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PROJECT FINAL REPORT

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4.1 Final publishable summary report

4.1.1 Executive Summary

The Greensyngas project has dealt with advanced upgrade and cleaning techniques for biomass- generated synthesis gas by gasification. The aim has been first of all to demonstrate new and innovative techniques and processes in different states, such as proof of concept, laboratory and pilot scale demonstrations. Techniques and processes demonstrated in the project belong to one, two or all of the three fundamentally different predefined process configurations. The first one was based on physical removal and utilization of the tars in the producer gas. The second was based on oxidative thermal treatment, i.e., partial oxidation, of the producer gas and the third configuration was based on catalytic reforming of the tars. Among the demonstrations were techniques and systems for high temperature particulate removal, high temperature sulpfur, chlorine and alkali absorption in bed tar removal, selective ammonia oxidation, new techniques for online tar, particulate and alkali measurement, regenerative partial oxidation, water gas shift, new catalytic materials for tar reforming, etc.

As a complication in the project, the original pilot demonstration site, VVBG with its gasifier in Värnamo, Sweden, withdrew from the project and was replaced by BKG Güssing. Due to the difference in technology between the two sites, Värnamo pressurized and Güssing atmospheric, it became very difficult to supply the already planned demonstration activities with correct working conditions. Some of the demonstration activities had to be moved to other locations, for instance to the gasifiers at TU Delft and Munich, while others had to be performed in the laboratories at NTNU Trondheim and ULUND in Lund. To overcome the problems, and make it possible to realize the pilot demonstration of high temperature particulate removal system, Porvair begun the construction of an educator and heating system, to boost the pressure. This work was not included in the original project description and no financial means were allocated for this purpose. Due to delays caused by the highly specialized parts of this system, it was not possible to finalize the system during the project time. The particulate cleaning system was demonstrated on a laboratory scale with excellent results, but due to the time frame of the project the pilot demonstration was not carried out.

An active dissemination of information has taken place during the project time: nine journal papers have been published, and more are planned. The results from the project have been presented at 20 international conferences. The results from the project will probably impact the technique development in Europe and there are expected commercializations of technique developed in the project, for instance, the high-temperature particulate removal system. Flowsheeting based on the partner's outcome of research was evaluated by JM and the results are considered as significant part of the exploitation that bring the conversion routes of biomass to biofuels closer to the market.

4.1.2 Summary description of the project objectives:

The main aim of the project was to develop and demonstrate advanced (bio) synthesis gas cleaning technologies based on physical separation (a combination of an optimised cyclone and sintered metal filter) and chemical conversion (*in situ* capture). The purified syngas produced would then be suitable for a number of downstream applications including conversion into synthetic biofuels for the transport sector, hydrogen, or electricity generation with carbon capture and storage (CSS).

The resultant producer gas arising from the gasification of a biomass feedstock contains - to different extents depending on gasifier conditions - both particulate and gaseous contaminants that can have a deleterious impact on the performance of downstream catalysts and metallurgy. Two of the most important contaminants necessary to address are condensable tars and alkalis; other contaminants of relevance to catalyst performance include ammonia, HCl, particulates and sulfur-containing molecules. Thus, for biomass feedstocks, advances are required in the gas cleanup technologies and associated processes to upgrade the raw producer gas. A key requisite for these operations is that they have a minimal impact on the overall efficiency of the process, such as not requiring a significant amount of additional heating and electrical energy consumption.

A key aspect of the project was the demonstration of a selection of the technologies that were developed. From the initial laboratory testing, it was intended that some of the technologies, including a novel high-temperature particulate removal system, would be demonstrated at the combined heat and power (CHP) demo plant at Biomasse-Kraftwerk Güssing (BKG) in Austria. This was an important criterion for assessing the technical viability and potential commercialization of the technologies.

Addressing the scientific objectives of the project: Three configurations for the downstream processing of producer gas were proposed and are described later in this summary. The project's objectives relate to the operations making up these configuration options.

One challenge addressed in this project was the characterization of the producer gas. When dealing with tars and particulate matter, this poses a significant problem, especially when an *in situ* measurement has to be taken under plant-operating conditions.

Particulate removal is necessary and conducting this operation at a high temperature has the benefit of maintaining process efficiency. A novel particulate removal system, fundamentally comprised of a cyclone and filter unit, was developed by one of the project partners for trial testing. A number of filter elements were tested as part of the project. Tar mitigation via reaction and necessary catalyst poison removal was a major aspect for the project consortium to address.

Different reforming options were assessed by means of experiment and theoretical simulations, using catalyst/sorbent materials supplied from a catalyst vendor in the consortium. Novel formulations were also developed during the project and comparison of their performances was carried out.

The inherent energy-efficient concept of regenerative partial oxidation was studied with a dedicated simulation tool and complementary experiments to provide a proof-of-concept of its suitability for (bio)syngas application.

Prior to any downstream utilization of a clean syngas for chemical synthesis, the stoichiometry (e.g., H_2/CO ratio) needs to be adjusted or conditioned for efficient conversion chemistry, such as methanation for substitute natural gas (SNG) or Fischer-Tropsch (FT) fuel synthesis. In addition to the previously mentioned reforming processes that may be an option, the conditioning of the gas can also be achieved by the water-gas-shift reaction. Thus, as another key part of the project, experiments were performed on both vendor-supplied catalysts and university-developed water-gas-shift catalysts to ascertain their suitability for this application.

Once laboratory testing and screening work were completed, the demonstration of the candidate materials and the particulate removal system was to be undertaken at the Güssing CHP pilot plant in Austria. In addition to laboratory-scale work, this pilot-scale testing was to form an integral part of proving that the technologies developed in this project were technically and commercially viable, with an appreciation of the environmental aspects as well. The different tasks that were carried out to meet the objectives ran in parallel with the necessary communication between the partners to maintain continuity in the project. A further objective was to draw up a feasible production route (from both technological and economical perspectives) for the efficient cleanup and conditioning of a producer bio(syn)gas ready for a downstream end-user (chemical synthesis or power generation), based on the results obtained from the various tasks in the project.

Summary of Scientific and technological objectives

1. *To develop advanced characterization techniques for the measurement of emissions from biomass gasification processes in a real process environment:*
2. *To develop high temperature particulate removal systems that have minimal impact of the overall process efficiency.*
3. *To achieve valuable products of tar via tar cracking, in an air- or oxygen-blown tar cracker*
4. *To demonstrate process efficiencies by maximizing the integration of tar treatment in the process..*
5. *To evaluate the impact of different reformer process options on system efficiency and durability. This includes the use of a novel and efficient "Regenerative Partial Oxidation (POX)" reactor.*
6. *To develop sorbent materials to remove the target contaminants under optimal process conditions (the temperature and location being dependant on the choice of the reformer configuration)*
7. *To develop and demonstrate water gas shift catalysts that can deal with gasification bio-derived syngas.*
8. *To quantify the environmental and economic improvements offered by the new materials and processes by demonstrating them in the stream of the Güssing gasification facility.*
9. *To find a production route for pure syngas based on energy efficiency.*
10. *To develop novel analytical methods those permit characterization of impurities (impurities in gas and particulate state) in product raw gas in real process environment (temperature, high pressure, corrosive environment, high tar concentration, etc.*
11. *Development and assessment of high temperature particulate removal system based upon Porvair combined high efficiency cyclone and blow back element technology.*
12. *To remove impurities in gas to the required limit, downstream the catalytic reaction to minimize catalyst poisoning To accomplish conditioning by catalytic high- and low-temperature water gas shift to tune the syngas*
13. *To verify the accuracy of the obtained data at laboratory scale in a pilot-scale testing*

The following criteria are proposed as quantitative targets to assess progress towards the project objectives (the all objective have been achieved; there is no a single value since the objectives have been verified by varying reaction conditions as highlighted in WPs 2-7)

Demonstration of gas flow capacity of pilot plant's slipstream	**0.1 kg/s**	**Achieved in project**
Purity of Syngas		
CO_2	< 10 %	Güssing gas and CO_2 removal; Greensyngas was not involved in CO_2 capture
Tar	< 0.1 mg/Nm^3	WPs 2 and 4
Hetero-atoms	< 0.1 mg/Nm^3	There is tar classification in WP 2
Inorganic compounds	< 0.01 mg/Nm^3	Azhar Malik Doctoral Thesis; June 16, 2011; ISBN: 978-91-7473-124-8
HCl (Cl)	< 10 ppb	WP4
HCN, NH_3	< 20 ppb	WP 4; regenerative nitrogen removal and publication in Biomass conversion and biorefinery
H_2S, COS	< 10 ppb	WPs 2, 4, 5, 6
Alkaline	< 10 ppb	WPs 2, 4, 5
99.98 % separation of particle	> 0.3 micron	WP3
95 % separation of particle	< 0.45 micron	WP3

4.1.3 Summary of scientific and technical results in the project;

WP1 Manegment

No scientific or technical activities in this WP.

WP2 Development of characterisation technique for emission measurement from biomass gasification

Online Tar measurements

To assure failure-free operation of biomass gasifiers and downstream applications, the surveillance of impurities in the producer gas plays an important role. Two main impurities in the producer gas are tar (mostly aromatic compounds) and gas-phase alkali compounds (like NaCl or KCl). Tar blocks equipment and tubes when the producer gas is cooled down under the tar dew point and alkali compounds lead to high-temperature corrosion of steel equipment. Online measurement techniques have the big advantage that a change in the gas quality can be detected immediately. For this reason two online measurement techniques were designed and developed at the Technical University Munich TUM and tested in the producer gas of biomass gasifiers. The main task was to investigate the influence of operational parameters on the formation and release of the above mentioned impurities.

