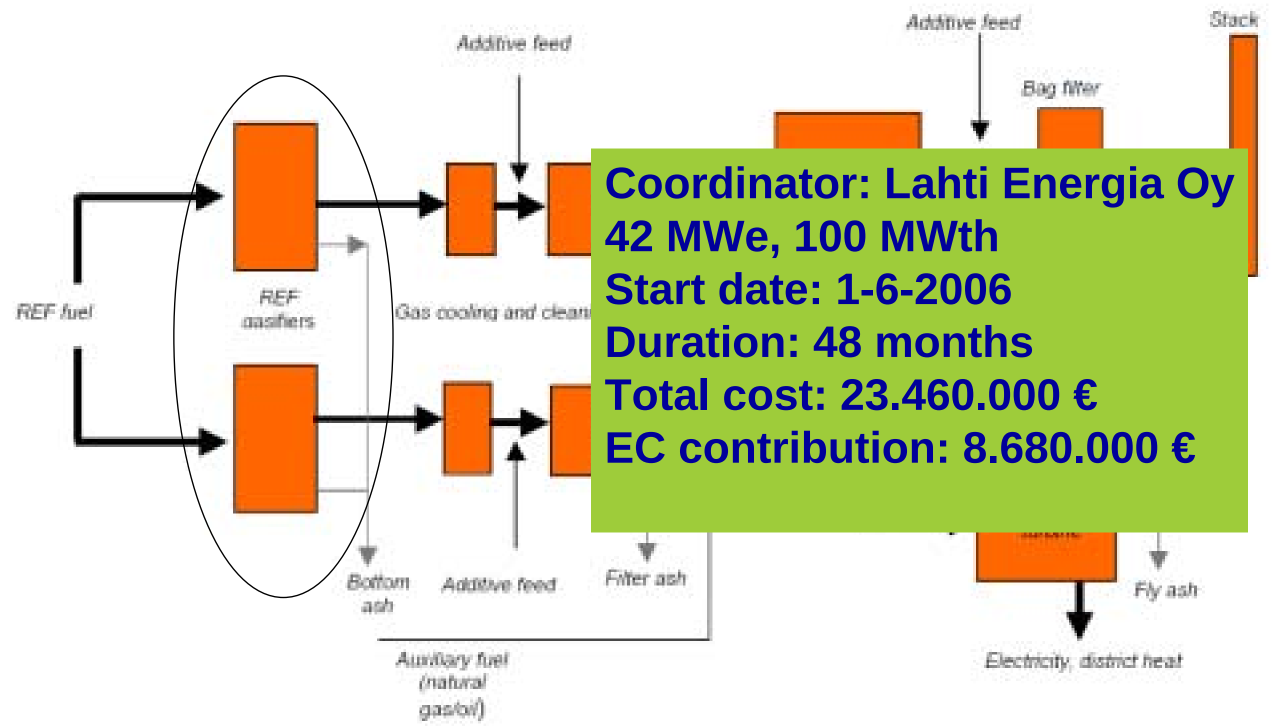
Directorate-General for Energy and Transport

Ongoing: Synthetic Bio Methane (BIO SNG)

Coordinator: IE Institute for Energy and Environment (DE)
Duration: 36 months
Start date: 1/5/2006
Total cost: 8.464.199 €
EC contribution: 2.875.157 €

Güssing FICFB - 2MWe, 4.5 MWth
Biomathane will be used in transport (buses) and fed into a NG pipeline.

Ongoing: FP6 - Lahti Streams



Coordinator: Lahti Energia Oy
42 MWe, 100 MWth
Start date: 1-6-2006
Duration: 48 months
Total cost: 23.460.000 €
EC contribution: 8.680.000 €

Sixth Framework Programme

On going research project: CHRISGAS

- Objectives: to develop a large scale biomass gasification process to produce clean hydrogen-rich gas which can be used for the production of transport fuels.
- Key research facility: Biomass fuelled pressurized IGCC plant in Värnamo, Sweden

- Coordinator: Växjö University, Sweden
- Start: 01/09/2004
- Duration: 60 months
- EU support: 9.5 M€

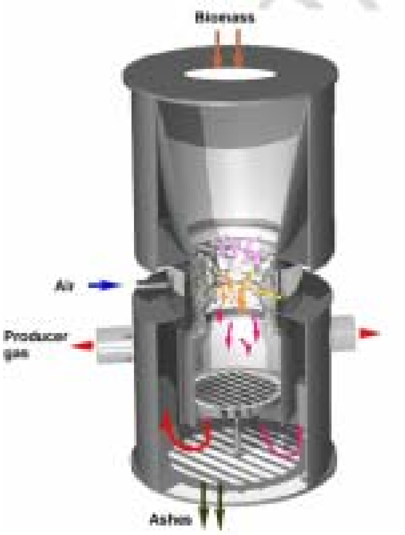
http://www.chrisgas.com


Värnamo biomass-fuelled pressurised IGCC plant

Directorate-General for Energy and Transport

Intelligent Energy Europe

Guidelines for Safe and Eco friendly Biomass Gasification



- Project: Gasification Guide
- Key Ation: ALTENER
- Coordinator: Btg Netherlands
- Start date: 01-01-2007
- Duration: 36 months
- Total cost: 1.041.163€
- EC contribution: 520.582 €

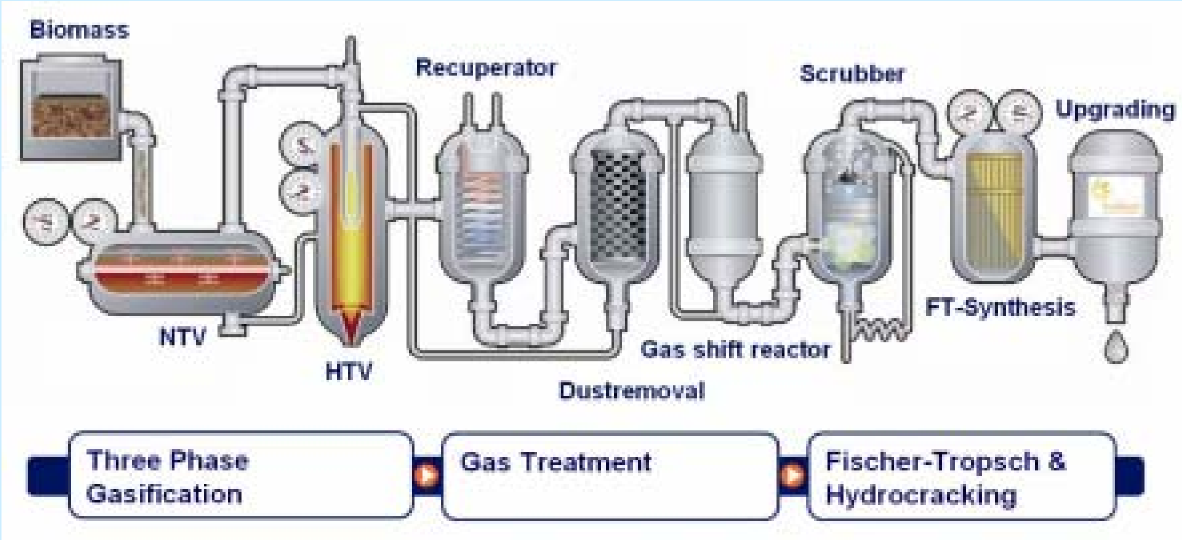
Directorate-General for Energy and Transport

2007 - 2013

Contract under preparation: OPTFUEL Biomass to Liquid biofuels

- **Project: OPTFUEL**
- **Coordinator: Volkswagen**
- **Start date: before the end of 2008**
- **Duration: 42 months**
- **Total cost: 13.601.816€**
- **EU contribution: 7.791.366 €**

The CHOREN simplified process flow sheet



Ongoing work at ISO for FT quality standards

Contract under preparation: BIO DME

Biomass to Liquid biofuels

- Project: BIODME
- Coordinator: Volvo
- Start date: before the end of 2008
- Duration: 48 months
- Total cost: 28.258.244 €
- EU contribution: 8.199.969 €

Contract under preparation: ENERCOM

Polygeneration of energy, fuels and fertilisers from biomass residues and sewage sludge

- Coordinator: IfaS
- Duration: 36 months
- Total cost: 5.200.961 €
- EU contribution: 2.528.833 €

The demonstration plant shall produce 2 GWh electricity, 4 GWh heat, 3,200 tons (10GWh) pellets/ briquettes, and 2,300 tons of enriched compost per year.

Contents

Conclusions

The European Commission strongly supports Bioenergy & biofuels with legislative actions & various programmes for technological advances & market penetration

High oil prices = high profile for bioenergy

Bioenergy's progress is solid but not fast enough to meet objectives

Plenty more work to be done at all levels

Calls for proposals
http://cordis.europa.eu/en/home.html

Research web site
http://ec.europa.eu/research/future/index_en.cfm
http://ec.europa.eu/research/energy/index_en.htm
http://ec.europa.eu/research/agriculture/index_en.html

Energy Policy
http://ec.europa.eu/energy/index_en.html

Conferences, proceedings, Newsletter
http://ec.europa.eu/research/energy/gp/gp_events/article_1567_en.htm
http://ec.europa.eu/research/energy/nn/nn_pu/renews/article_1402_en.htm
http://www.europa.eu.int/comm/research/conferences/2005/kbb/index_en.html
http://biomatnet.org/home.html
http://www.epobio.net/workshops.htm

Biomass Action Plan
http://ec.europa.eu/energy/res/biomass_action_plan/green_electricity_en.htm

EU Strategy for Biofuels
http://ec.europa.eu/agriculture/biomass/biofuel/index_en.htm

Thank you for your attention!

Anthi.charalambous@ec.europa.eu

State of the art of Gasification in the EU

Needs for Creating Favourable Conditions

Harrie Knoef

BTG biomass technology group

Company profile BTG

- Spin-off company University of Twente ('87)
  - Independent private firm
  - More than 20 spin-off companies established
- Consultancy
  - Studies & technology assessment (industry, int. organizations)
  - Due diligence (investors)
- Technology development
  - Contract research (industry, public organisations)
- Project Development
  - Business development (new companies, new regions)
  - carbon credits

Status Bio-energy BTG Technologies

Household energy

Densification (Briquetting/Pelleting)

