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RENEW

Renewable fuels for advanced powertrains

Integrated Project

Sustainable energy systems

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Report of analysis of integrated process of synthetic gas production from different type of biomass

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Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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1 INTRODUCTION

In many regions a lot of biogeneous materials and wastes are available in various qualities and amounts. These materials are mostly rich in energy and, therefore, can be used for energy supply if suitable technologies will be developed and applied.

Biomass gasification will be one key component as it is possible to produce a synthesis gas from solid biomass which subsequently can be converted to valuable products used today.

This report contains the results of the design of an integrated process to convert biomass to liquid fuels by thermal gasification and Fischer – Tropsch synthesis.

Possible plant configurations were evaluated with respect to efficiencies and feasibility. Besides energy and mass balances also the design of the apparatuses of the main stages were considered. The works were based on the results of a research unit consisting of fine gas cleaning, gas compression and Fischer-Tropsch-synthesis which was realised and operated in a slip-stream of the biomass power plant in Güssing.

All works have been carried out in a close cooperation with the RENEW partners BKG, EDF, IEE and especially TUV.

2 RESULTS

2.1 Concepts and Sizes

According to the availability of different biomass and the use of the by-products electricity and heat two scenarios can be seen as most promising: a decentralised plant concept with a 50 MW atmospheric steam gasification plant, co-production of Fischer-Tropsch biofuels, electricity and district heat and a centralised plant concept with a 500 MW pressurized steam gasification plant, maximized FT-fuel production and some additional electricity production, mainly for in-plant consumption.

Both concepts end with the production of a FT – raw product. The upgrading of the raw product should be done in a centralised plant utilising the synergies to conventional fuel up-grading.

According to possible fuels fixed in SP 5 two specifications of Biomass have been used:
Willow – Salix and Miscantus.

Composition Willow-Salix

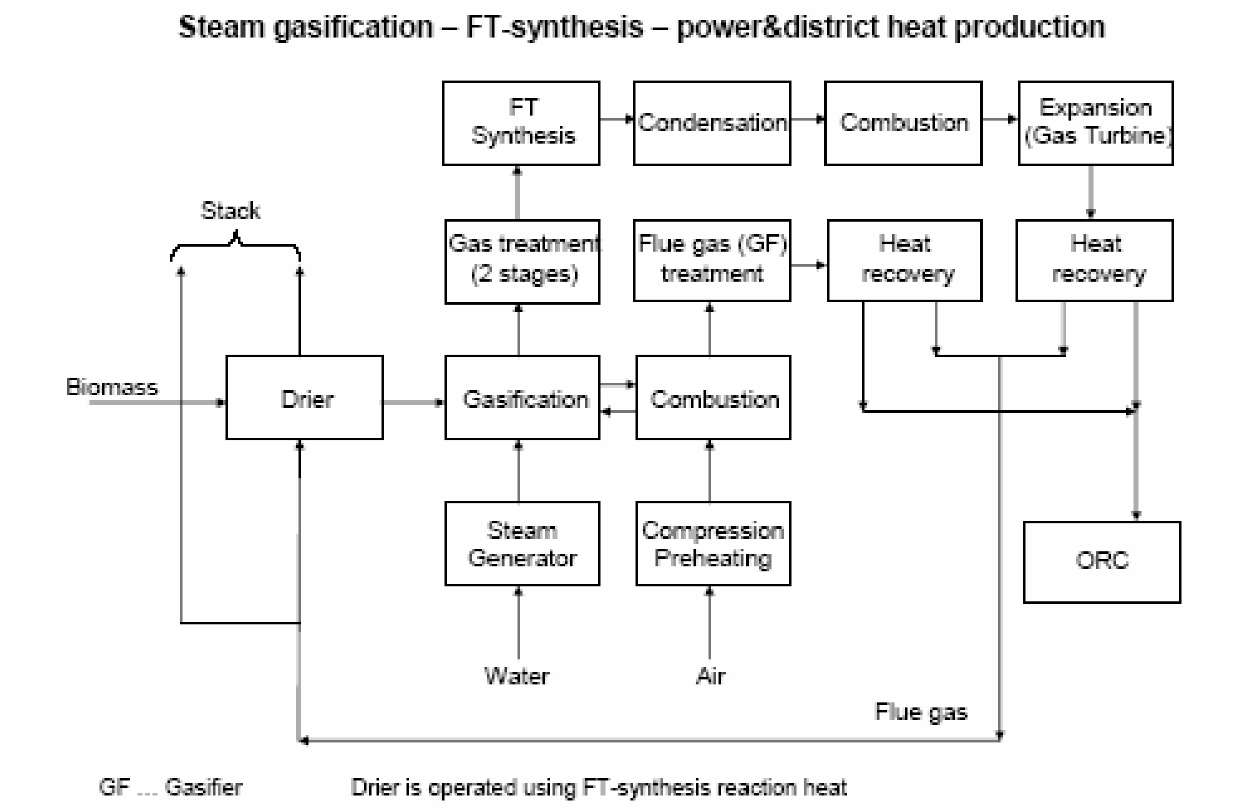
Water content	wt %	30,0
Ash content	wt %	2,0
C	wt %	48,02
H	wt %	6,08
O	wt %	43,33
N	wt %	0,49
S	wt %	0,05
Cl	wt %	0,03