Tar measurements:

An optical, online, tar-measurement system based on laser-induced fluorescence has been developed, built and tested at TUM. Tar containing producer gas from the biomass gasifier is channelled through the heated measurement cell. The laser beam passes through a quartz glass window and excites the tar molecules in the gas. These excited tar molecules emit a specific fluorescence spectrum of light that is observed with a camera through quartz glass windows perpendicular to the laser beam. The intensity and shape of this observed spectrum contains information about the tar concentration and the tar species that are present in the producer gas. Before application the measurement setup was calibrated with synthetic tar mixtures of known concentration and composition to correlate the fluorescence spectrum and the tar concentration.
Measurements with this optical online measurement system were performed with the biomass gasifier at the Technical University Delft TUD (circulating fluidised bed CFB) and the biomass gasifier at TUM (bubbling fluidized bed BFB). Operational parameters were varied and the influence on tar was studied. The main results are gathered in Table 1 and **Figure 1**.

Table 1: Main results on the influence of operational parameters on tar formation

Parameter	Variation	Influence on tar content
Reactor type	cfb - bfb	• higher tar content at cfb gasifier
Biomass feedstock	agrol, willow, ddgs	• no clear tendency observed for gasification in bfb • agrol seems to produce most tars in cfb
Reactor temperature	700°C → 840°C	• total tar content decreases with increasing T • light polyaromats have a maximum at ~750°C to 800°C
Reactor pressure	1bar → 2.5bar	• agrol produces more tars at 2.5 bar • willow produces less tars at 2.5 bar
Steam to biomass S/B	0.8 → 1.2 (TUM)	• total tar content decreases with increasing steam content
Bed material	treated untreated olivine	• no significant difference

Online alkali measurements

An optical online measurement system based on Excimer Laser-Induced fragmentation Fluorescence was applied to measure the alkali compounds NaCl, NaOH, KCl, KOH. The online measuring system for gaseous alkali compounds (measurement performed at lab scale and field measurement (TUM gasifier)), based on Excimer Laser Induced Fluorescence (ELIF) revealed:

- The obtained result based on exposure to the real gas revealed the possibility to distinguish in the gas between sodium (Na) and potassium (K) but not between different salts, such as NaCl and NaOH.

- The studies of gaseous alkaline content in the TUM reactor as a function of the reactor temperature, steam to biomass content, pressure and the type of biomass (Agrol, willow, DDGS) showed that the Na signal was almost negligible compared to the K signal (due to the lower Na content).
- Obtained results from alkali measurement confirm that the steam-biomass ratios (in other words, the water partial pressure) influenced the alkali content of the gas the most.
- Alkaline concentration and steam partial pressure during Willow gasification in **Figure 2**

High-temperature particulate sampling system

The high-temperature dilution system has been redesigned to achieve a better temperature profile and to make it more practical during field measurements. The dilution setup has been evaluated in the laboratory using model compounds, with agglomerated soot particles as the non-volatile phase and Dioctylsebacete (DOS) as a tar compound. During the laboratory work a new device, a packed bed of activated carbon, was introduced as a complement to the previously tested denuder. The packed bed has a much higher adsorption capacity compared to the denuder. The dilution setup has been applied in the field where it has been used to sample particles from the product stream of the TU Delft gasifier. A dilution temperature of 450^{o}C was utilized during two different days, Day 1 and Day 2, where the gasifier was operating at the same conditions. As mentioned this was the same temperature as the operating temperature of the filter unit. The dilution-corrected and normalized size distributions; is shown in **Figure 3.** GMD was in both cases 144 nm. The lab scale result was in agreement with the field measurement, which reinforce the repeatability and reproducibility of the system.

WP3 Gas purification of particulates

A combined cyclone-filter unit for high-temperature particle removal have been designed and constructed. The optimisation of the cyclone was performed following completion of the laboratory-scale work. A patented metal membrane filter media Sinterflo®MM, has been incorporated into the filter system to enable a significant step change further in the separation technology. The laboratory scale equipment was constructed that the design was made based on conditions/specifications at the pilot plant. The laboratory-scale equipment tested consisted of a cyclonic pre-separation stage followed by a pulsejet, blowdown, and filter unit. The equipment was installed on the PFG positive pressure air filter test rig, which utilises a dedicated compressed air source with dust injection facilities. The solid used for the challenge was a conventional silicon oxide-based test dust that is widely used for the purposes of testing filters. This was selected, as it is a standardised test dust regulated by international standards providing both traceability and repeatability.
The performance of the cyclone whilst within the anticipated range is still lower than was originally foreseen. This will need to be reviewed and the model investigated further to determine whether improvements can be made before the plans for building the pilot unit are finalised. The pulsejet filter has functioned in line with expectations and performance is in compliance with test standards for the selected filter media.

Comments

1. The performance of the cyclone whilst within the anticipated range is still lower than was originally anticipated. This will need to be reviewed and the model interrogated further to determine if improvements could be obtained before final build of pilot unit.

2. Pulsejet filter has functioned inline with expectations and performance is in compliance with test standards for the filter media selected.

Significant results:

The laboratory trials demonstrated that the combination of a cyclone and filter element to form an Integrated Multistage Separation System (IMSS) is effective in achieving high mass removal efficiency. The effectiveness of the on stream pulse jet cleaning system was also demonstrated. The performance of the cyclone was within the expected range of performance though towards the lower end of the efficiency. The tests were run several times for confirmation.
The particulate distribution of the contaminant downstream of the cyclones was measured and is graphically represented in **Figure 4**.

WP4 Tar, alkali, HCl, NH3 and sulfur removal at high-low temperature

High temperature Alkali, H_2S and Cl sorption

The sorption experiments conducted at FZJ shows that bauxite, kaolinite and zeolites are suitable for KCl reduction down below 0.1 ppmv. This results in a condensation temperature of about 535 ^{o}C downstream from the chemically hot gas cleaning.
The results of the sulfur sorption experiments show that Ca-based sorbents are more suitable in H_2S sorption under Güssing conditions (T=850^{o}C, P= 1 bar) than Cu-based sorbents. Furthermore H2S concentrations of 50 ppmv are achievable at 800^{o}C. **Figs 5 and 6**
The results of HCl sorption on Na_2CO_3 and K_2CO_3 in a syngas with high moisture content at temperatures between 400°C and 550°C show that this reaction is kinetically limited. In order to prevent the limitation through kinetics, the space velocity has to be reduced to 4900 h^{-1} for the Na_2CO_3 sorbent and to 3750 h^{-1} for the K_2CO_3 sorbent. Below these space velocities the limit of 1 ppmv HCl is achievable. Based on the conditions appearing in the Güssing gasifier (850°C, 1 bar, 0.8 kg H_2O per kg biomass), calculations were made on the gas composition resulting from gasification of the "project" biomasses, the achievable alkali concentrations and resulting condensation temperatures depending on used biomass **(Figure 5),** the achievable H_2S and COS concentrations depending on used biomass **(Figure 6)**, and the achievable HCl concentration. The results are in good agreement with the experimental results. Aluminosilicates achieve alkali reduction below 0.1 ppmv**.** Thus, the condensation temperature decreases to 492°C. However, this sorption mechanism is limited to syngases with low HCl concentrations. The commonly used sulfur sorbents such as calcium oxide and copper are not suitable for sulfur reduction below 410 ppmv - 340 ppmv. However,

the new Ba-based sulfur sorbent is suitable for sulfur reduction below 1 ppm. Alkali carbonates are suitable to limit the HCl concentration in the syngas to values below 1 ppm at temperatures below 550°C.

New in-bed, tar-cracking catalyst

UNIBO prepared a new tar-cracking catalyst, for in-bed usage, based on iron (Fe3+) hydrotalcite. The catalyst was characterised at UNIBO and the activity of the catalysts was evaluated under real conditions at the TUM gasifier. The catalysts were tested in a reactor placed in a slipstream downstream from the gasifier as a first step to evaluate their activity in the tar removal. The catalytic data are reported in WP7.

Online tar measurements

Two on-line tar-measurement campaigns have been carried out on the 100kW_{th} CFB gasifier at TUD and the PBFB gasifier BabyHPR at TUM. The main objectives of these two measurement campaigns were to quantify tar content by means of two on-line measuring techniques (OTA and LRS) and one off-line Solid Phase Adsorption (SPA) technique developed by the Royal Institute of Technology, Sweden (KTH) and to evaluate the accuracy and reliability of two on-line tar-measuring techniques by comparing SPA results and analysing the possibilities for the improvement of the TA120-3 on-line tar analyser (OTA). As a conclusion, the LRS method is a reliable on-line tar measuring technique. Its measurement results showed a good agreement with the SPA method. Both the LRS and OTA methods can be used as an indicator to observe real-time change in the performance of the gasifiers. However, to achieve good and reliable tar measurement results, a regular calibration of the OTA is extremely important. The settings of the analyser used for the measurement should be kept the same as those used during calibrations, since the response factor is very sensitive to all parameters. Moreover, the change of any of the parameters could lead to a significant influence on the actual measurement results. Although all settings remained the same, a fluctuation margin in the range of ±10% among the measured results was not avoidable due to several reasons such as real-time continual change in the operational conditions from the gasifier, and measuring sthe ensitivity of the tar analyser.