Slow Pyrolysis - carbonisation

Combustion

Anaerobic digestion

Biodiesel

Bio-ethanol

Gasification

Fast Pyrolysis

Tar & tar removal

Torrefaction

Bio-oil Applications

Supercritical Gasification

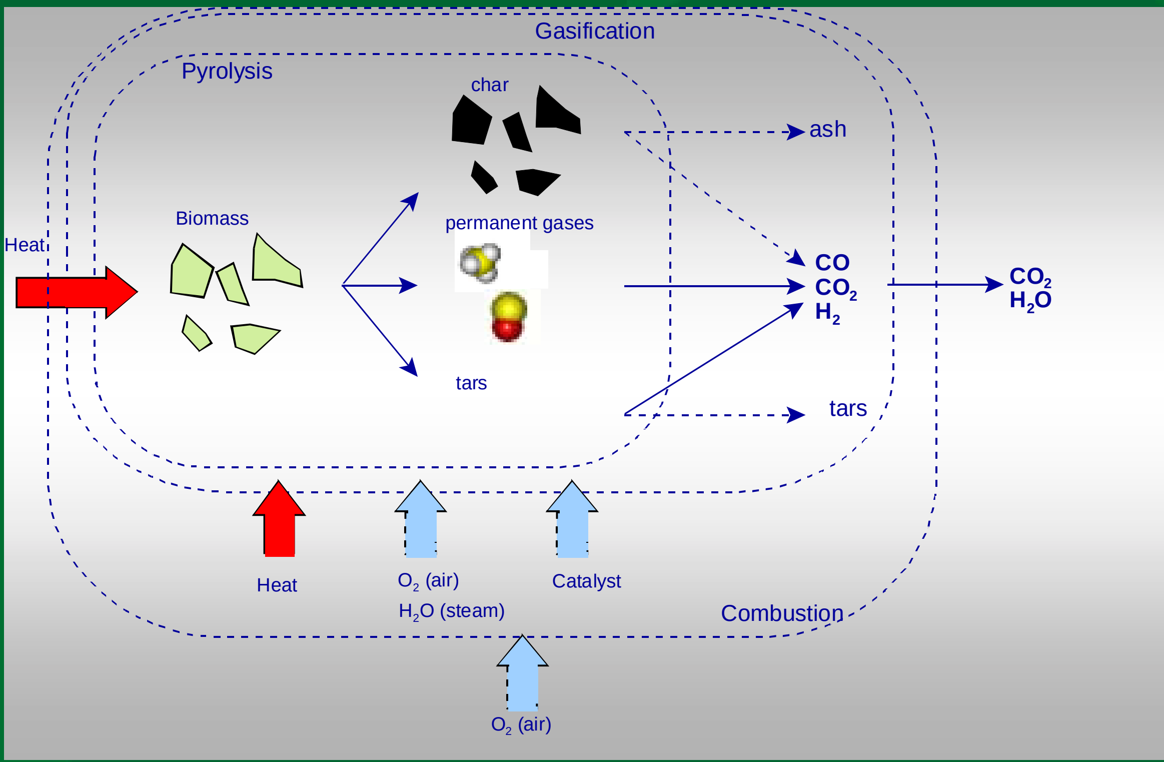
Bio-chemicals

R&D | Demonstration | Commercial

Market drivers biomass gasification

> 1900: “town gas” – lighting, gas engine
> 1940: “transportation” fuel
> 1970-80: oil crisis, CHP, heat application (distrit heating, industrial application)
> 1990: awareness of climate change effect, search for high efficiency, Kyoto, policy measures, directives, etc.
> 1994: IGCC “targetted“ projects (limited success)
> 2000: CHP, co-firing, syngas, BtL, H_2, chemicals
> 2005: Waste to Energy (WtE) or Energy from Waste (EfW)

What is gasification?



Classification of BGP technologies

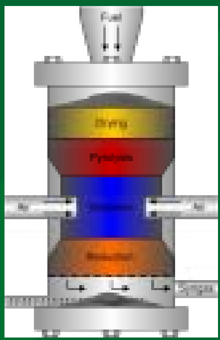
> Reactor type
  – Fixed bed, fluid bed, staged, entrained flow

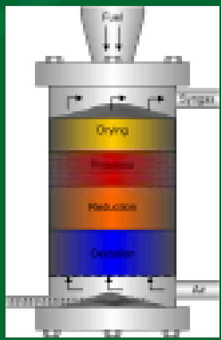
> Gasification agent
  – air, oxygen, steam

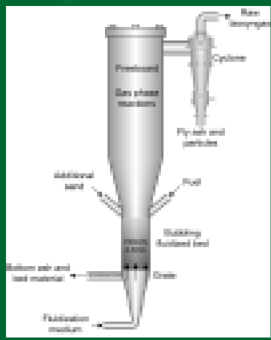
> Heat supply
  – Allothermal (heat transport media or heat exchangers)
  – Autothermal (internal partial combustion)

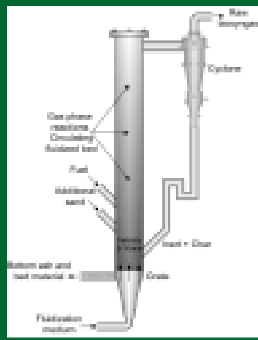
> Reactor pressure
  – atmospheric, pressurized

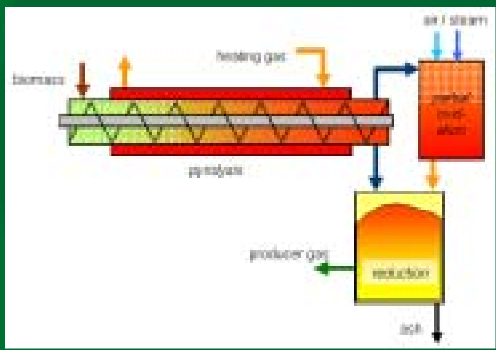
Classical and “new” designs

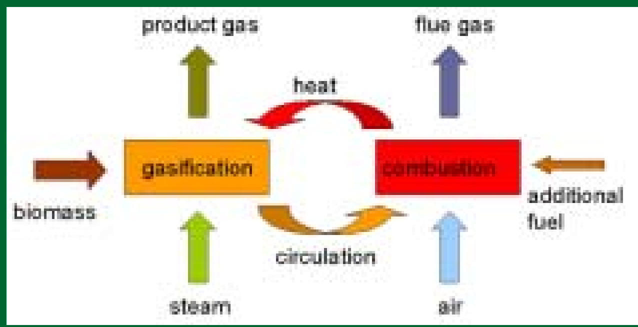




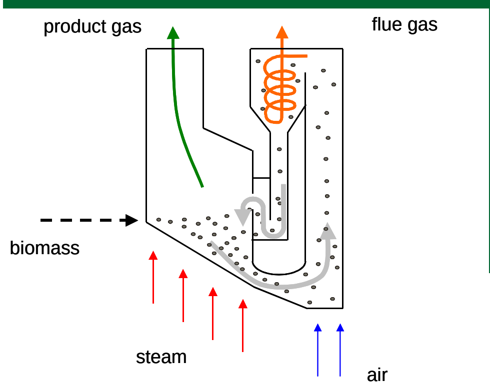






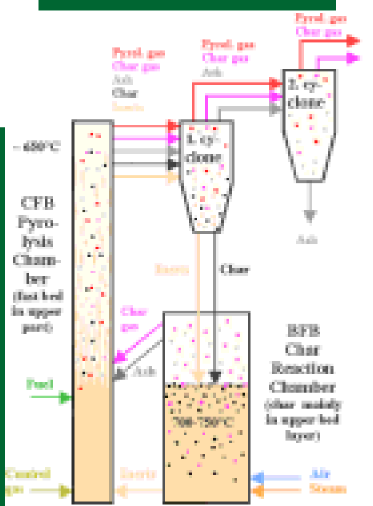


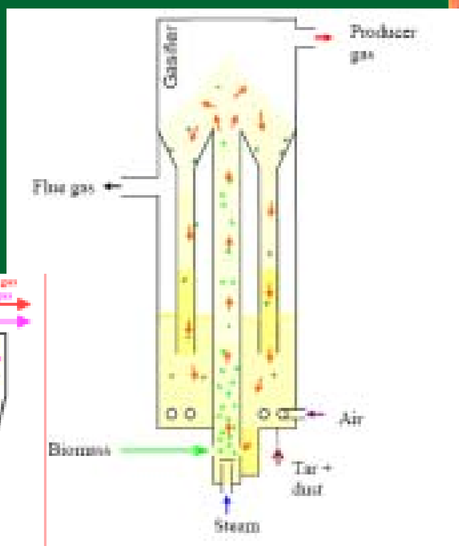
Allotherm gasification processes



FICFB

LT-CFB



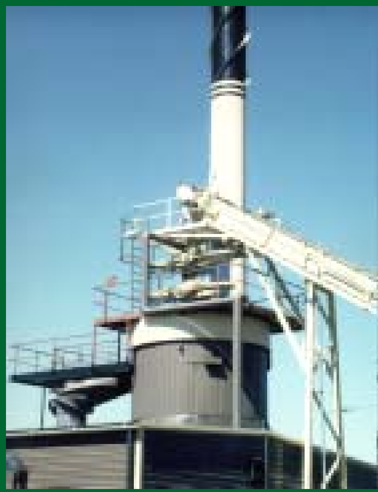


Milena

State of the art: heat gasifiers

Lurgi - Rüdersdorf

PRM Energy – Rossano



Bioneer - Finland

Many in developing countries for agricultural / food drying / industrial heat

Commercial processes

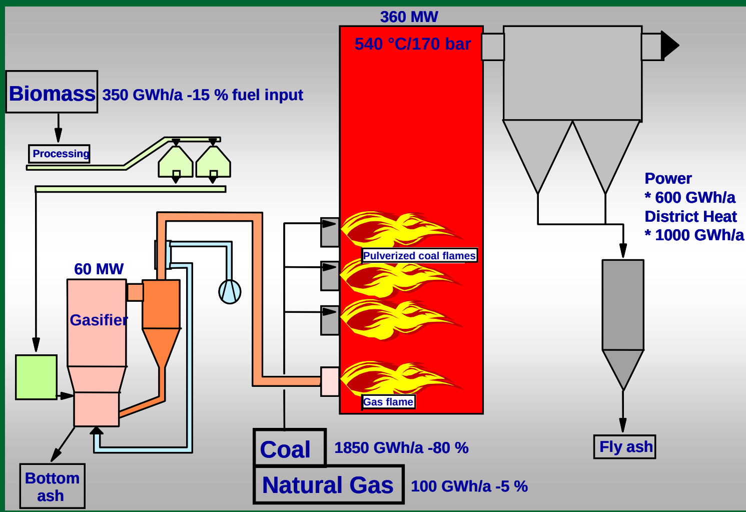
> More than "5 installed" systems:
- Bioneer
- Co-firing
- Biomass engineering, UK
- Eqtec, Spain
- Xylowatt, BE
- Mothermik, DE
- Pyroforce, CH
- Güssing concept, AT
- Volund (DK, DE, Japan, Italy))
- India, China (thousands, but unfavourable emissions)

State of the art: Co-firing

> Lahti – Finland

> Amer – The Netherlands

> Ruien – Belgium



State of the art: Staged gasification

> Physical separation pyrolysis – gasification
- DTU – Denmark (Viking)
- TUV – Austria (Güssing)
- TKE – Denmark
- TUG – Austria
- Xylowatt – Belgium
- LT-CFB – Denmark
- Waste to Energy gasification processes
- (Choren, SVZ, …)

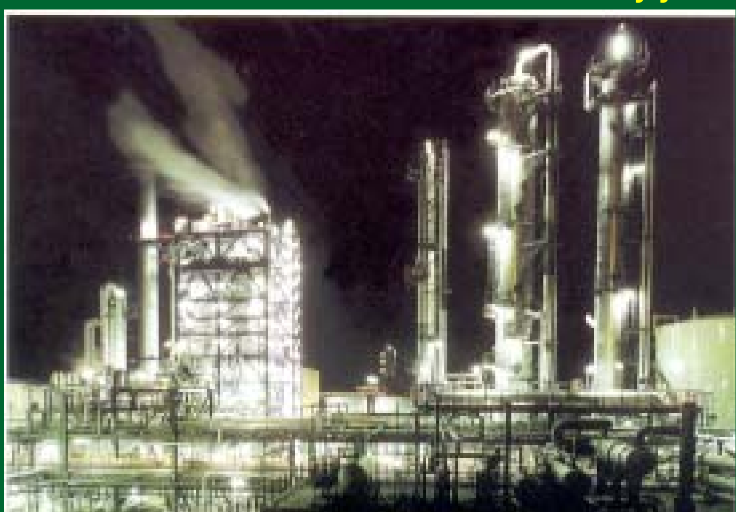
State of the art: Entrained flow

- Czech Republic (tar destruction)
- Choren – Germany (Carbo-V)
- Future Energy, (now Siemens)
- Shell, Texaco: co-gasification at power stations (NUON)
- Chemrec – black liquor
- Schwarze Pumpe - Germany (SVZ)