Composition Miscantus

Water content	wt %	20,0
Ash content	wt %	4,0
C	wt %	47,04
H	wt %	6,14
O	wt %	41,77
N	wt %	0,67
S	wt %	0,19
Cl	wt %	0,19

2.2 Decentralised Plant Concept

A block flow chart of the decentralised plant process is provided in the following figure:



The first step before biomass gasification is size reduction. The size of the biomass particles for fluidised bed gasification should be between 0 and 100 mm.

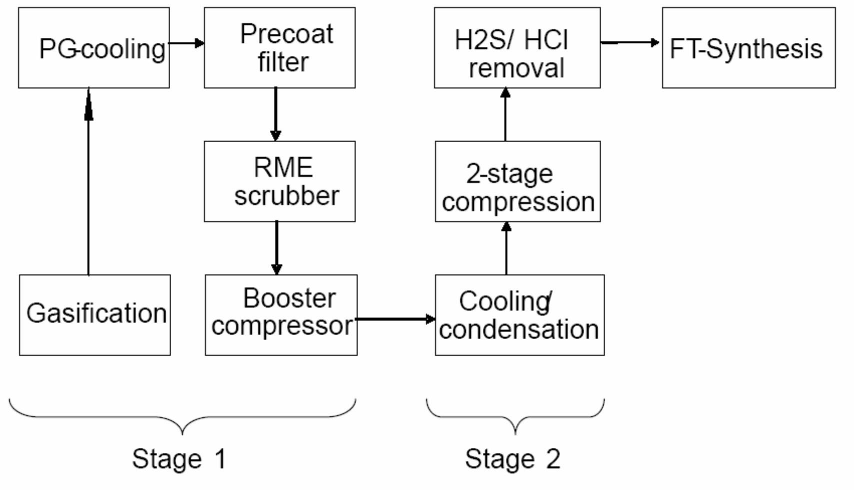
Biomass is then dried until the moisture content is about 15%. For drying biomass waste heat from the process can be used.

As gasification technology a steam blown fluidised bed gasifier is used, which produces a nitrogen free gas with a high calorific value (12 MJ/Nm3) and a low of tar content. The heart of the plant, the fluidized bed steam gasifier, consists of two connected fluidized bed systems. In the gasification zone at approximately 850°C the biomass is being gasified with steam. By utilizing steam instead of air as gasifying agent a nitrogen free product gas with a low tar content and a high heating value is produced.

To keep the energy balance for the gasification process additional heat has to be fed into the gasifier. Not completely gasified carbon (charcoal) is partly fed into the combustion zone together with the circulating bed material, which serves as a heat carrier, and is burned. The exothermic reaction in the combustion zone provides the energy for the endothermic gasification with steam.

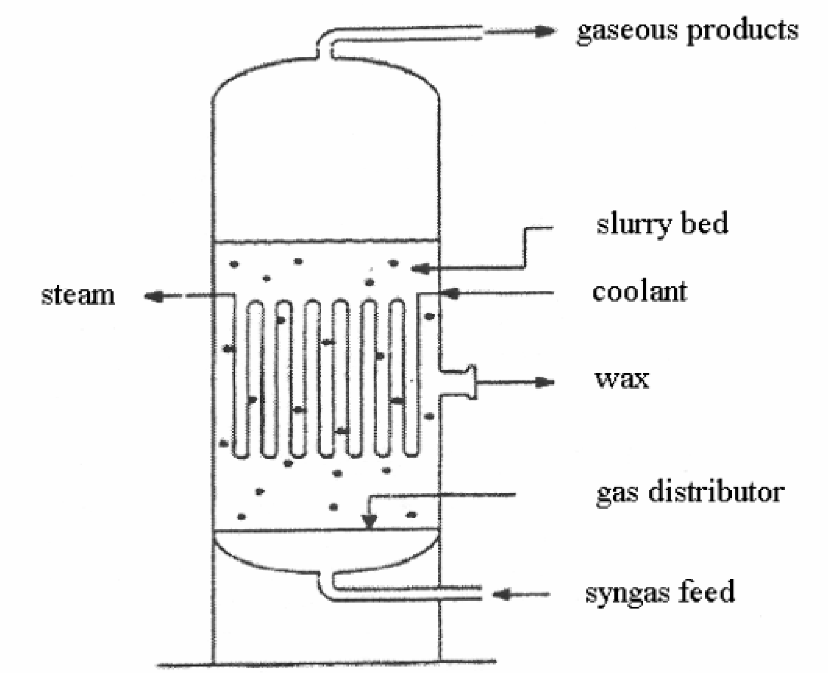
Two seperated gas streams are produced: a flue gas stream, comparable to flue gases from a conventional combustion and the product gas stream.