In-bed sulfur capture

The distribution of sulfur species during biomass gasification and the thermodynamic analysis of H_2S sorption using different sorbents have been calculated /predicted using the software package Factsage version 5.4.1 (GTT Technologies). Furthermore, kinetic studies toward on/off the sorption capacities of various sulfur capture materials such as ZnO, Fe_2O_3, MnO and CuO have been carried out using a mixture of H_2S in N_2 using TG analysis. The conversion rate versus time of ZnO sulphidation under different H_2S concentration and different temperatures using N_2 as carrier gas is presented **in Figure 7. From Figure 7**, it can be seen that a fairly low conversion rate was observed under all the conditions and a higher H_2S concentration led to a higher conversion rate. However, some unexpected results have been observed during sulphidation testing, especially with MnO and CuO. This part of the research work will be continued.

Oxidation of Ammonia with NO_2

The reduction of NO_X with NH_3 has been known for decades as SCR. SCR is performed in oxidising environments. The ammonia oxidation in synthesis gas is the opposite. The reducing environments propose a potential problem as to how long NO_2 remains in the gas without being reduced. NO_2 is reduced to NO and, without oxygen in the gas, leads to a decrease in ammonia conversion. A small reactor was built to perform the reverse SCR experiments. **Figure 8** shows a typical run for the system. Starting just below 2000 ppm ammonia and after a few minutes the N_2/NO_2 is added to the stream. Initially the concentration of ammonia increases as the increased gas flow decreases the temperature over the catalyst. Thereafter the ammonia concentration drops rapidly to settle at around 340 ppm. The stoichiometry NO_2/NH_3 is increased to 1:1.125 and the outlet concentration falls to 150 ppm. The final stoichiometry of 1:1.25 leaves the gas with only 50-60 ppm ammonia in the outlet. The N_2/NO_2 injection is then turned off and the ammonia concentration increases rapidly and settles around the starting concentration. The inverted SCR process for reduction of ammonia in synthesis gas seems very promising.

WP5 Non-catalytic and catalytic steam-reforming, catalytic poisoning and process flow sheeting tasks.

Reforming and catalytic partial oxidation (CPO) of hydrocarbon to synthesis gas

Tests have been performed at UNIBO in a laboratory setup with catalysts provided by JM. Ni and Rh catalysts in the form of pellets and monoliths were tested.
As general conclusions of the catalytic experiments:

- The presence of NH_3 does not change significantly the activity of the catalyst.
- The presence of aromatics decreases the selectivity of H_2 and CO_2 while it increases the selectivity of CO
- In the returned tests the catalyst is not deactivated and works as the fresh one. The presence of H_2S strongly decreases the conversion of CH_4 and the main product of reaction is CO_2.
- After regeneration, the activity of the catalyst is less than the fresh one. The presence of Rh increases the stability towards the sulphur deactivation.
- - Both Ni- and Rh-based commercial reforming catalysts were capable of giving significant tar conversions in the presence of H_2S at temperatures of 700 – 900°C though little methane conversion was observed. In the absence of H_2S, significant methane conversions could be obtained for the best catalysts at 800°C and above and tar conversions were increased.
- -Both toluene and naphthalene were converted to similar extents and the only hydrocarbon product observed was benzene. Removal of the H_2S from the gas feed led to rapid improvement in hydrocarbon conversion indicating that H_2S was a significant poison but probably exhibited a transient site blocking effect.

Steam-reforming configuration 3

Lab-scale experiments have been carried out by NTNU in order to evaluate the effect of potential poisons and tars. Model compounds have been used to simulate the poisons that might be present during a real operation: KNO_3 and KCl, soot, and toluene as a model tar compound. Finally, combined steam reforming and water-gas shift experiments have been carried out with a compressed gas from the Güssing gasifier. An Rh-containing monolithic catalyst has proved to be active for the steam reforming, and was the chosen material for the lab-scale demonstration of the steam reformer, **Figure 9.** The effect of poisons has been evaluated.

- Small amounts of K deposited on the catalyst indicate a small increase in catalytic activity, but larger amounts of K result in deactivation.
- The presence of toluene reduced the CH_4 reforming activity, due to competitive reactions or possibly dealkylation of toluene.
- A lab-scale demonstration of the combined steam reforming and water-gas shift reaction shows that it is possible to tune the H_2/CO ratio of the product gas to the desired value (described in detail in the WP6 section.)

Exposure of catalyst to size-selected particle of ashes composition

Deposition of soot particles on reforming catalysts in non-reducing environment at medium temperatures has been performed by ULUND. Soot particles have been deposited and the loss in catalytic activity has been observed on reforming catalysts. The results indicated that even small amounts of carbon (0.5 - 1.0 wt %) could lead to a 50% drop in activity as compared to the activity of a fresh catalyst. In continuation to carbonaceous particle depositions on reforming catalysts, the exposure to the inorganic particle has also been carried out in lab-scale experiment. During these tests reforming catalysts have been *ex situ* exposed to inorganic particles, leading to the investigation of the effects of particle deposition and the resulting activity loss during the reforming process. The presence of small amounts of potassium salts has positive effect on the initial catalytic steam-reforming activity of the precious metal catalyst JM GSG-05, **Figure 10.** With larger amounts of the salt deposited on the catalyst, the activity drops. The deposition of small amounts (0.5-1.0 wt %) of fine particulate carbon on Ni catalysts may result in a significant drop of the catalytic activity.

Regenerative partial oxidation

A computer model was created by ULUND to simulate the behavior of the regenerative process. The model was put to work and generated information about the process and design data for the bench-scale model that was built, **Figure 11**. Initially the kinetic model was the GRI-Mesh 3.0. This model does not take into account the soot formation. A much larger kinetic model, from MIT, was applied. This model showed that soot formation during the regenerative operation, while using producer gas, is most likely to occur. Since the unit is constructed with a packed bed, this would be very problematic. Instead, the regenerative, partial oxidation process is a methane-reforming unit. The bench-scale unit was run under partial oxidation conditions and the temperature profile was recorded.

WP 6 Water-gas shift and scale-up.

Investigation and selection of catalyst

- Fe-Cr water-gas shift catalysts can withstand the presence of sulfur (100 and 200 ppm H_2S) as it has been observed in the tests performed at ULUND. However, the huge amount of sulfur in the DDGS producer gas (about 2000 ppm H_2S) will affect the catalytic properties of Fe-Cr catalysts, since the Fe-Cr catalyst will be sulfided and this form is less active than the oxide.
  - CoMo sour water-gas shift catalysts are sulfur-tolerant; in fact, they are active in the sulfide form:
    - They are an alternative to the Fe-Cr catalysts. CoMo catalysts were prepared by impregnation of a CoMo precursor on $CeZrO_2$ and MgAlO mixed oxide supports.
    - The CoMo precursors are Anderson-type heteropolyoxometalates [$(NH_4)_3CoMo_6O_{24}H_6$ $7H_2O$ and $(NH_4)_4CoMo_6O_{24}H_6$ $5H_2O$], which after calcinations give rise to CoMo oxides on the support that will subsequently be activated. Moreover,
    - FeMo catalysts were also prepared. The characterisation by means of Raman and FT-IR spectroscopy and PXRD revealed that the CoMo Anderson polyoxometalates were synthesized and impregnated (with different loadings) on the supports, without largely altering their structure. Conversely, iron-containing phases instead of polyoxometalates were obtained for FeMo compounds. The activity was evaluated by modifying the composition of the gas mixture, activation and reaction conditions. However, despite all these efforts the activity of the catalyst was very low. After characterisation of the used catalyst it was concluded that the CoMo active phase was not properly activated.

System integration

The WGS demonstration was carried out: to do the steam-reforming experiments combined with the WGS reaction on a lab scale, using a compressed gas from the Güssing plant. The objective is to demonstrate how the composition of the final product gas can be tuned by adjusting operational parameters. Combined steam reforming and WGS reactions have been carried out on a lab scale using the compressed Güssing gas and the FeCr (high temperature) WGS catalyst. It was possible to tune the composition (H_2/CO ratio) of the product gas in the WGS unit. H_2/CO ratios (between 2 and 3) were achieved, which is suitable for a number of reactions involving syngas, **Figure 12.**

WP 7 Demonstration activities

Reforming tests at TUD

Ni- and Rh-based catalysts (both prepared at UNIBO and supplied by JM) were chosen to perform the demonstration of the reforming of a real producer gas at the TUD oxygen/steam fluidized bed gasifier. Ni-based catalysts (JM-NiRef5 and Ni-HT) were used in the reforming of Agrol producer gas, and Rh-based ones (JM-R3P and Rh-HT), in the reforming of willow producer gas.

- Ni catalysts gave total methane conversion at 950ºC, but their activity dropped sharply as the temperature was decreased to 850ºC.
- Furthermore, the catalysts deactivated with time-on-stream probably because of the sintering and deposition of particulates on the surface of the catalyst.
- The Ni-HT catalyst was more active than the JM-NiRef5 one. The JM-R3P catalyst showed high activity in the reforming of willow producer gas even at low temperature, i.e., 850ºC.
- Conversely, the Rh-HT one showed poorer performances and the activity decreased at lower temperature. Tars were almost completely removed with both Rh catalysts after the reformer regardless the temperature.