FEE Fördergesellschaft Erneuerbare Energien

(Heart) Breaking News

Shut-down and dismantling of Sekundärrohstoffverwertungszentrum SVZ Schwarze Pumpe has constituted the biggest European setback for gasification of coal and residues for the last almost twenty years



Needs: advanced gas cleaning

- Heat (kilns)
- Co-firing
- Gas engines
- Gas turbines
- Stirling engines
- Syngas
- Fuel cells

mg/m^3

ppm

ppb

Needs: feedstock and feeding

> Infrastructure to ensure supply as
- Quantity + Quality
- Availability (price, long-term contracting)
- Seasonal availability

> Logistics / fuel delivery

> Awareness of the HSE risks
- Self-ignition
- Dust explosion
- Smell/odour, noise
- Back-firing, gas escape from gasifier reactor

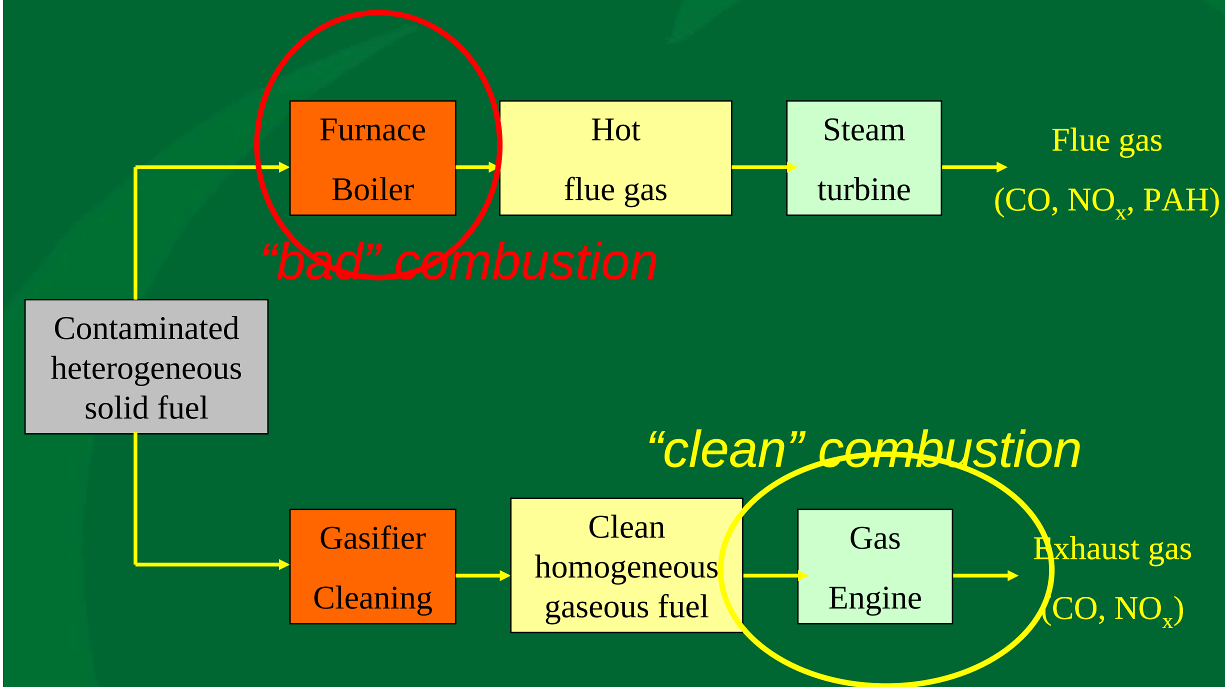
Needs: Favourable regulations

> There is no specific regulations for BGP's
  - Gasification is often treated similarly to other thermal processing technologies such as combustion or incineration, which hampers the market penetration of small to medium scale BGPs

> BAT does not exist in gasification
  - what is the benchmark?

> WID, BAT, etc.:
  - Propose annual load (kg/yr) instead of concentration (mg/Nm^3)

Needs: favourable emission limits



1. **Difference between combustion/incineration**
2. **Equal treatment independent for fuel origin**

Proposed new IPPC Directive: COM (2007) 844 of 21.12.2007

> Proposed new IPPC Directive (Dec. 2007) includes all biomass gasifier plants
  - would subject all new BGPs to licensing in Europe in a few years
  - emission limit values (ELVs) to be based on best available techniques (BAT) would become mandatory

ANNEX I

Categories of industrial activities referred to in Article ~~1~~ 11

1. Energy industries

1.1 Combustion ⌦ of fuels in ⌫ installations with a ⌦ total ⌫ rated thermal input ~~exceeding 50 MW (1)~~ ⇨ of 20 MW or more ⇦

1.2. ⌦ Refining of ⌫ m~~M~~ineral oil and gas ~~refineries~~

1.3. ⌦ Production of ⌫ c~~C~~oke ~~ovens~~

1.4. ~~Coal~~ Gasification ⌦ or ⌫ ~~and~~ liquefaction ⌦ of fuels ⌫ ~~plants~~

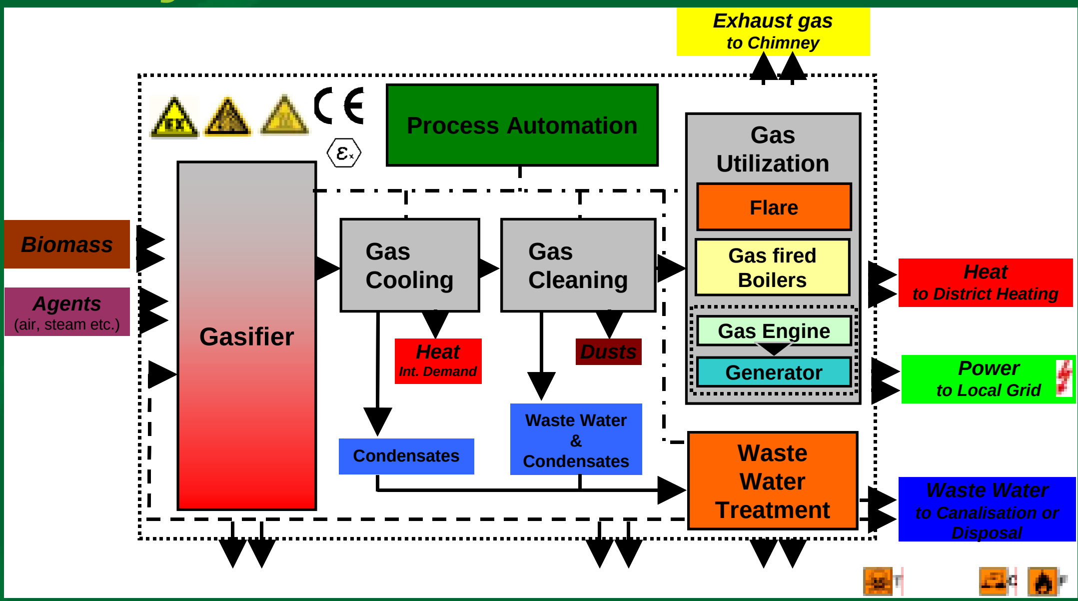
Emission limit values for biomass gasification in Europe

> In most European states, emission limit values (ELVs) ***specific to biomass gasification plants with gas engines*** have not been defined yet

> Denmark: ELVs for gas engine exhaust gas in biomass gasification plants (reference state: dry exhaust gas at STP, 5% O_2)

NO_x: 550 mg/m³
Uncombusted hydrocarbons,
UHC: 1500 mg C/m³ (valid for 30% electrical efficiency)
CO: 3000 mg/m³
Smell: 20000 smell units/m³

Need for Awareness of Health, Satefy & Environment hazards



www.gasification-guide.eu

Need for Guideline on HSE hazards

1. A **guideline** and **harmonization** of regulations will have a positive impact on the overall economics
2. Project developers, bankers, investors and insurance companies **demand** safe equipment, meaning that HSE hazards much have been considered and documented properly
3. **Immature** products will harm the technology in general and should be avoided entering the market
4. HSE hazards and RA need to be **respected** at all times irrespective the economics

Need for Standardization

> Harmonization of legislative aspects
> Simplication of permitting procedures
> Which directives are valid / how to interprete
> Share information of common interest
> Modular design, no “special gasifier” for a client
> Acceptance tests, guarantee measurements
> Defining “conditions” for commercial implementation

Need for financial support

> High initial investment
> Limited private investments
> Remuneration of CHP
  – Italy: 300 €/Mwhe for 15 yrs for < 1 MWe
> Feedstock availability and price increase
> Material prices increase (steel)
> Reduce risk for ‘first-of-its-kind’
> Subsidies tend to decrease

Needs for favourable condition (1)

> Leading EU BGP manufacturers that respect client demands for safe equipment, CE marking and risk assessment are **close to full commercialisation** of small to medium scale biomass gasification technology

> Streamlining of BGP **permitting procedures** and **harmonization** of existing BGP **regulations** within the European Community is considered crucial for the accelerated deployment of biomass gasification plants

Needs for favourable condition (2)

> Technology implemented must be mature
  - Proven prototype models
  - Long-term duration tests

> Adequate infrastructure
  - Local manufacturing capacity
  - After-sale service
  - Training facilities
  - Sustainable feedstock supply

> Motivated & skilled labor
  - Operators, Management
  - Incentives

Needs for favourable condition (3)

- Information & knowledge exchange
  - Performance, limitations, opportunities
  - Evaluation with competing options
  - Set-up monitoring program of successes in India, China
- Clear regulations
  - Permitting procedures
  - Emission according to "ALARP"
  - Health, Safety & Environment
- Sale of electricity and heat
  - Any legal obstacle should be removed
  - Long-term fixed price is prerequisite

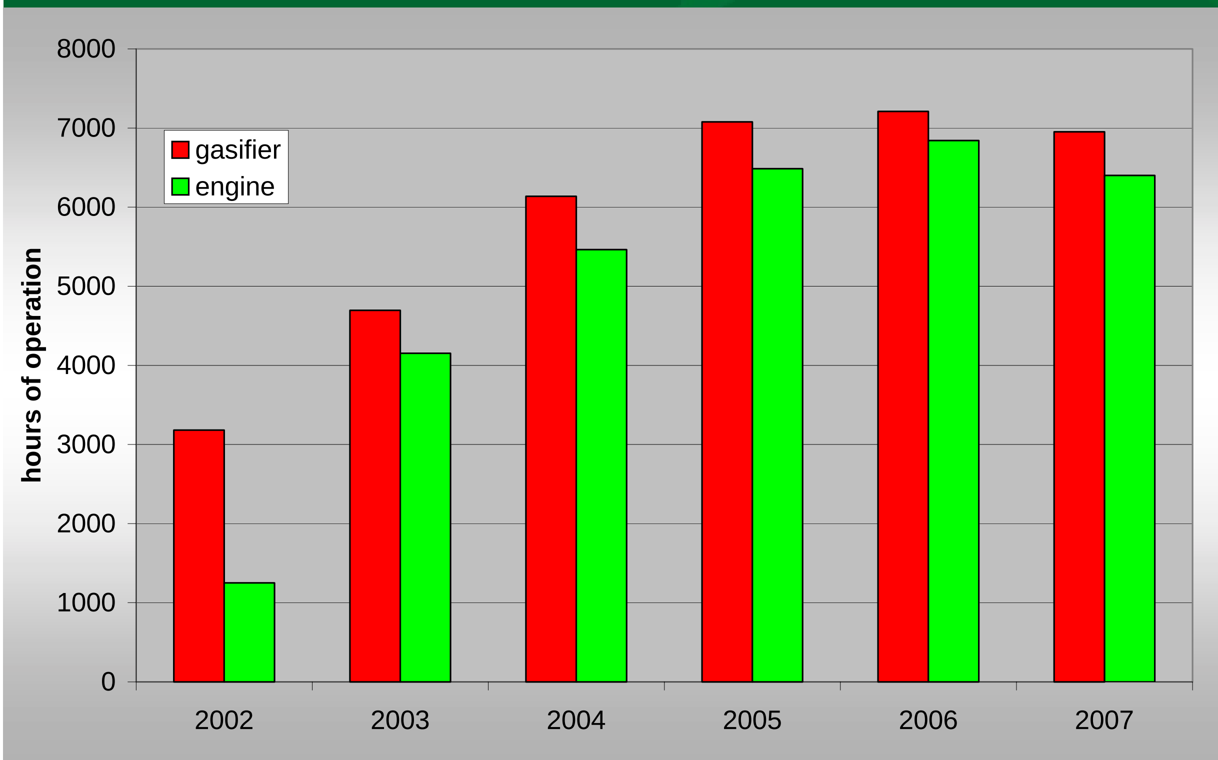
Needs for favourable condition (4)