Details on the gas treatment, which is done in a two-stage process, are shown below:



For the FT synthesis a slurry bubble column is used. This reactor presents several advantages:

- simple construction,
- very good heat transfer in isothermal conditions,
- scaling allowed (possibly complex), and
- high capacities can be achieved (2500t/d).



The products with more than 5 carbons (C_{5+}) are easily separated by a condensation stage and sent to a cracker for obtaining fuel oil.

The wax is hydrocracked for yielding the desired cut (C_{10-22}).

The flow at the outlet of the reactor still contains CO and H_2 besides FT products. Instead of optimising the biofuel production, the system can be optimised by burning the tail gas in a combustion turbine for electricity production.

Performance data		
Fuel power	kW	50000
Electricity production (gross)	kW	9707
Gas turbine	kW	7180
ORC	kW	2527
In-plant consumption	kW	2795
Electricity production (net)	kW	6912
District heat	kW	22774
Fischer-Tropsch liquids		
Gasoline	kg/h	445
Diesel	kg/h	545
Wax	kg/h	217

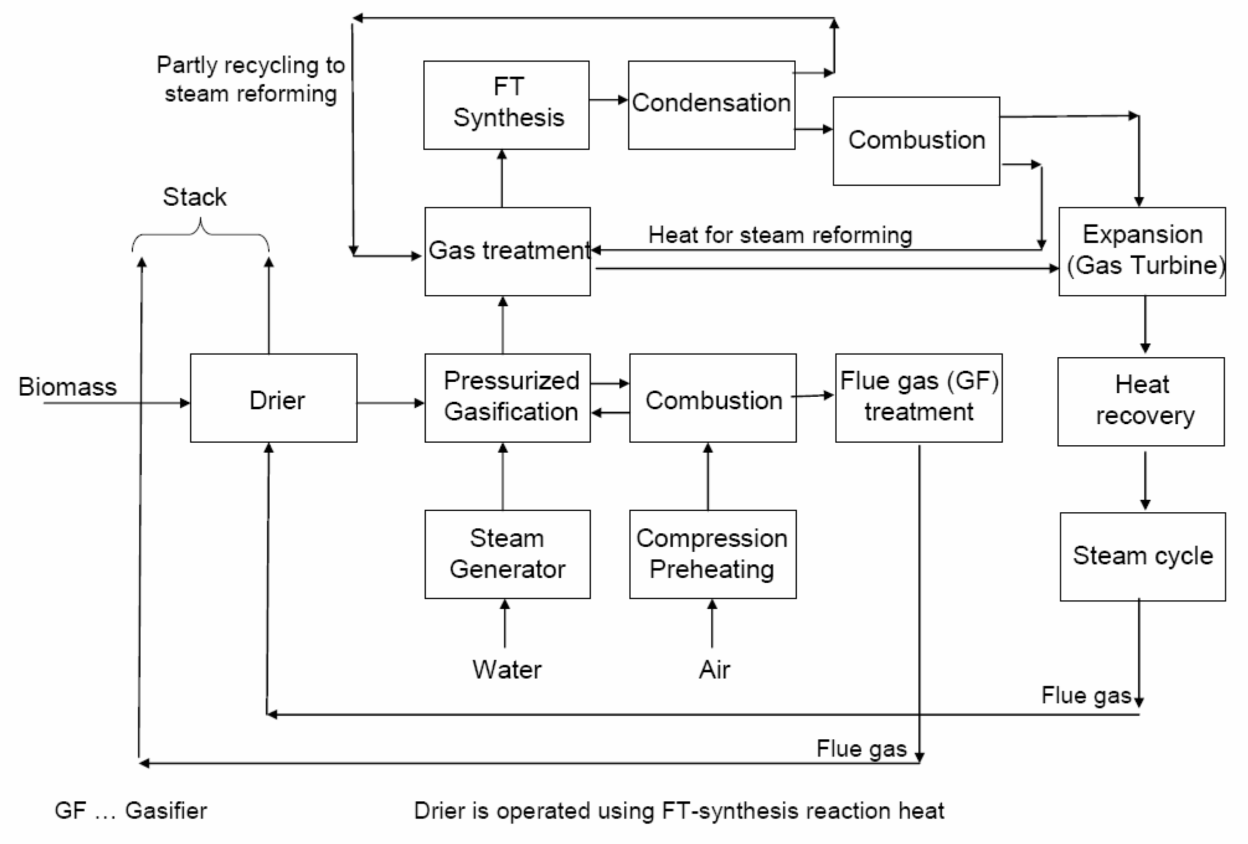
Energetic Efficiencies		
Total efficiency (gross)	%	94.6
Total efficiency (net)	%	89.0
Electric eff. (gross)	%	19.4
Gas turbine	%	14.4
ORC	%	5.1
In-plant consumption	%	5.6
Electric eff. (net)	%	13.8
District heat	%	45.5
Fischer-Tropsch liquids	%	29.7