Tar removal at TUM

Fe-based catalysts obtained from Fe/Mg/Al hydrotalcite-type compounds with carbonate and silicate as interlayer anions were tested in a fixed bed reactor at the TUM gasifier to study their tar removal efficiency. The reactor was placed in a slipstream downstream from the gasifier. Sulfur and chlorine were removed by JM sorbents upstream the catalytic reactor. The tests were performed at a temperature close to the gasifier one (ca. 820ºC). The tar content of the gas before and after the reactor was measured by SPA analysis, **Figure 13.** Not only was the tar content modified after the catalytic bed but also the dry gas composition. The water-gas shift reaction, promoted by the iron, yielded to an enrichment of the gas in H_2 and CO_2 regardless of the catalyst formulation. The order of activity was HT-sil1 > HT-sil2 > (HT-sil1 + HT-sil-CO_3). The HT-sil1 catalyst reduced the total tar by over 80% of the initial tar load; HT-Sil2 reduced it by 37% and the mixture HT-Sil1 and HT-CO_3, by 75%. The reducibility of iron species determines the distribution of the iron-containing phases in the used catalyst (iron oxide or spinel phases with Fe^{2+} and Fe^{3+} species). The HT-sil1 catalyst displaying better performances seemed to show a higher amount of spinel than FeO. These features together with the different S_{BET} values and Fe-content may explain the different catalytic activity in the tar removal and the possible deactivation by carbon formation.

The particle sampling probe

The particle sampling probe has been designed and constructed by ULUND. The probe was optimized for minimum sub-micron particle loss at lab-scale with model compounds of organic and inorganic substances. In a later stage the probe was tested on a stream of gas from a gasifier located on the TUD site. The pilot test supports the results obtained from the laboratory test. The probe was further developed in order to measure the performance of the cleaning device designed by PA. In case the demo activity on the site of Güssing will not be realised, the results from the TUD gasifier will have a sufficient supply of data to cover this sub-task.

Dissemination of the suggested flowsheeting in production routes of biofuel

The flowsheeting work performed as part of the GreenSyngas study by JM has been a useful exercise in considering what an actual process might look like and the piecing together of the cleaning and conditioning stages that can be required in a potential biosyngas flowsheet. It has emphasized that there could be multiple solutions may exist for a clean-up and conditioning section, with the configuration being dependent on the end use of the biosyngas and the hydrocarbon and contaminant removal needs. Catalytic downstream conversion processes are significantly more stringent in purity requirements than for use in a boiler system, gas engine or gas turbine and this will likely dictate the need for additional purification operations with chemical synthesis.

Some interesting points that have arisen from the simulation work are:

- For an SNG end use, a reforming stage leads to increased syngas (conversion of tar to additional CO, H_2) subsequently favoring increased methane formation. However, there is a need to also compare with the amelioration in syngas formation rate from tar recycling back to the gasifier. Also, a reforming stage increases H_2/CO ratio and thus can reduce the need/capacity for a separate water-gas shift step. Furthermore, it would reduce the need of on-site wastewater treatment capacity and a tar recycle stream that is most likely necessary with water-scrubbing-based tar removal systems, although in fairness, this needs to be compared with more efficient/effective hydrocarbon/oil-based scrubbing systems.

- For FT synthesis, the concurrent removal of methane and higher hydrocarbons as well as the tars is beneficial for cost and operation of the downstream FT synthesis section. Saturated hydrocarbons act as inert / dilutent whilst unsaturated hydrocarbons can unpredictably influence the FT product spectrum. On the other hand scrubbing processes generally do not remove some of the hydrocarbons present in producer gas such as benzene and ethylene, and of course not methane, the latter being present at levels >10 mol.% for some low temperature gasifiers.

- The use of an oxygen-fired Auto Thermal Reformer (ATR) for tar removal is energy intensive and both the CAPEX (Capital Expenditures) and OPEX (Operating Expenditures) of an associated oxygen plant should also be considered in any economic evaluation. As an aside, for large-scale biosyngas flowsheets, oxygen-blown entrained-flow gasifier technology has been suggested in the literature, itself requiring Air Separation Unit (ASU). However, with these high-temperature gasification technologies, bulk tar removal is not usually an issue.

- It is envisaged that the compressor requirements of the syngas produced from an low pressure gasifier make a large energy demand on the process, although a significant part of this energy may be recuperated from cooling the producer gas and generating high pressure steam for a turbine.

- The decision to do process configuration is ultimately influenced by process economics, which have not been duly considered in this preliminary simulation work. For example, with SNG production as an end user of the bio-syngas, the cost of incorporating a dedicated reforming stage needs to be compared with coping with higher hydrocarbons in the gas stream and also water treatment costs generated by a bulk water-scrubbing unit for tar removal instead. With FT synthesis the corresponding reforming cost (possibly an ATR with ASU) would need to be looked at instead of handling increased methane and other hydrocarbon diluents (some reactive) in the synthesis section. As an indicator, the main equipment costs (not including compression) are thought to follow these stages: ASU > Gasifier > CO_2 removal >> Gas clean-up.

- As an aside, operation at pressure has been briefly examined and at first glance the flowsheet configuration seems to be similar in layout to the low pressure case with obvious savings with the compressor requirements.

4.1.4 The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages)

The engineering and assessment of an efficient particulate removal system to operate at high temperature, based on the design (PA) was developed as part of this project and was also scheduled to be tested on the stream of an established pilot plant (Güssing CHP) in 2011. The laboratory trials demonstrated that the combination of a cyclone and filter element to form an integrated multistage separation system (IMSS) was effective in achieving high mass-removal efficiency from a model flue gas. The project time frame was short considering implementation of the pilot testing, which offer an invaluable asset in the decision making process (biomass-biofuel) for commercialization**.** A pilot-plant trial of this cleaning device that predicate the long-term trial will be discussed in a future funding with JM, PA and BKG. Whether the ultimate use of the (bio)syngas will be for chemical conversion to fuels or simply power generation, an efficient particle removal system is a prerequisite, and in some cases the ability to operate such a system at high temperatures will improve the energy efficiency of the process. The high temperature sampling probe constructed and built by Lund University, will complement this particle removal device and will also be installed for the pilot-plant trials and may prove itself to be a key piece of equipment in such plants. The viability of probe was already tested on stream of TUD gasifier.

To evaluate the impact of different reforming options based on system efficiency and durability, the investigation of the catalytic and non-catalytic systems has been conducted via lab-scale experiments (using model compounds, supply gas from Güssing gasifier, and on stream of TUD and TUM gasifiers) and also process simulation of the non-catalytic "Regenerative Partial Oxidation (POX)" concept. The simulation results from this latter concept revealed the probability of soot formation, derived from lower hydrocarbons (except methane) present in the gasifier producer gas. This soot would contaminate and effectively render inactive any downstream catalyst without some suitable protective measure installed; however any filtration device would be at the expense of pressure drop. It has already been shown in this project that soot deactivates reforming catalysts to different extents. Although experimental observation of this prediction is still required to be obtained, this result may steer future research into looking into an additional upstream reforming stage to convert the hydrocarbons that are present.

The results from the work carried out on candidate materials such as catalysts and absorbents in GreenSyngas has been valuable in helping to assess the viability of the materials for real applications. In order to be conclusive as to their performance in a commercial application then further investigation would be necessary in particular more studies utilising a real producer gas downstream of a gasifier. There is also the requirement for long-term testing under these real conditions. No timetable of commercial or other use of the catalytic materials can be predicated at this stage in development, but the results derived from GreenSyngas are indeed useful, notably when comparing nickel-based reforming catalysts with PGM versions, with further work involving a cost-analysis.

The conditioning of the syngas via water gas shift catalysis has been experimentally studied in this project and with further testing using Güssing gas samples and also syngases derived from lab-scale gasifiers, the results contribute towards assessment of the viability of a catalytic water gas shift stage in a commercial biofuels flowsheet.

Finally, the consolidation of the simulation, experimental and pilot-scale work was incorporated into a suggested process flow diagram that has also considered the energy efficiency of the various configurations. The process flowsheeting work can also support this area to decide whether or not catalytic unit operations are beneficial in biosyngas processes considering the limitations of the scrubbing-based solutions (for tar removal) that currently exist at demonstration scale.

In this project a multidisciplinary competences have been gathered to solve the problem with technology in producing fuel from biomass. The straight impact of these results is foreseen to be in commercial use. The second impact is based on distribution of the finding to the target groups (involve producing companies) in improvement of existing techniques.

Contact with relevant industrial partner has been established in international conferences on use of syngas for chemicals and fuel production. The SME contact except BIL Sweden has not been widely implemented since need to be focused on specific innovation. Of course, the Project Partners were agreed that an important part of the successful completion of the Project is that the Project results are disseminated through appropriate channels, in accordance with the Project Publication plan (Deliverable number D8.2), and consider BIL Sweden Adm AB to be one such appropriate channel. BIL Sweden Adm AB assisted the Project Partners with the dissemination of the Project results to a broader societal audience, including SMEs (BIL Sweden Adm AB is SME). The coordinator provided Bil Sweden with general information concerning GREENSYNGAS. Further action in dissemination initiated by EC through publication in BIOMAP, “Template for mapping of EC funded contracts on biofuels”. The project results concerning flowsheeting of the process and the novelty of cleaning device are example of such exploitations that have also potential to be commercialized.