- Product quality must meet client specifications
  - Technical performance
  - Financial/economic performance
  - Operational performance
  - Gaining confidence
- Certification
  - stimulation
  - product must meet defined quality standards
- Scale-up, demonstration, replication, optimization
  - Economy of numbers (instead of economy of scale)
  - Reduced capital costs
  - Improvement from learning by doing

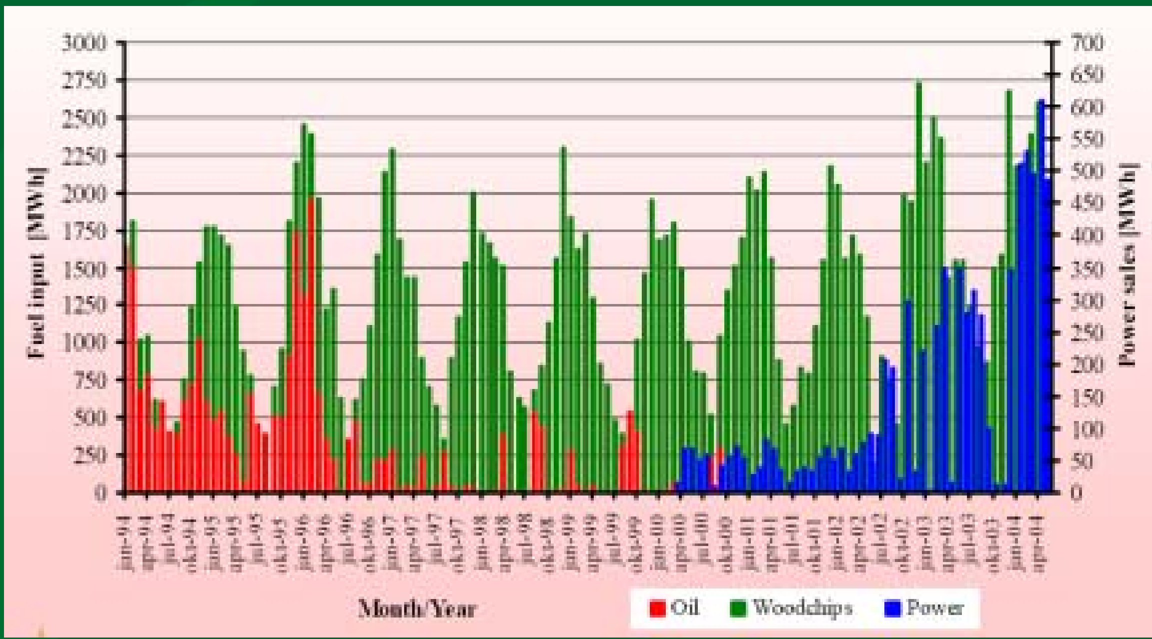
Needs for favourable condition (6)

> Do not repeat the mistakes from the past
  - learning by doing and not by a scientific approach (cooperation is prefered)
  - too optimistic approach of the economics, efficiency and availability, projections: 7000 hrs of operation in 1st year
  - no optimal cooperation of the ownership-consortium and conflicting interests (who is responsible for what).
    - Manufacturer versus plant owner
    - Plant owner/technology supplier versus permitting authority

Need for availability data Güssing



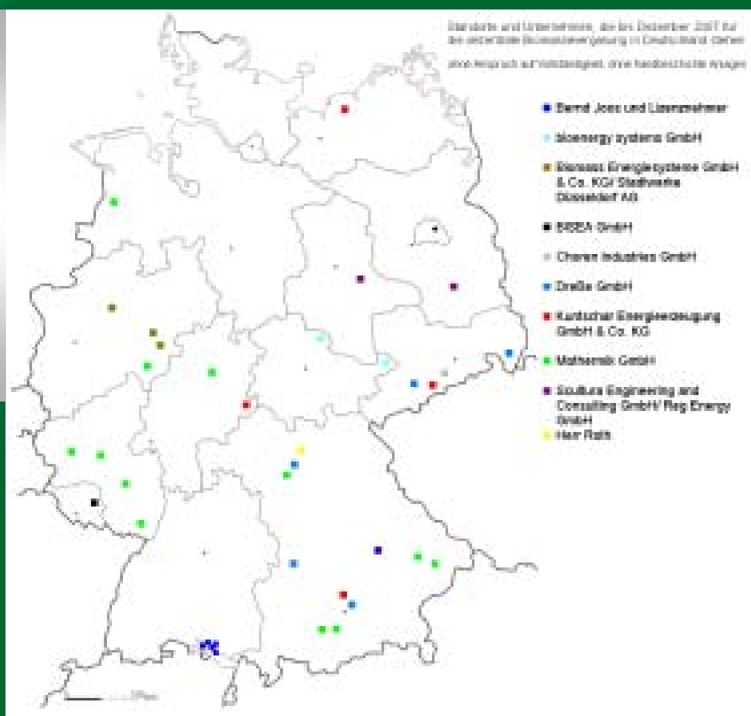
Need for availability data Harboore



State of the art: Germany

Plants in operation in Germany

March 2008:
Concerning plants reported by manufacturers and operators, only.
© FEE. No claim for completeness



Dual fluid bed steam gasifiers

Location	Electricity production	Fuel / Electr. MW, MWel	Start up	Status
Güssing, AT	Gas engine	8,0 / 2,0	2002	operational
Oberwart, AT	Gas engine / ORC	8,5 / 2,8	2008	operational
Villach, AT	Gas engine	15 / 3,7	2009	construction
Klagenfurt, AT	Gas engine	10 / 2,5	2010	contract signed
Ulm, DE	Gas engine / ORC	20 / 6,4	n.d.	contract for detailed engineering
Geislingen, DE	AER-process/ Gas engine / ORC	10 / 3,2	n.d.	contract for detailed engineering

Source: Prof. Hermann Hofbauer, TU Vienna

Upcoming trends

> Waste to Energy concepts

> High temperature slagging gasifiers

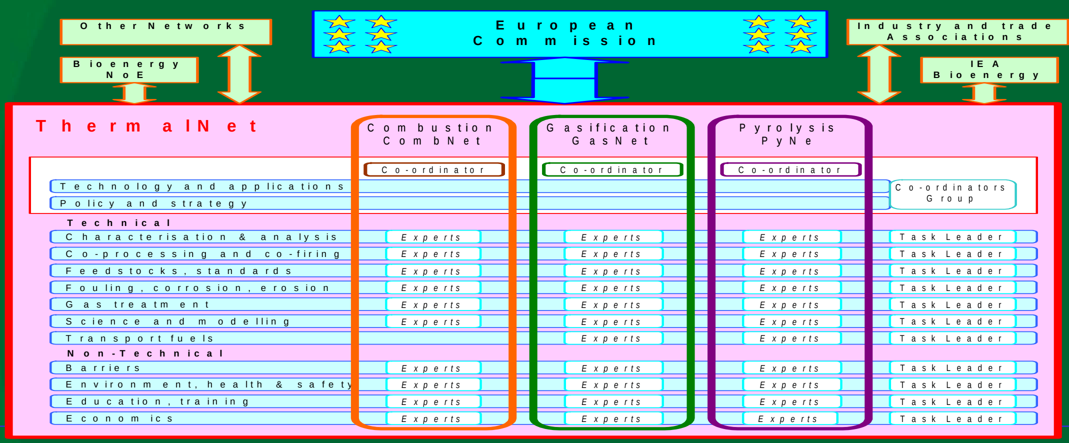
- Decentral waste processing / energy production in competition with large scale incineration
- Recycling of metals

> Plasma gasification

- More than 20 suppliers worldwide
- De-central waste processing and syngas production
- Inertization of bottom ashes, electronic scrap, etc.

Needs for Networking

The European Commission stopped further financial support for the world-wide unique network ThermalNet established by joining combustion (CombNet), gasification (GasNet) and pyrolysis (PyNe) an efficient platform for biomass strategy, technological development, information exchange involving Research, small medium and big biomass industry.



Needs for Networking

> Networks are important instruments for information exchange and identifying R&D needs.

- IEA Bioenergy Task 33 Gasification (www.ieatask33.org)
- ThermalNet (www.thermalnet.co.uk/)
- Fördergesellschaft Erneuerbare Energien e.V. (www.fee-ev.de) Stuttgart January 2009

International Seminars on Gasification
Swedish Gas Centre

For information contact:

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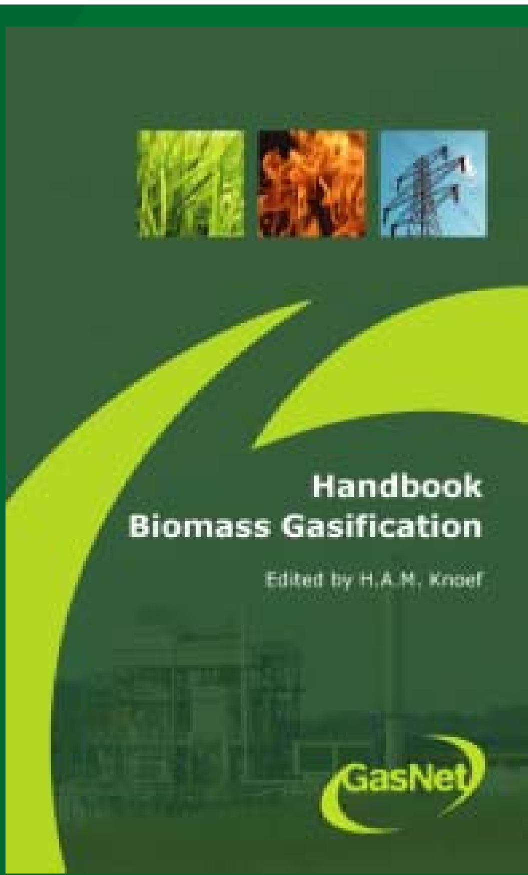
Mobile +31-6-52560040



The Dutch Situation on Green Gas

Mathieu Dumont
Bert van Asselt

Contents

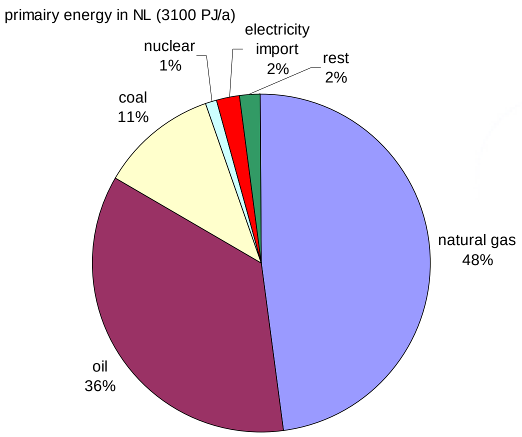
- Dutch ambitions on renewable energy
- The Dutch energy system
- Approach Green Gas discussion
- Stimulation programms
- Actual situation on Green Gas including gassification of biomass
- The future?