To improve the economy of the process support mechanisms for the production of green electricity like the “Ökostromgesetz” in Austria or the “EEG” in Germany are highly welcome. These laws fix the feed-in tariffs for electricity from the plant to app. 16 ct/kWh.

Also the heat can be utilized in local district heating grids. That improves the overall efficiency and brings additional revenues to the plant.

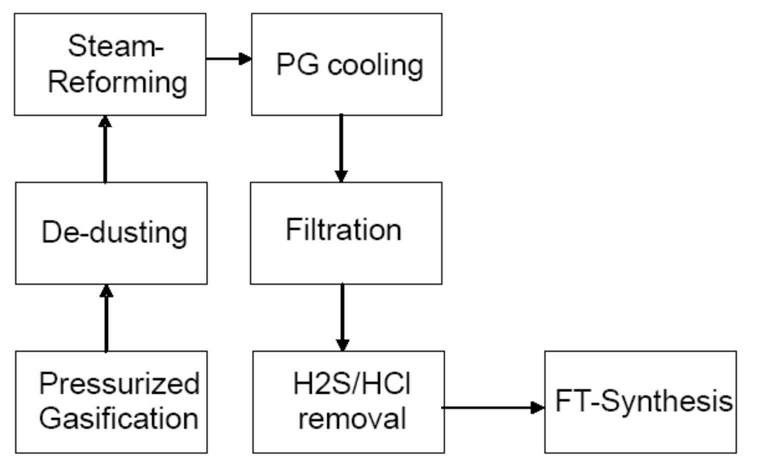
2.3 Centralised Plant Concept

A block flow chart of the process is provided in the following figure:



Compared to the process for the decentralised plant gasification is performed under pressurised conditions. The pressure is app. 20 bars in accordance to the conditions used for the FT synthesis.

To maximise the output of FT – liquids the raw gas passes a steam reformer. Details on the gas treatment, which is done by steam reforming and gas cleaning, are shown below:



The synthesis itself is more or less the same than for the smaller concept.

The flow at the outlet of the reactor still contains CO and H_2 besides FT products. For maximising the production of biofuel, the H_2 and the CO as well as the light hydrocarbons contained in the tail gas is recycled to the inlet of the reactor, or to the inlet of the reformer or of the tar cracking unit.

Performance data

Fuel power	kW	500000
Electricity production (gross)	kW	68659
Gas turbine	kW	6527
Hot gas turbine	kW	30486
Steam turbine	kW	31646
In-plant consumption	kW	33985
Electricity production (net)	kW	34674
Fischer-Tropsch liquids		
Gasoline	kg/h	5560
Diesel	kg/h	10324
Wax	kg/h	9466

Energetic Efficiencies

Total efficiency (gross)	%	75,8
Total efficiency (net)	%	69,0
Electric eff. (gross)	%	13,7
Gas turbine	%	1,3
Hot gas turbine	%	6,1
Steam turbine	%	6,3
In-plant consumption	%	6,8
Electric eff. (net)	%	6,9
Fischer-Tropsch liquids	%	62,1

As there are not enough heating grids with a capacity of several hundred MW are existing the utilisation of the by-product heat is not realistic in this concept.

On the other hand the integration of heat consuming steps of the upgrading of the FT raw product could be considered.

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