The results expected from the GreenSyngas project represent a great knowledge and experiences required to solve troublesome of cleaning step, and likewise very challenging, stage of the development in three process configurations. That is; in the future project it require that the concept to be demonstrated the more energy efficiency and techno-economic feasible production routes of the motor fuel, in GREENSYNGAS in the laboratory-scale, future “pilot plant testing” (the estimated time of three years for pilot plant demonstration was not sufficient), and then later at commercial scale-up at competitive costs throughout Europe. The know-how resulting from this project will be representative of a variety of European conditions and will support any plans for large-scale implementation of transport fuel (the achievement obtained up to now).

On the European level, valuable “multidisciplinary” in the research area resulted and the tested/unique achievement are of value to international interest.

The results from the project will be used to guide the design of future production routes of pure syngas from complex biofeeds, bioenergy companies, chemical and petrochemical, and oil companies. In addition, a non-profit organization, Bil Sweden, assisted GreenSyngas partners in the dissemination to society of the usage of synthesis biofuels and their benefits for climate change.

Strategic impact

The need for sustainable energy sources is fundamental for a continued economical and industrial European development. Within this context, renewable energy sources such as biomass-based combustion/gasification or ethanol production is becoming increasingly important. The possibility of using and improving this technology is based on available know-how.

One common theme in the requested technological knowledge is the fact that the technology is related to different multiphase reacting system, i.e. the reacting system producing energy constitutes reactants and/or products that exist in different state of phase (liquid, solid, gas).

From a scientific point of view, this kind of reacting system is very complex. The phases are continuously moving in relation to one another, a movement that more often than not include non-linear behaviour and highly turbulent phenomenon. To this end of complexity one should add also non-linear reactions and the fact that the different phases might change in volume, state and shape as a result of the chemical transformations taking place.

The complexity of the phenomenon involved makes it difficult for one country alone to have enough skilled people in the necessary areas, in order to be able to develop the technologies further. Also, in different parts of Europe different techniques have emerged and a European network might facilitate spreading of new technology.

In many cases, new fuel production techniques from solid biomass, such as gasification of biomass, develop their own methods and standards without fully taking advantage of existing techniques and scientific skills. At the same time the established energy structure does not always easily incorporate new ideas. Therefore, to establish a network of expertise where all techniques and scientific aspects are studied together, will enhance the exchange of knowledge between the new and the old.

This project aims also worldwide environmental concern regarding the release of e.g. greenhouse gases, European Strategy’s of Commission’s Green Paper for improvement of the sustainable, competitive and secure energy system and the presumed oil shortage. The problem is more concern substitution of fossil fuel by bioenergy as a transport fuel. The previous R&D program and demonstration have faced technology problem in production of pure syngas. In this project a variety of unit operation have been suggested. However by evaluating process conditions is, to substantiate the given targets through comparisons and analysis (three process configurations) of the conceptual energy calculation to be developed within the project. The basic idea is energy minimisation by re-using consumed energy in production routes. Very much of the expected impact listed in the work programme is therefore the very core and targets for GreenSyngas will be listed. The following expected impacts have been attained within the GREENSYNGAS, except a deviation concerning demonstration of pilot plant of cleaning system on the stream of Güssing gasifier. It seems that the time frame of three years is not sufficient in order to move from lab-scale achievement to demo activities.

Up to now:

Expected impact: Smooth facility of communication between partners in consortium and commission, overall financial plan including EC contribution and co-financing for implementation of the project, easy delivery of the projects result to the specific target group within European Society (WP 1)

Expected impact: On-line information on tars and gaseous alkalis were evaluated using two different techniques (WP2)

Expected impact: The results will minimize the risk of catalyst poisoning and reduce the environmental impact of gas cleaning and conditioning technologies. Knowledge of influence of operational parameters on tar and alkali emissions (WP2)

Expected Impact: on-line information of particulate phase in flue-gas (WP2)

Expected Impact: The results will provide feedback concerning performance of hot gas cleaning (WP2)

Expected impact: Identification of impurities and removal that could be basis for the design and construction and pilot testing implementation of high temperature cleaning system and as well as catalytic system (WP 3)

Expected impact: Identification of impurities and removal that could be basis for the design and construction and pilot testing implementation of cleaning system and as well as catalytic system (WP 4)

Expected impact: flowsheeting of the most reliable and energy efficiency reforming step (WP5)

Expected impact: Integration of reforming and water-gas-shift reactor with exposure to the Güssing gas and useful result from pilot testing that may be provide basis for large-scale application (WP 6)

Expected impact: The extent of long-term catalytic system, absorbents for capturing alkali, sulfur, chlorine and tar cracking catalysts, advanced characterization technology with respect to tar and alkali analysis in slipstream testing of real gas will provide valuable information concerning process optimization of clean syngas production (WP 2, 4, 5, 6, 7).

Expected impact: Contaminates in the raw product gas that are in gas-phase state, their removal are not aimed by filtering. For capturing of concentrations of gas phase impurities different absorbent in –situ has been applied. An efficient cleaning system is expected to produce a gas with required standard in producing of high yield pure syngas; the device provide excellent removal efficiency including coarse and partially fine particulate at lab-scale demonstration (WP 7).

Expected result: Smooth communication of gained knowledge to Consortium members, EC and targeted industry group, at the same time ensure that IPR is protected for involved industries in the project (WP 8)

Main dissemination activities and exploitation of results (reference also to the Template of Part B2)

Publication activities increased significantly in the third year of the project as even more results were generated. These results exhibited significant novelty and also described “the state of the art” with regards to their contents. The novelties of the results from GREENSYNGAS have naturally provided opportunities for publication in journals that have a high impact factor on the academic and industrial research communities.The public website and the thematic and teleconference meetings with the corresponding minutes have been useful in communicating the project’s vision and results.

Arrangements were made for a WORKSHOP, 23 February 2011, with participants from European industries and organisations in the field of sustainable energy. This WORKSHOP also aimed to aid in the exploitation of the results gained in order to diminish the gap between applied research and commercialisationManuscripts of all the publications were uploaded electronically and were available for the partners who had access to the LUVIT internal communication platform. It was not possible to put them on the public GREENSYNGAS website since the embargo dates of these publications had not expired at the time of writing.
The Coordinator was in communication with the editorial board of the *Biomass Conversion and Biorefinery Journal* to arrange for a special issue focused on the results from GREENSYNGAS.
The flowsheeting results have added an additional supportive aspect to this bioenergy theme of GREENSYNGAS and the techniques are naturally applied frequently in the oil & gas and petrochemical sectors. Flowsheeting results from GREENSYNGAS aim to assist the industries that are involved in bringing the biosyngas processes closer to the market place.
A key processing step when considering the production routes of biofuels involves the ability to incorporate a reforming stage (for which several alternatives have been investigated and also suggested in GREENSYNGAS) with due consideration to the exploitation of the findings.
A fairly novel technology in product gas cleaning was investigated in GREENSYNGAS and has been shown to work. The laboratory results until now have been very promising. Unfortunately, the duration for the project has proven short and further demonstration of the cleanup system in the real gas stream of Güssing was not possible
Presentations at public conferences were used to disseminate the project objectives and activities. Key conferences such as those pertaining to ammonia synthesis, gasification, cleaning technology of flue gas and syngas conversion have been chosen for dissemination to help facilitate contact with industrial players in this research area.

The following dissemination activities were performed by the partners of GREENSYNGAS:

a) Keynotes speaker: 10 invited lectures
b) Journal publications: 9 papers
c) Proceedings of different conferences: 22 presentations
d) Popular science (since in society): 12, mostly by Bil Sweden and the Coordinator

Project website[2] address: **http://www.eat.lth.se/greensyngas/**

Professor Mehri Sanati

Lund University

Faculty of Engineering / Department of Design Sciences

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ;

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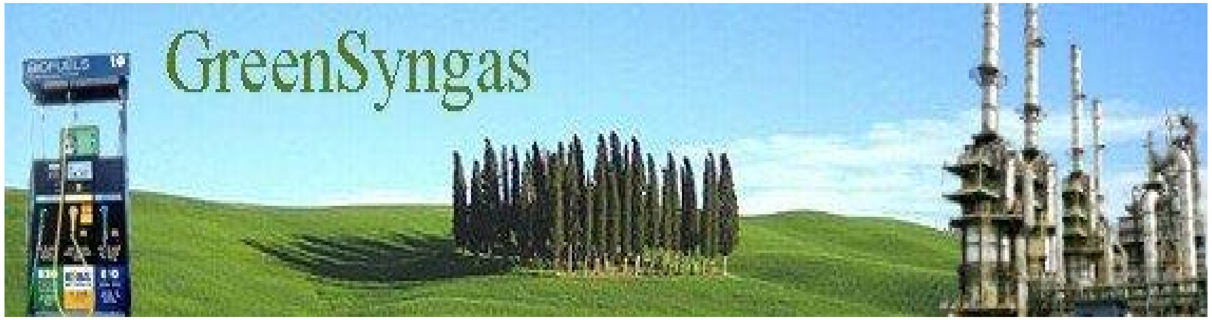
Sweden

4.1.5 Furthermore, project logo, diagrams or photographs illustrating and promoting the work of the project (including videos, etc…), as well as the list of all beneficiaries with the corresponding contact names can be submitted without any restriction.