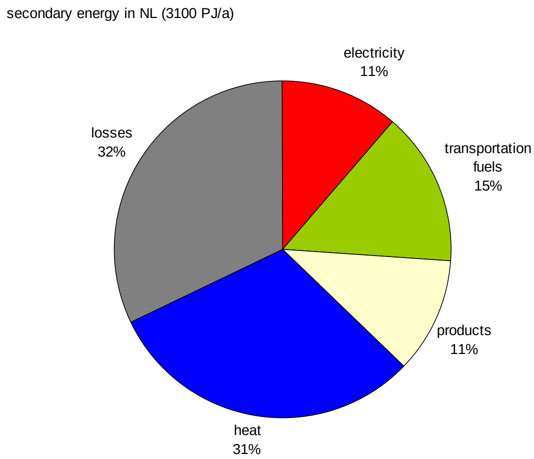
Dutch ambitions on renewable energy

- policy target up to 2020
  20% renewable energy
  30% emission reduction of green house gases (reference 1990)
  2% energy saving yearly

  Total GHG emission in 2020:
  150 Mton CO_2-eq
  Governemental plan: “Schoon en Zuinig” published sept. 18th; 2007

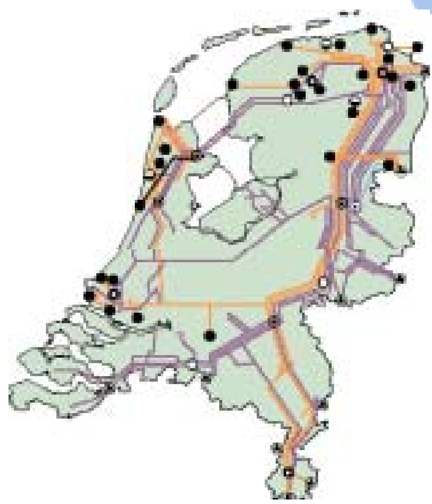
Energy situation in the Netherlands Netherlands and Natural gas



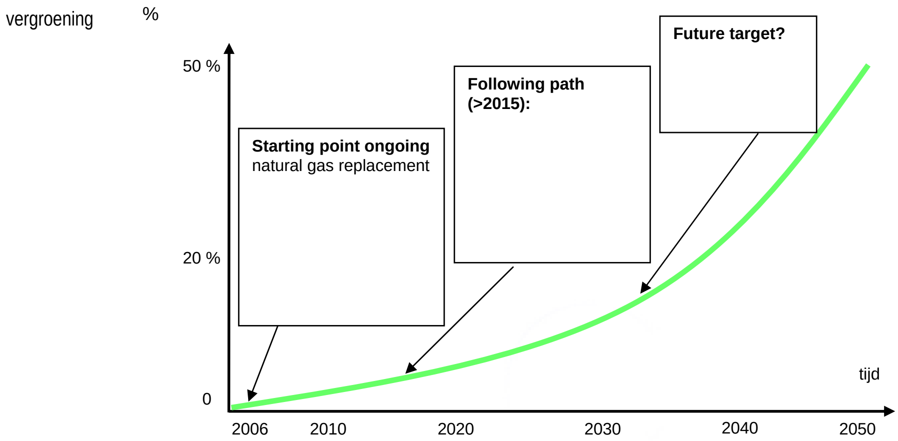


Extensive Gas net and Trading

- Natural gas since 1965
- Yearly Energy consumption
  Natural Gas 1500 PJ
- 2 Qualities:
- -- Groningen gas (L-gas)
- -- H gas
- Transport: HTL- 67 bar
- Regional: RTL- 40 bar
- Local : 8 bar
- 135.000 km pipe line
- 94% of houses connected to gas grid
- International grid connections



Ambition for Green Gas



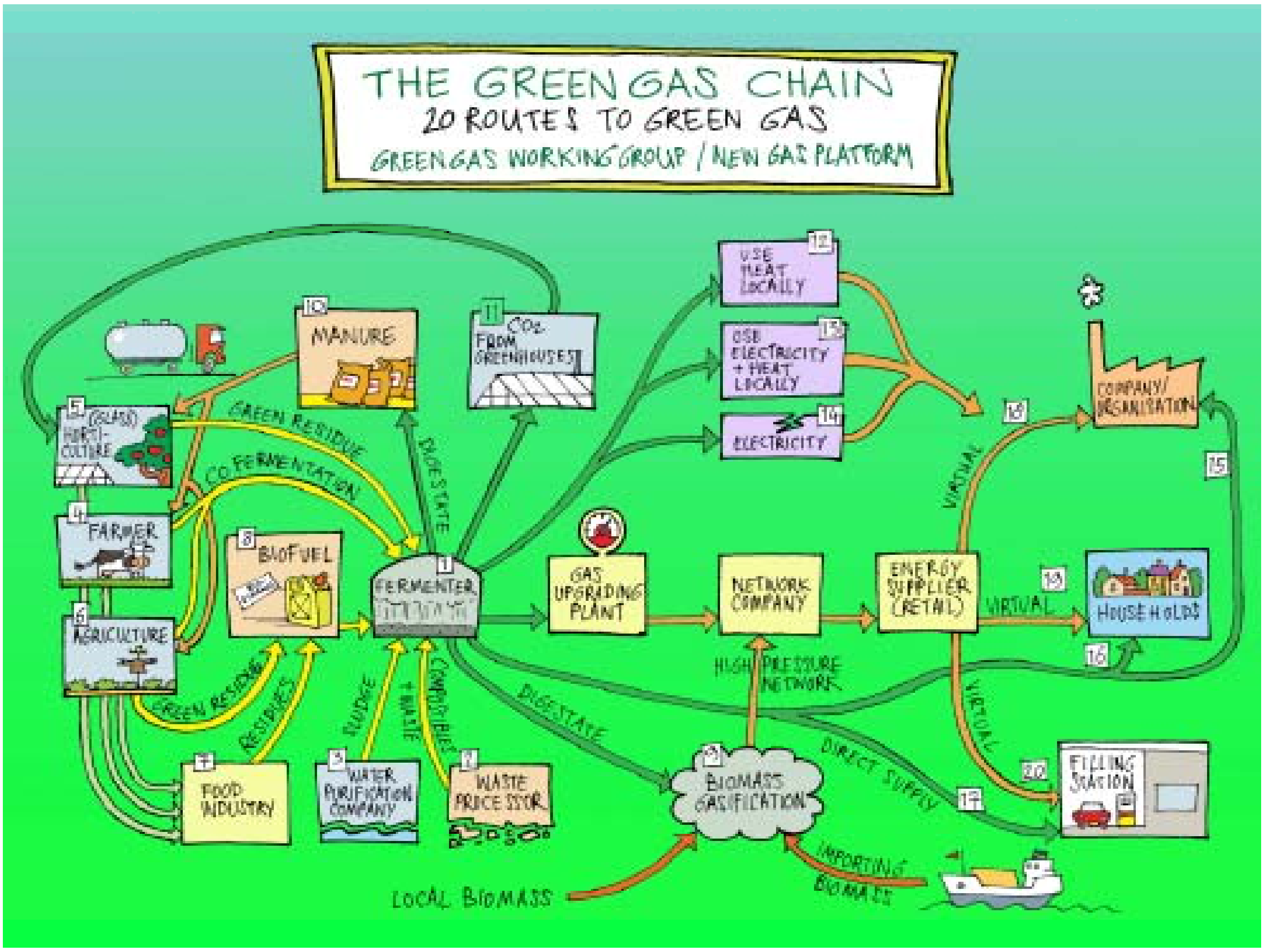
- Short term target:Replacement of natural gas by upgraded biogas 1-3%
- Midterm target: 8-12% replacement of natural gas in 2020
  (4 billion Nm3/y), inclusive SNG production from biomass
- Long term: Upscaling to 50% replacement of natural gas by green gas in het gasgrid

Approach Green Gas discussion:
Energy transition platforms (public private co-operation)

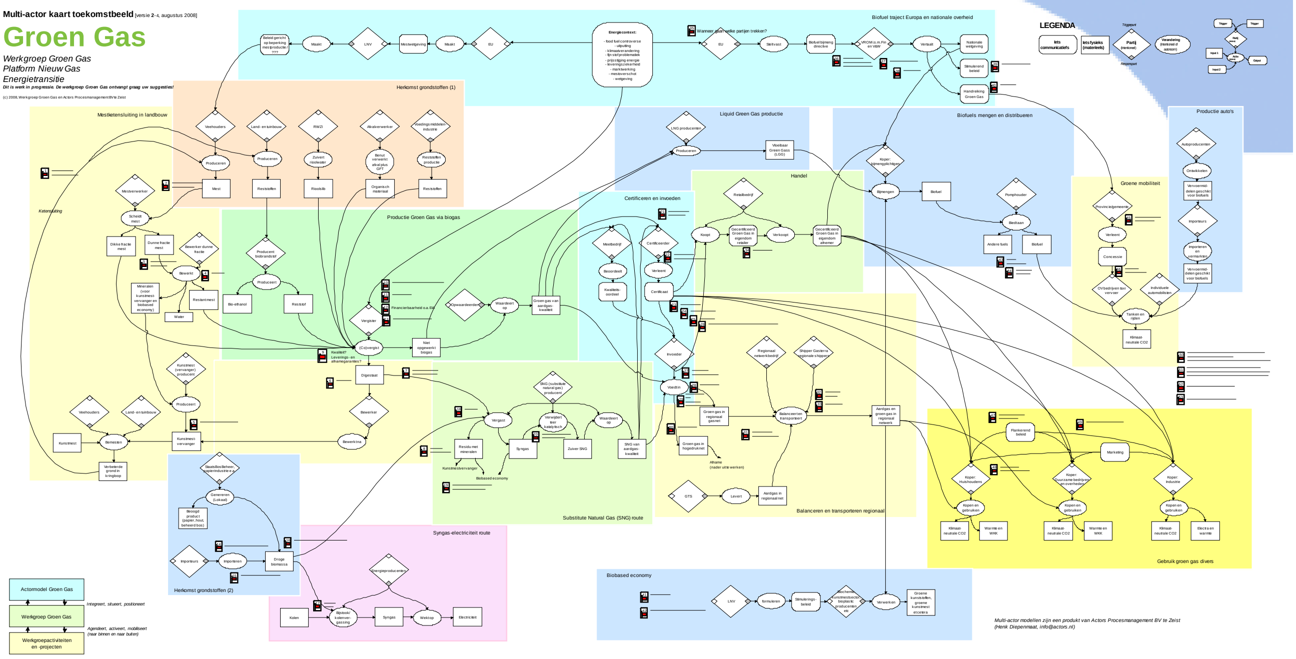
Creatieve Energie
EnergieTransitie

Transition approach by discussion platforms:
info: http://www.senternovem.nl/EnergyTransition/Index.asp

- Sustainable Mobility Platform
- Biobased Raw Material Platform
- New Gas Platform (with working group on Green Gas)
- Platform for Chain Efficiency
- Sustainable Electricity Supply Platform
- Energy in the Built Environment Platform