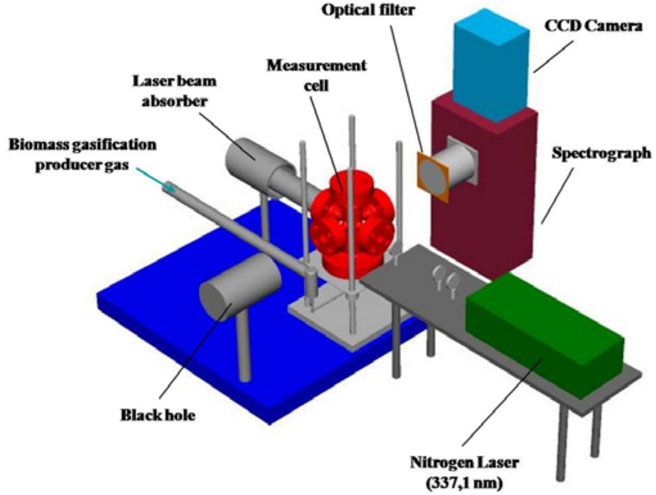
Logo: **GreenSyngas**



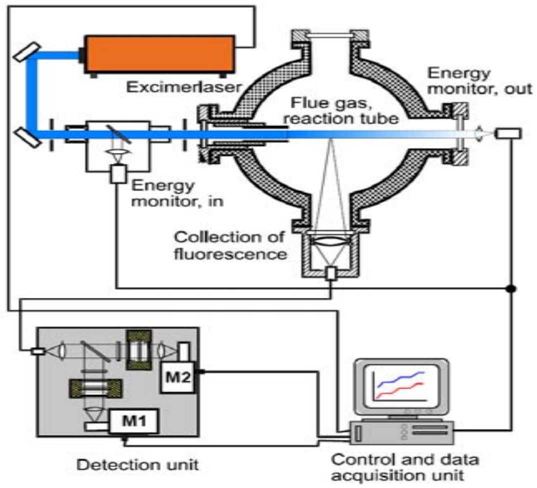
Beneficiaries in GREENSYNGAS with the corresponding contact names

N°	Name of the Contractor	Short name of the Contractor*	Website (url) of the contractor	Address of the contractor	Type of Organisation°°
1	**Lunds universitet**	**ULUND**	**www.lu.se** **Professor Mehri Sanati**	Paradisgatan 5, SE-22100 Lund, Sweden	**Higher education - public**
2	**Technische Universität München**	**TUM**	**www.tum.de** **Prof. Dr.-Ing. Hartmut Spliethoff**	Technische Universitaet München Faculty of Mechanical Engineering / Lehrstuhl Fuer Energiesysteme Boltzmannstrasse 15 D-85748 Garching Germany	**Higher education - public**
3	**Technische Universiteit Delft**	**TUD**	**www.tudelft.nl** **Dr. Ir. Wiebren de Jong**	Technische Universiteit Delft Faculty 3mE Dept. of Process & Energy/EnergyTechnology Section Leeghwaterstraat 44; Delft, 2628 CA, Netherlands	**Higher education - public**
4	**Porvair Filtration Group Ltd**	**PA**	**www.porvair.uk** **Andrew Hill**	Porvair Filtration Group Ltd Concorde Close Segensworth Fareham, PO15 5RT Hampshire; UK	**Industry-large**
5	**Forschungszentrum Jülich GMBH**	**FZJ**	**www.fz-juelich.de** **Dr. Michael Müller**	Forschungszentrum Jülich GMBH Institute for Energy Research, IEF-2 Leo-Brandt-Strasse D-52425 Jülich Germany	**Research institute**
6	**Alma Mater Studiorum-Universita, Di Bologna**	**UNIBO**	**www.unibo.it** **Dr. Francesco Basile**	Alma Mater Studiorum-Universita, Di Bologna Dept. of Industrial Chemistry and Materials; Viale Risorgimento 4 I- 40136 Bologna Italy	**Higher education - public**
7	**Johnson Matthey PLC.**	**JM**	**www.matthey.com** **Suzanne Ellis**	Johnson Matthey PLC. Johnson Matthey PLC. Low Carbon Technologies FARRINGDON STREET 25 5th floors, London, EC4A 4AB, United Kingdom	**Industry-large**
8	**Norges Teknisk – Naturvitenskapelige Universitet**	**NTNU**	**www.ntnu.no** **Professor Edd A. Blekkan**	Norges Teknisk – Naturvitenskapelige Universitet Dept. of Chemical Engineering Sem Saelands v. 4 NO-749 Trondheim Norway	**Higher education - public**
9	**Biomassekraftwerk Güssing GmbH & CO KG**	**BKG**	**www.eee-info.net** **Ing. Reinhard Koch**	Biomassekraftwerk Güssing GmbH & CO KG Europastrasse 1 A-7540- Güssing Austria	**Industry-small**
10	**Lantmännen Energi AB**	**LANTM**	**www.lantmannen.com** **Per Erlandsson**	Lantmännen Energi AB; Research and Development S:t Göransgatan 160 A; SE-10425 Stockholm, Sweden	**Industry-large**

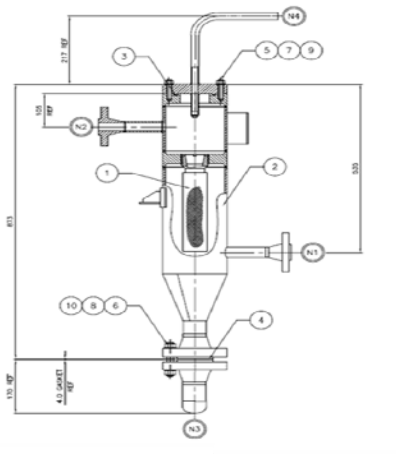
Photographs of equipment and devices used in GREENSYNGAS



Experimental setup of the online tar measurement technique (WP2)



Experimental setup of the online alkali measurement system (WP2)



Section through filter vessel showing element and particulate catch pot (WP3)

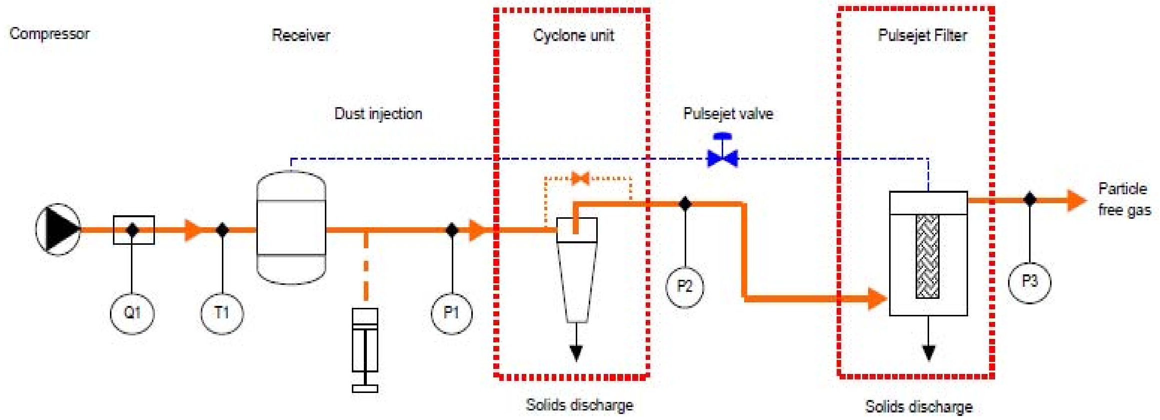
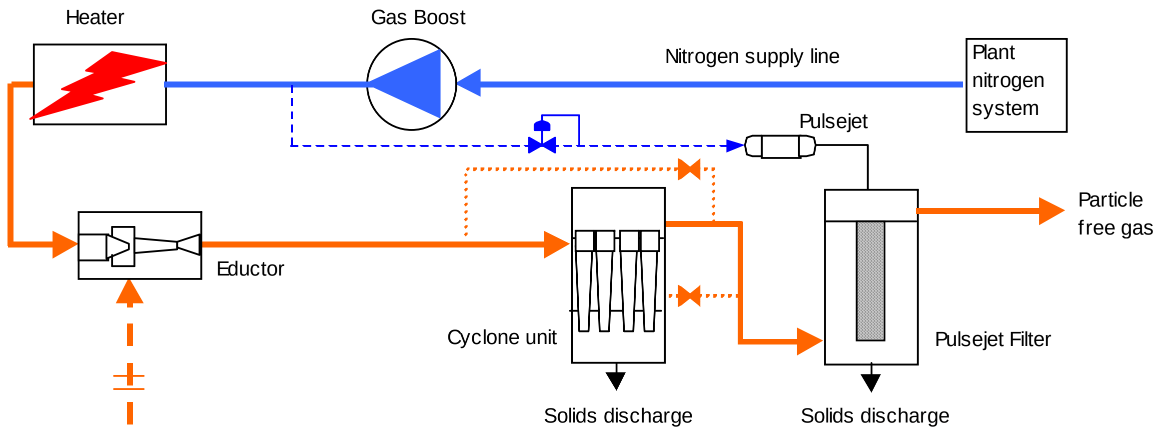
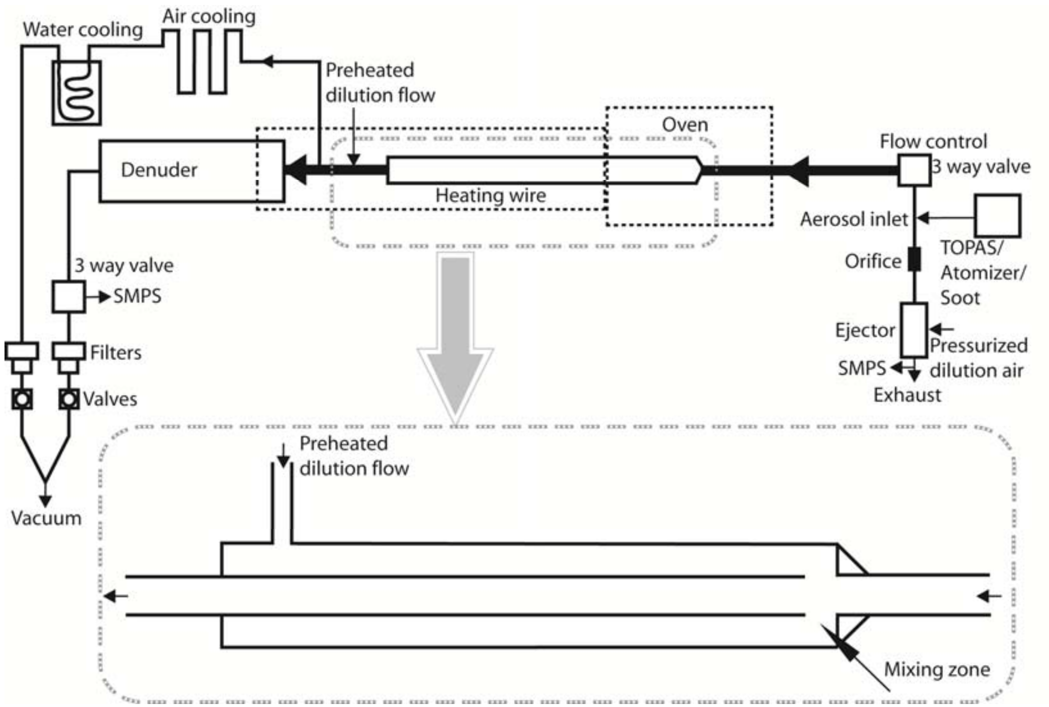