Actor analyses



National Energy Research Strategy
EOS R&D-instruments
Investment subsidy

actor

Universities

Institutions

Companies

Consultancies

ECN: EOS

financial instruments

EOS Long Term Research

EOS: Energy Innovation subsidy collaboration (with companies)

EOS-Demon-stration

UKR

Market push

EOS: NEO (new ideas)

long ⇐ Time to market ⇒ short

Exploitation subsidy in a new programm: SDE

- With tenders for windpower (land and offshore)
- Biomass: including a tender for stimulation production of Green Gas (digestion: from sewage sludge and co-fermentation)
- Solar energy

- Duration of stimulation over 12 years
- Financial support depending of the category of RE

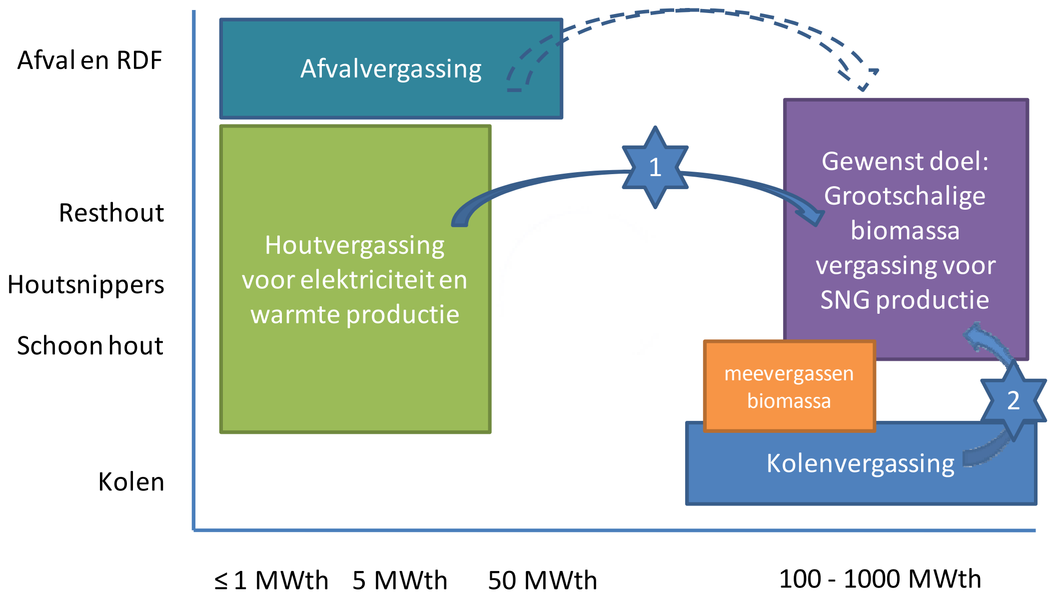
Regulations on grid injection in local gasgrid

Kwaliteitscomponent	Conform advies Gastec	
	Grenswaarde	eenheid
Calorische bovenwaarde	31,6 – 38,7	MJ/nm^3
Wobbe-index	43,46 – 44,41	MJ/nm^3
Waterdauwpunt	-10(8 bar)	^oC
Temperatuur in te voeden gas	0-20	^oC
Zwavel (totaal)	45	mg/nm^3
Anorganisch gebonden zwavel (H_2S)	5	mg/nm^3
Mercaptanen	10	mg/nm^3
Odorantgehalte (THT)	>10, nom 18<40	mg/nm^3
Ammoniak	3	mg/nm^3
Chloorhoudende verbindingen	50	mg/nm^3
Fluorhoudende verbindingen	25	mg/nm^3
Waterstofchlorice (HCL)	1	ppm
Waterstofcyanide (HCN)	10	ppm
Koolmonoxide (CO)	1	Mol%
Kooldioxice in droge gasnetten (CO_2)	6	Mol%
BTX (benzeen, tolueen, xyleen)	500	ppm
Aromatische koolwaterstoffen	1	Mol%
Zuurstof in droge gasnetten	0,5 (3)	Mol%
Waterstof	12	Vol%/nm^3
Methaangetal	>80	-
stof	Technisch vrij	-
Siloxanen	5	ppm
Ruikbaarheid (geodoriseerd biogas)	voldoende	-

Experience with Green Gas production from digestion

- 20 years of experience with upgrading landfillgasproduction with grid injection
- Two new upgradingsplants as pilotplant since 2006
  - Beverwijk (sewage sludge; 80 Nm3/h natural gas quality)
  - De Marke
  (pilot 15 Nm3/h see pictures)
- About 10 plants in direct preparation and in planning: capacity range: 40 Nm3/h-700 Nm3/h
  20-30 in capacity range:
  200 Nm3/h – 3000 Nm3/h

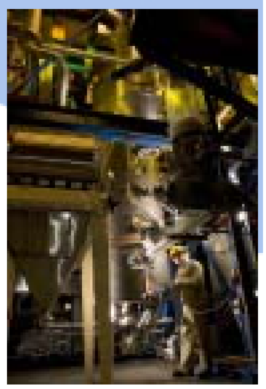
Gasification of biomass: two possibilities:
- "Co"-gasification of biomass with coalgasification (right)
- direct gasification of biomass (left)



“co”- gasification

- Amer Powerplant (30 MWe based on biomass)
- Buggenum (total capacity gasifier 120 MWe, roughly about 30% from biomass (Photo)

Biomass gasification



- Milena gasifier (800 kW) at the researchinstitute ECN in Petten (opening sept. 4th 2008)

- Gasifier of chicken manure in Tzum (500 kW) (without gascleaning; syngas used in a boiler)

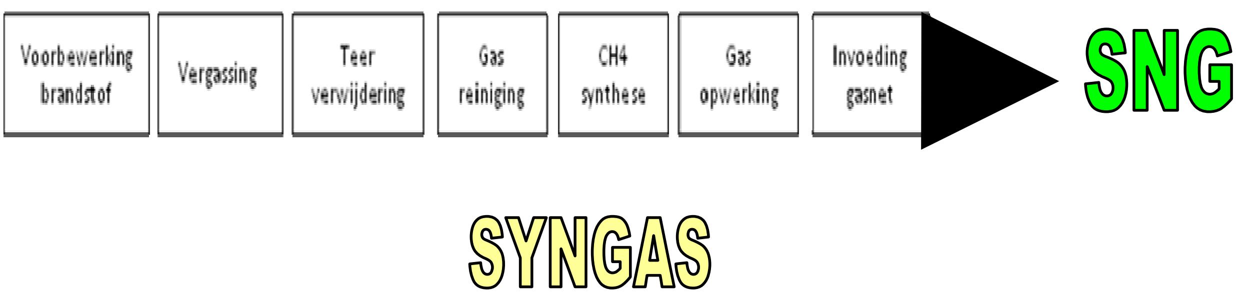
Participation in international networks

- IEA-Bio-energy task 33 (gasification)
- ERA-NET Bioenergy
  workshop october 27th Amsterdam:
  (clusters: Measurement and cleaning / Cleaning and reforming)
  Topics:
  - Project presentations
  - Presentations of the Consortia
  - Discussion and comments on projects and interim results
  - Dissimination of the results

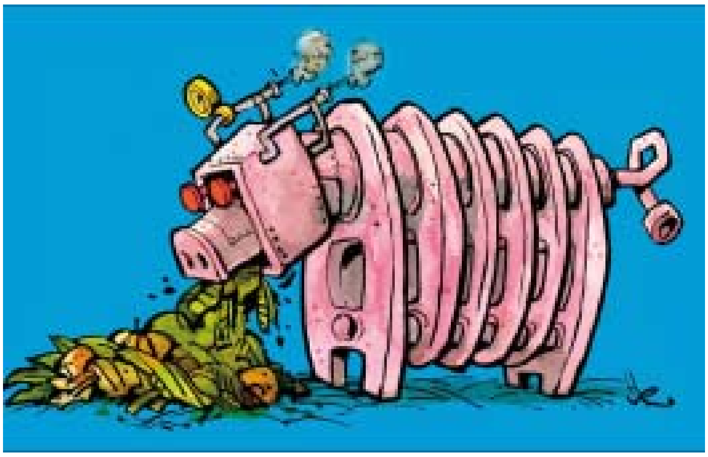
  (information and registration m.brijder@senternovem.nl)

The future of biomass gasification in the Netherlands

- Big potential for SNG production
- Import of biomass will be necessary with increasing number of natural gas replacement (harbors locations preferend locations)
- Focus on SNG as an flexibel fuel (powergeneration / storage in old gasfields)
- Not only need for SNG but partly Syngasquality is required for industrial purposes



Thank you for the attention
m.dumont@senternovem.nl



A Swedish Strategy for Gaseous Fuels

Henrik Kusar

Energy Technology Department –

Fuel-based Energy Systems & Transport Unit

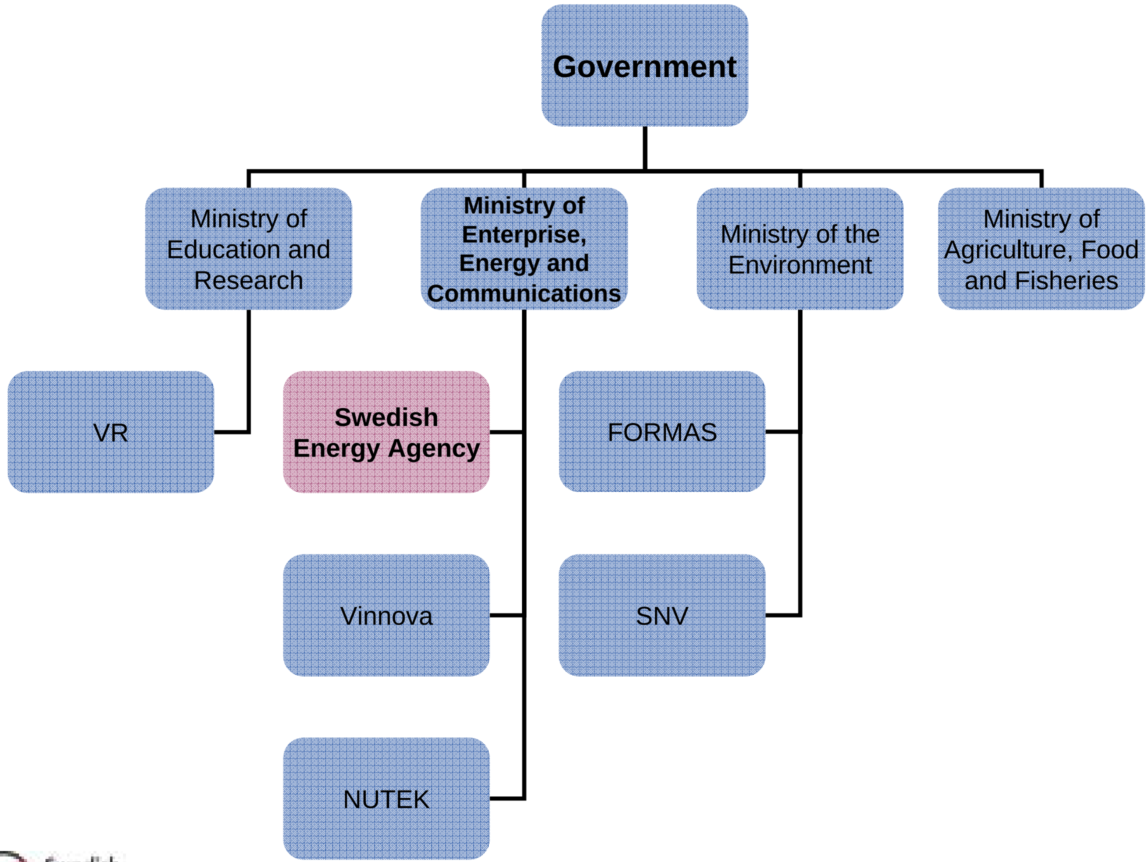
Swedish Energy Agency

Swedish Energy Agency

Presentation Outline

- The Swedish Energy Agency
- Swedish Energy Policy
- Swedish energy research
- Focus areas
- Gaseous fuels - gasification
- Large scale

Swedish Energy Agency



Swedish Energy Agency
Eskilstuna

- **Formed in 1998**
- **Office in Eskilstuna 120 km west of Stockholm**
- **Small office for meetings in Stockholm**
- **Employs around 250 people**
- **Promotes new energy technologies, energy production and efficiency**
- **Disseminates knowledge and information**

Swedish Energy Policy

Security of supply

- Self-sufficiency in power generation at competitive prices
- With the least possible impact on people and environment

Sustainability

- Promote the development of a ecologically and economically sustainable energy system
- Contribute to a broader cooperation about energy-, environment- and climate issues in the Baltic Sea region

General energy/carbon policy in the Transport Sector

- The Swedish national target is 5,75% renewable transport fuels 2010 and the new targets from EU will be implemented when decided
- Today the main policy instrument for this target is tax reduction on renewable fuel
- There is also a law stating that the majority of petrol stations has to deliver at least one renewable fuel
- There is a definition of “environmentally friendlier car” and connected to it a subsidy for private buyers of energy efficient cars and cars adapted to renewable fuels
- Most tax system connected with vehicles are successively changed towards carbon emission intensity reduction
- Technology neutral policy instruments

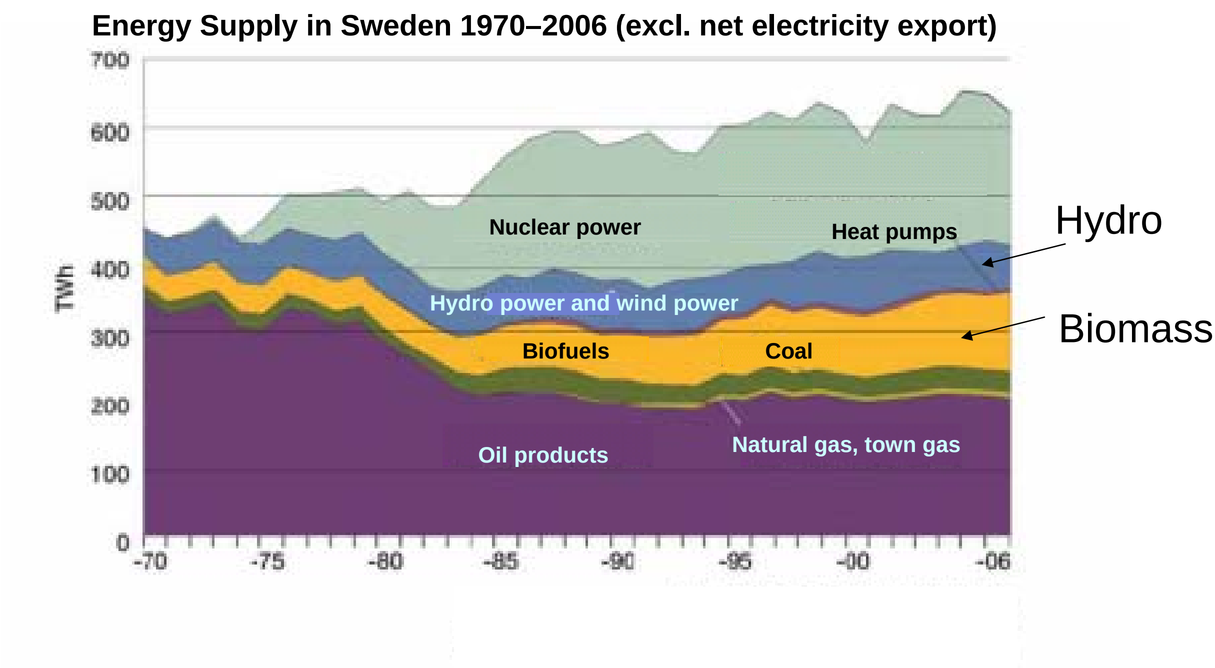
EU’s Energy Package
- Towards 2020

- Reduce CO_2 emissions by 20 %
- Save 20 % energy
- Increase share of renewable by 20 %
- Use at least 10 % biofuels in each member state
- 2nd generation biofuels accounted twice

For the purposes of demonstrating compliance with national renewable energy obligations placed on operators, the contribution made by biofuels produced from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels.

Swedish Energy Agency

Sweden has 39,8% renewable energy in final consumption



Swedish Energy Agency

Energy RD&D

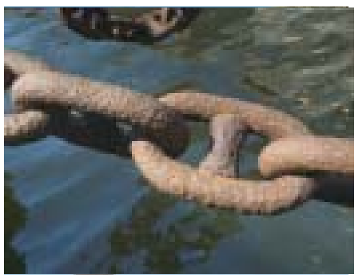
- The needs of the users in focus
- Deployment of R&D results
- Commercialization
- Based on Swedish conditions
  - In an international perspective

Swedish Energy Agency

Six Focus Areas





Swedish Energy Agency

The Focus Areas of Swedish Energy Research

- Energy System Studies
- Buildings as Energy Systems
- Transport Sector
- Energy Intensive Industry
- Electricity Generation and Distribution
- Bioenergy, Including CHP

Swedish Energy Agency

Transport Sector

- Second generation of fuels, mainly ethanol from forest industry and gasification of biomass
- Hybrid vehicles and energy-efficient combustion engines, adapted to alternative fuels

Swedish Energy Agency

Transport Sector Research at the Swedish Energy Agency

The Swedish Energy Agency supports technical research and development in issues related to road vehicles and the production of renewable fuels.

- **Close cooperation with the vehicle industry** to develop more energy-efficient vehicles and vehicles able to use renewable fuels
- Development of **energy efficient processes for biofuels**. In the long term, biofuels will be able to meet a significant part of the transport sector's needs
- Budget ~200 Mkr/yr + 245 Mkr extra (2007-2010)

Swedish Energy Agency

New budget proposal for 2009-2011

- An addition of about 800 MSEK in 3 years mainly for demonstration projects!

Swedish Energy Agency

Interesting activities

- Three pilot plants (biomass gasification, black-liquor gasification and ethanol production)
- Research program on engines, hybrid systems, fuelcells etc
- Competence centres on engine development and catalysis
- New hybrid-vehicle centre
- New hybrid demonstrations (garbage trucks and busses)
- DME as fuel for heavy vehicles

Swedish Energy Agency

Large scale gasification

- Värnamo

– biomass gasification

- Piteå

– black liquor gasification

Swedish Energy Agency

Fuel roadmap for transport?

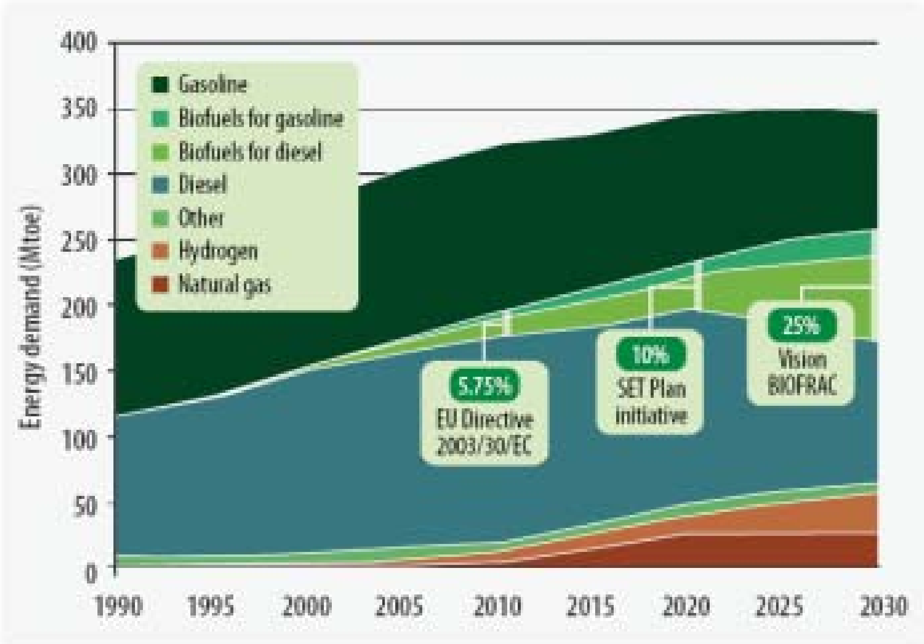
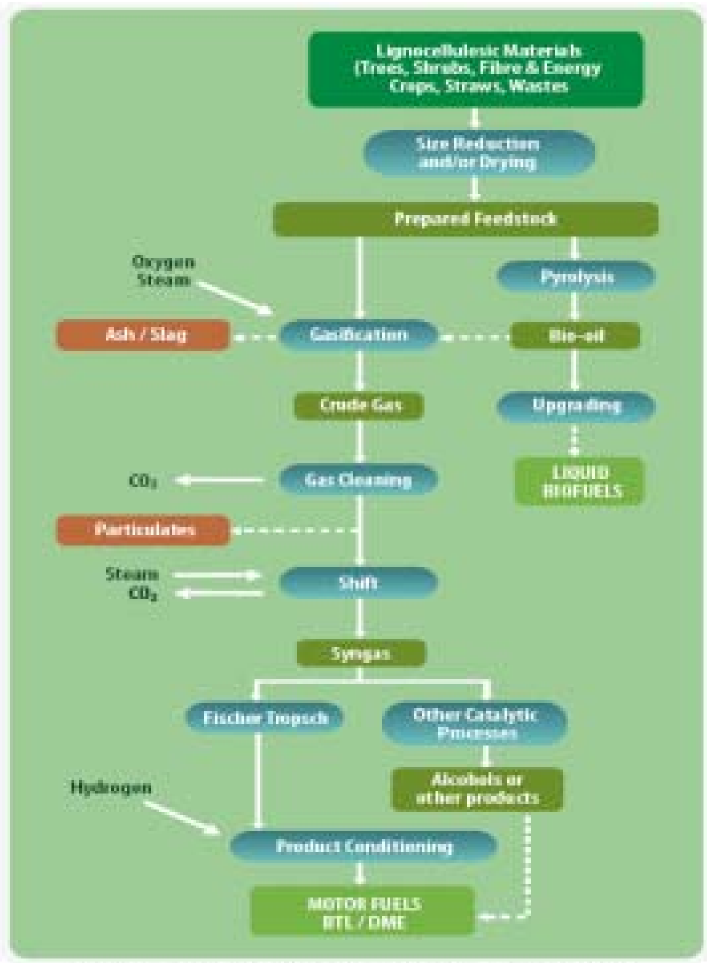


Figure 1.13. Fuel Roadmap for Transport Source: BiofuelsTP – WG3

Swedish Energy Agency

Gaseous fuels?