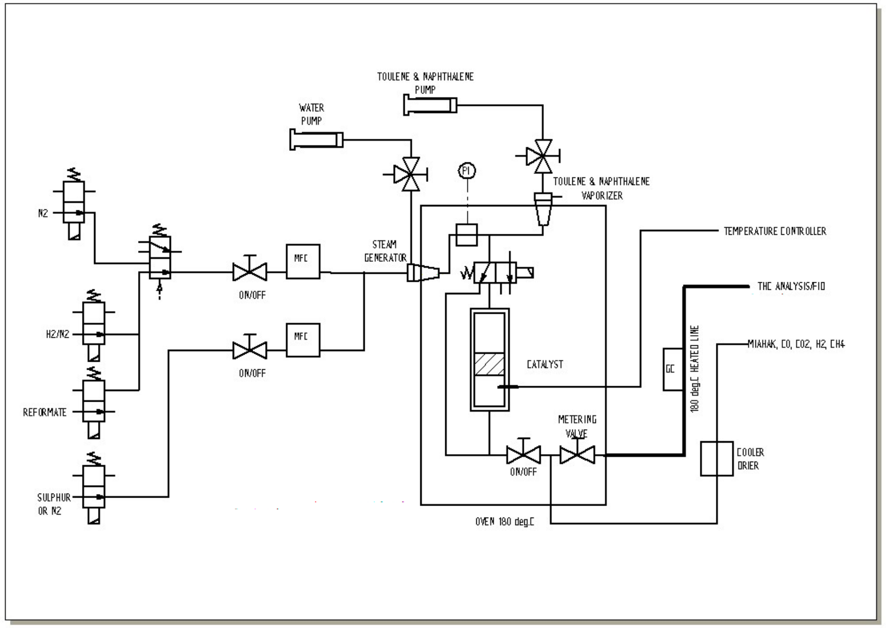
Diagram of test set-up of cleaning device (WP3)



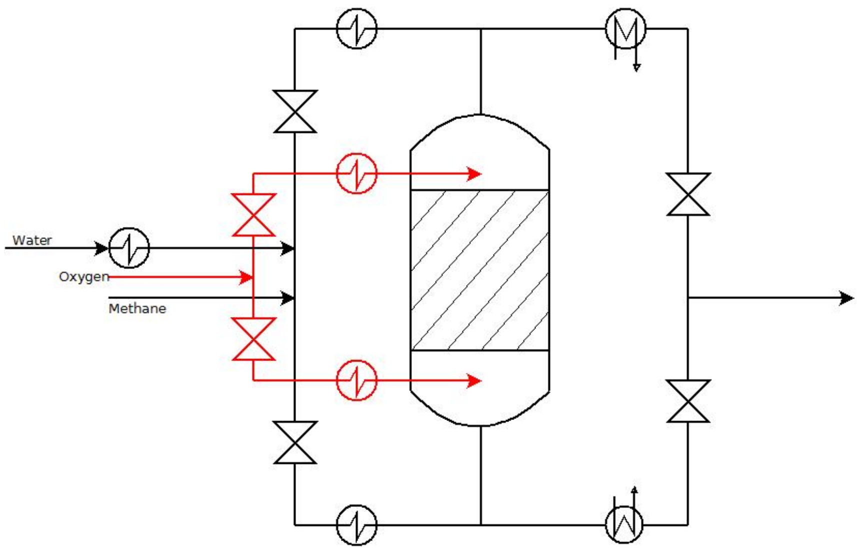
Pilot scale set up of proposed cleaning set up (WP3)



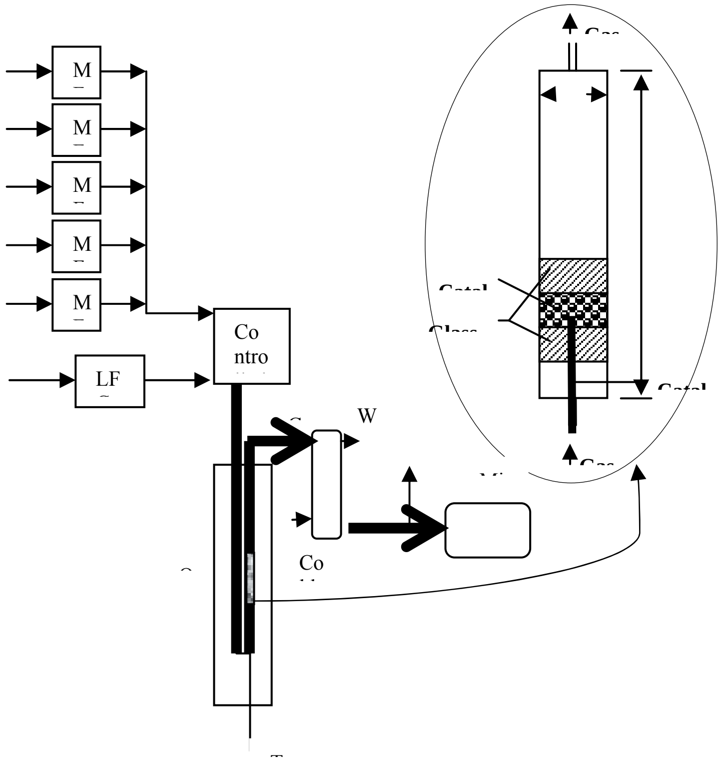
Particle measurement set up (WP 3 and 7)



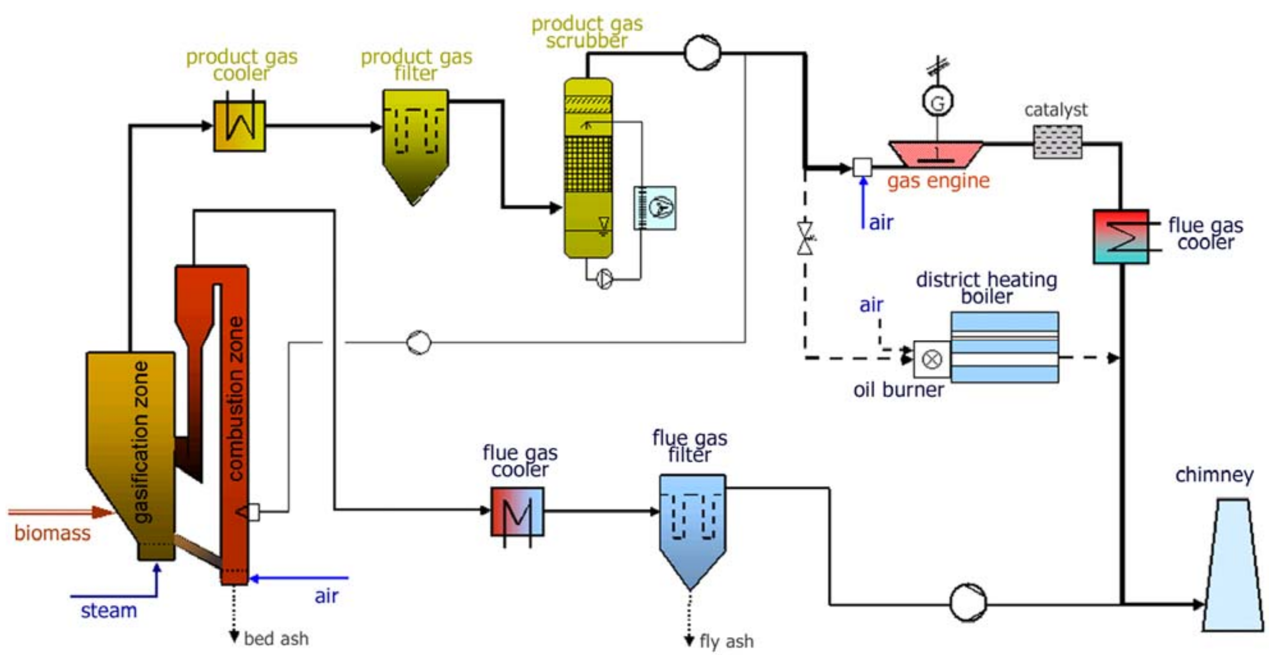
Schematic presentation of the experimental catalytic rig (WP5)



Schematics of the laborator regenerative refomer setup (WP5)



Schematic presentation of catalytic rig for experiment within WP6 (shift reaction)



Schematic presentation of gasification at Güssing (demo activities in WP7)

Demonstration of the high-temperature cleaning device at BKG

The planning for the demonstration activity at BKG was conducted. The design for the high-temperature gas cleaning was done by Porvair with the assistance of BKG and JM, following Figs.