- **SNG**
- **DME**
- **H2**



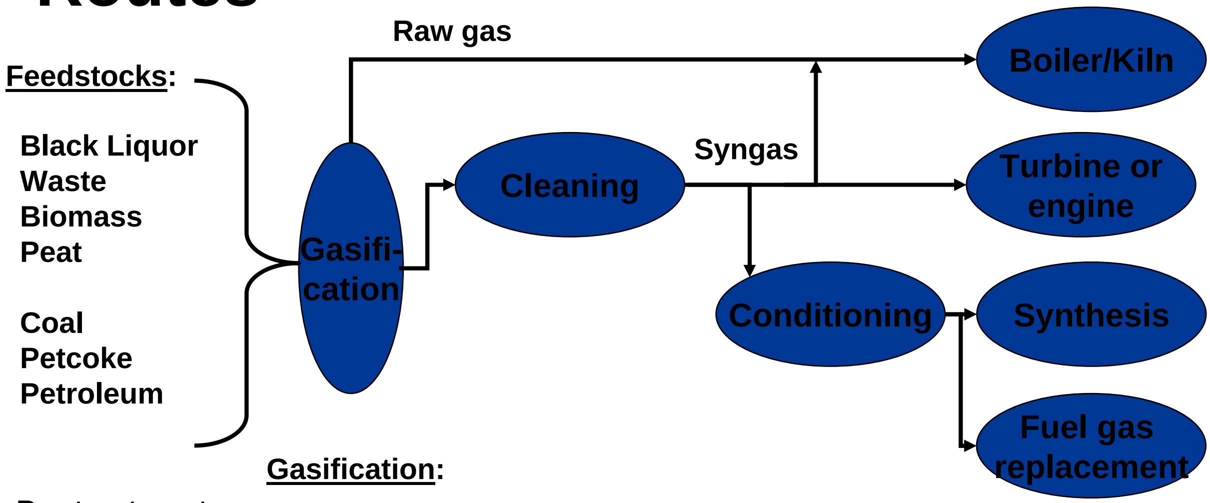
Technology Box C. The thermochemical routes to liquid biofuels

Swedish Energy Agency

Gaseous fuels – advantages

- Can be produced with higher efficiency than liquid biofuels
- No need of road transportation – in grids
- For electricity production
- Replacing oil in the industry

Flexibility of Gasification, Possible Routes



Pre-treatment:

- Grinding
- Drying

Gasification:

- Air, oxygen, steam or mix
- Low or high pressure/ temperature
- Direct or indirect

Gas cleaning:

- "Wet", cold
- "Dry", hot

Gas conditioning:

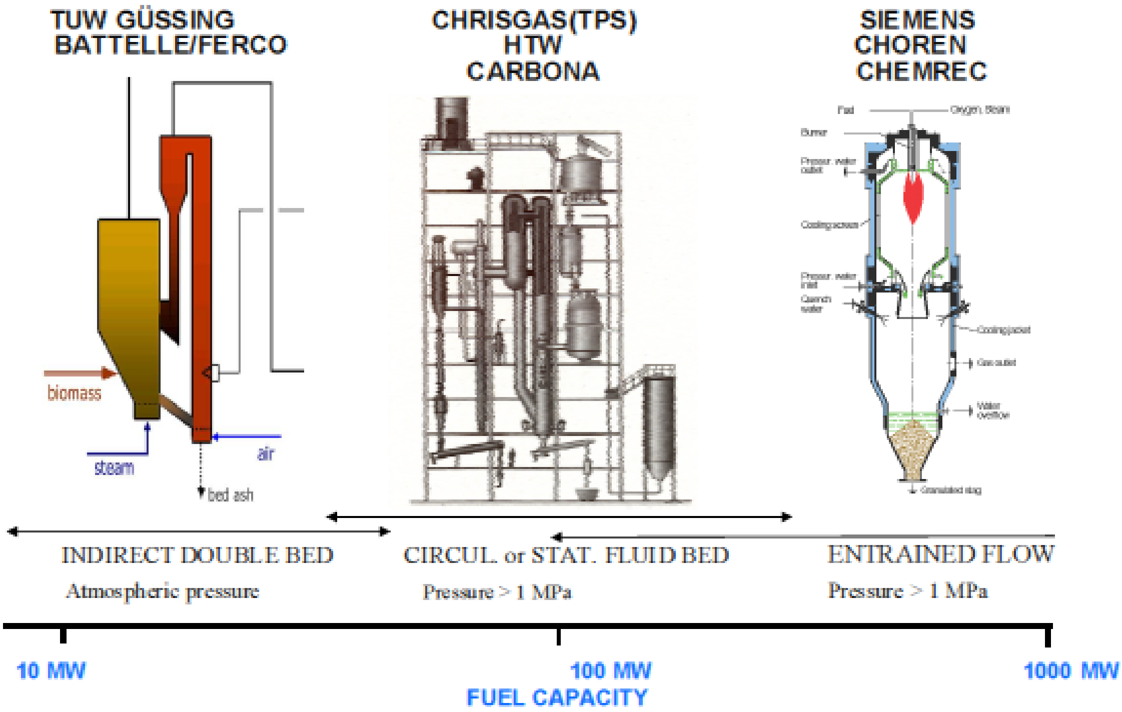
- Reforming
- Shift
- CO_2 removal

Synthesis:

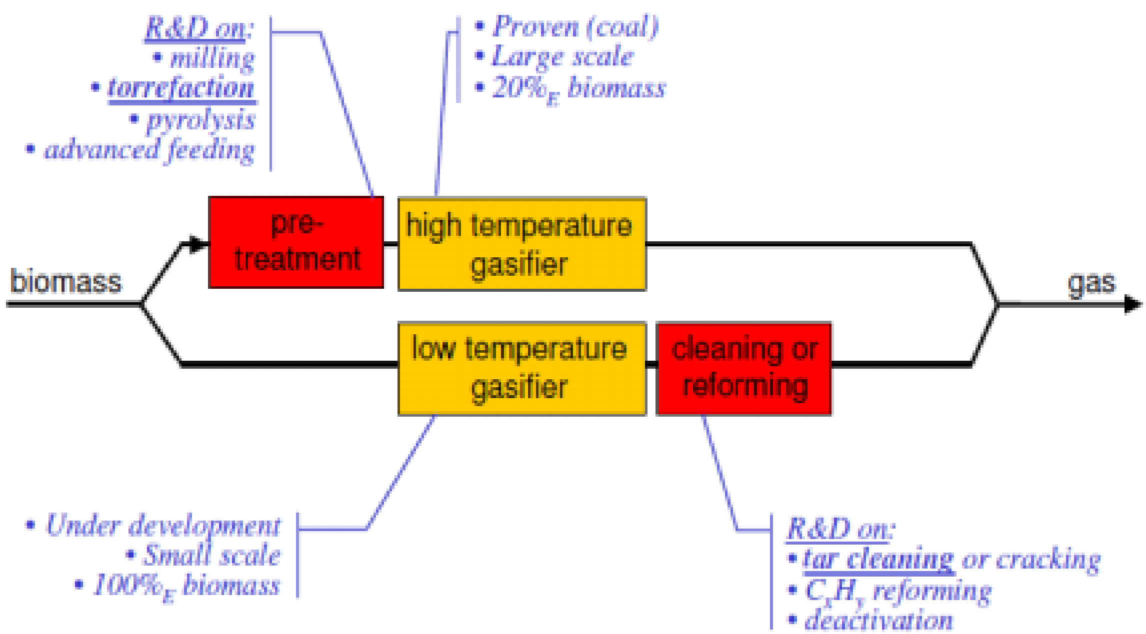
- DME
- Methanol
- F-T diesel
- SNG, H_2 etc.

Source: Tomas Ekbom, Nykomb

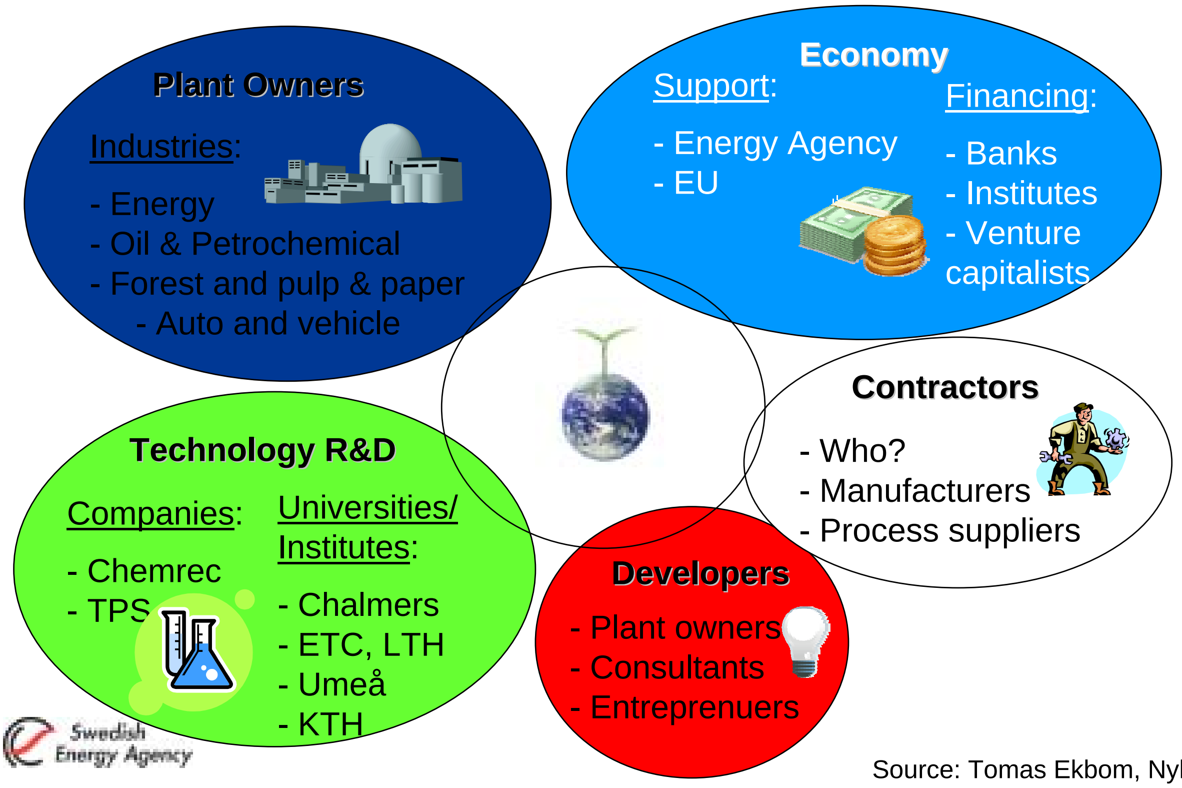
Gasifier concepts at different scales



Biomass Treatment vs Gas Cleaning



Actors Involved Taking Technology to Plant



Source: Tomas Ekbom, Nykomb

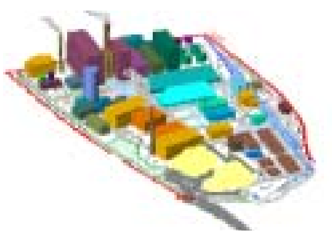
Development Time Span

Demonstration Plant

1-2 year construction

2-6 years op. program

€50-100 million

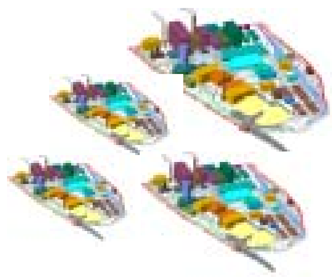


Industrial Prototype

2-3 year construction

€100-400 million

Self-supporting based on sales, grant, support



Deployment

3 year constr.

€200-500 M

”Commercial”

2008 **2012** **2016** **2020**

Requirements on biofuels for large-scale solutions

- Must be harmonized with the automotive industry
- Must produce comparable or lower emissions of substances that are harmful to the environment and human health
- Must lead to only a moderate increase in manufacturing costs compared to fossil petrol/diesel
- Must be based on long-term raw material supply with regard to the system perspective

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