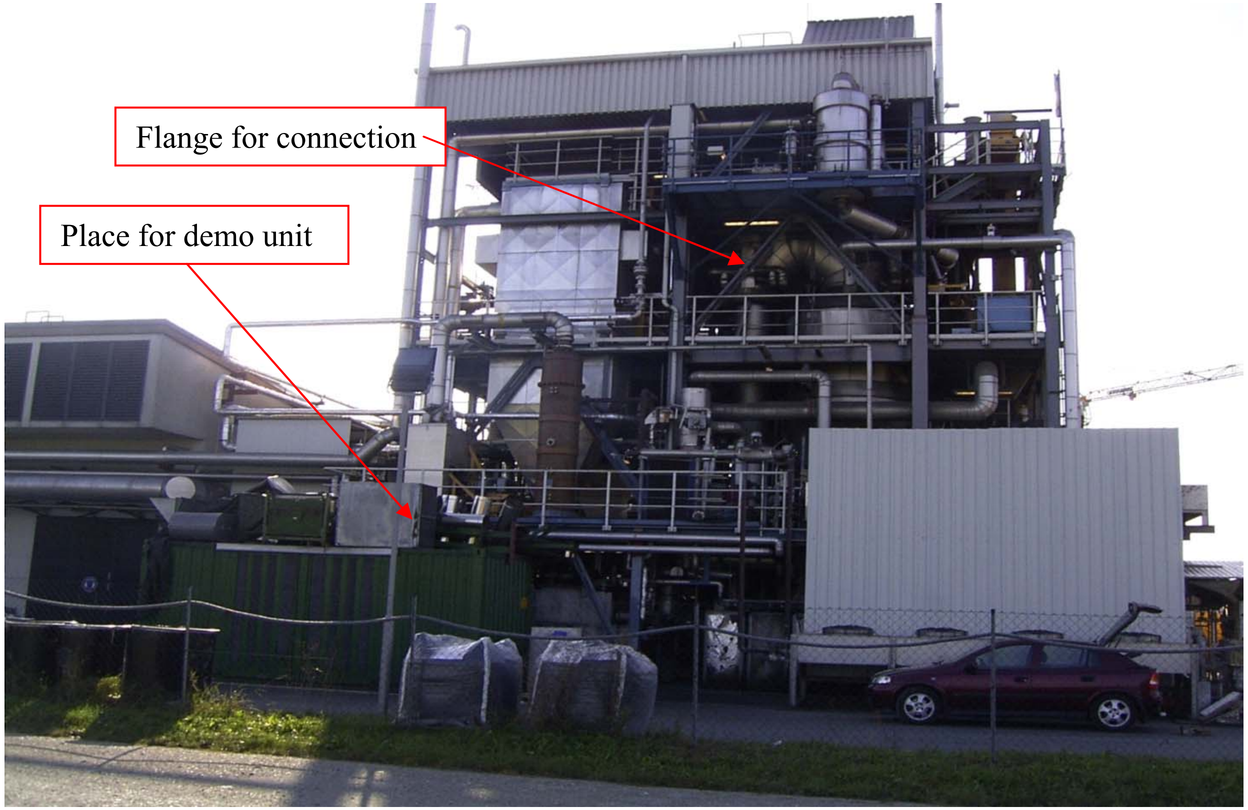


Photo of the connection point (WP 3 and WP 7)

Significant results achieved in different WPs

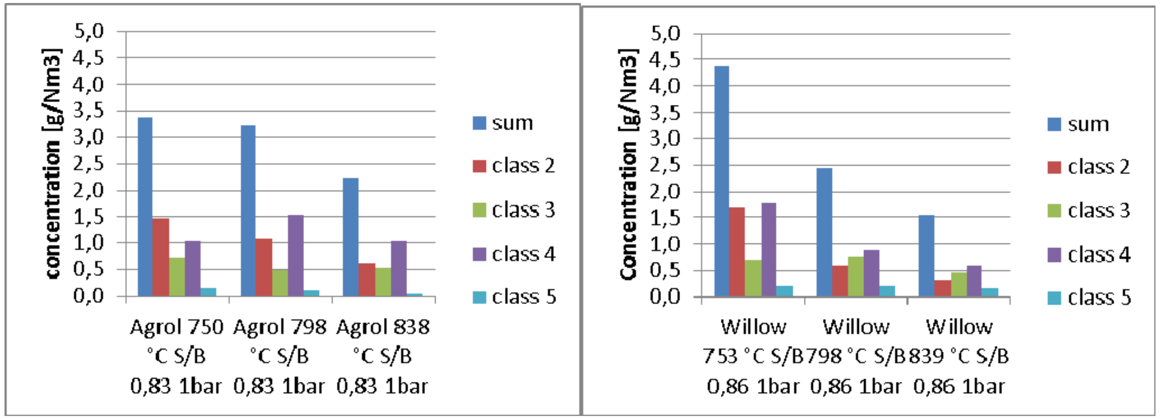


Figure 1: Tar composition during Agrol/Willow gasification varying the temperature (WP2, 4, 7)

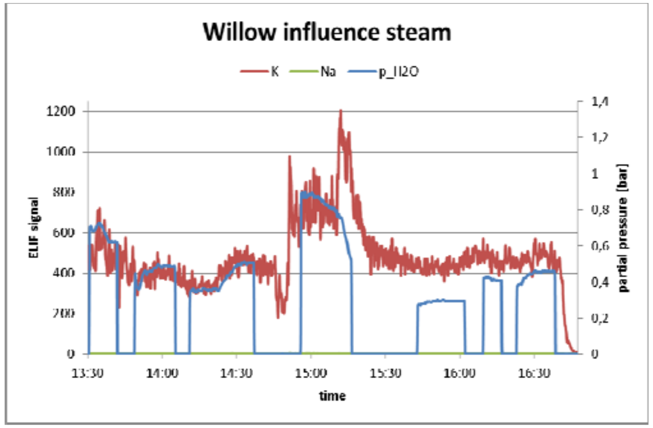


Figure 2: Alkaline concentration & steam partial pressure during Willow gasification (WP2, 4, 7)

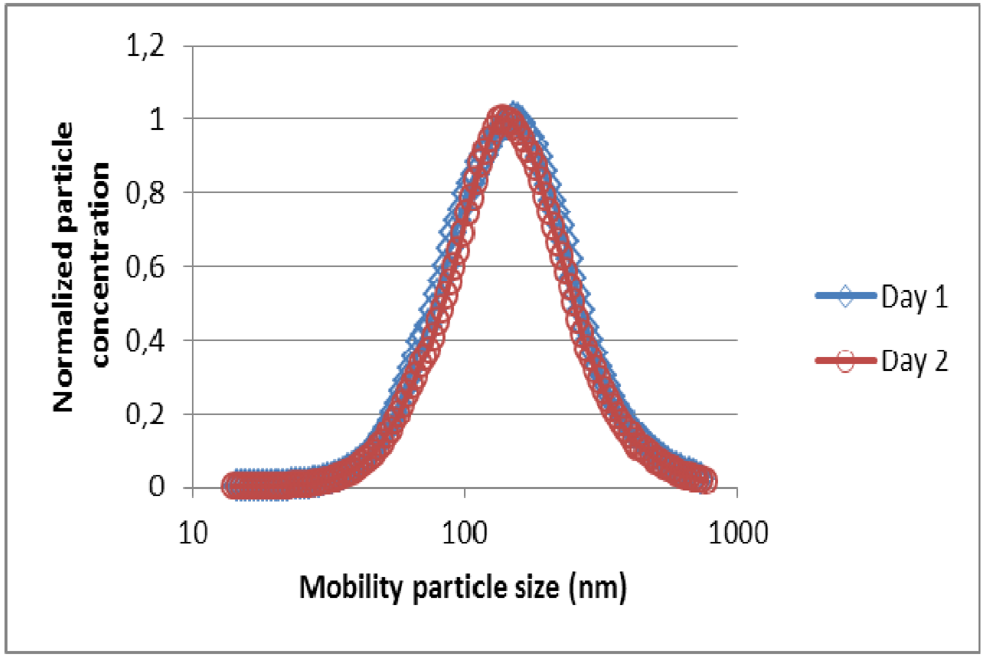


Figure 3: Normalized particle size distribution from day 1 and day 2 at TUD gasifier

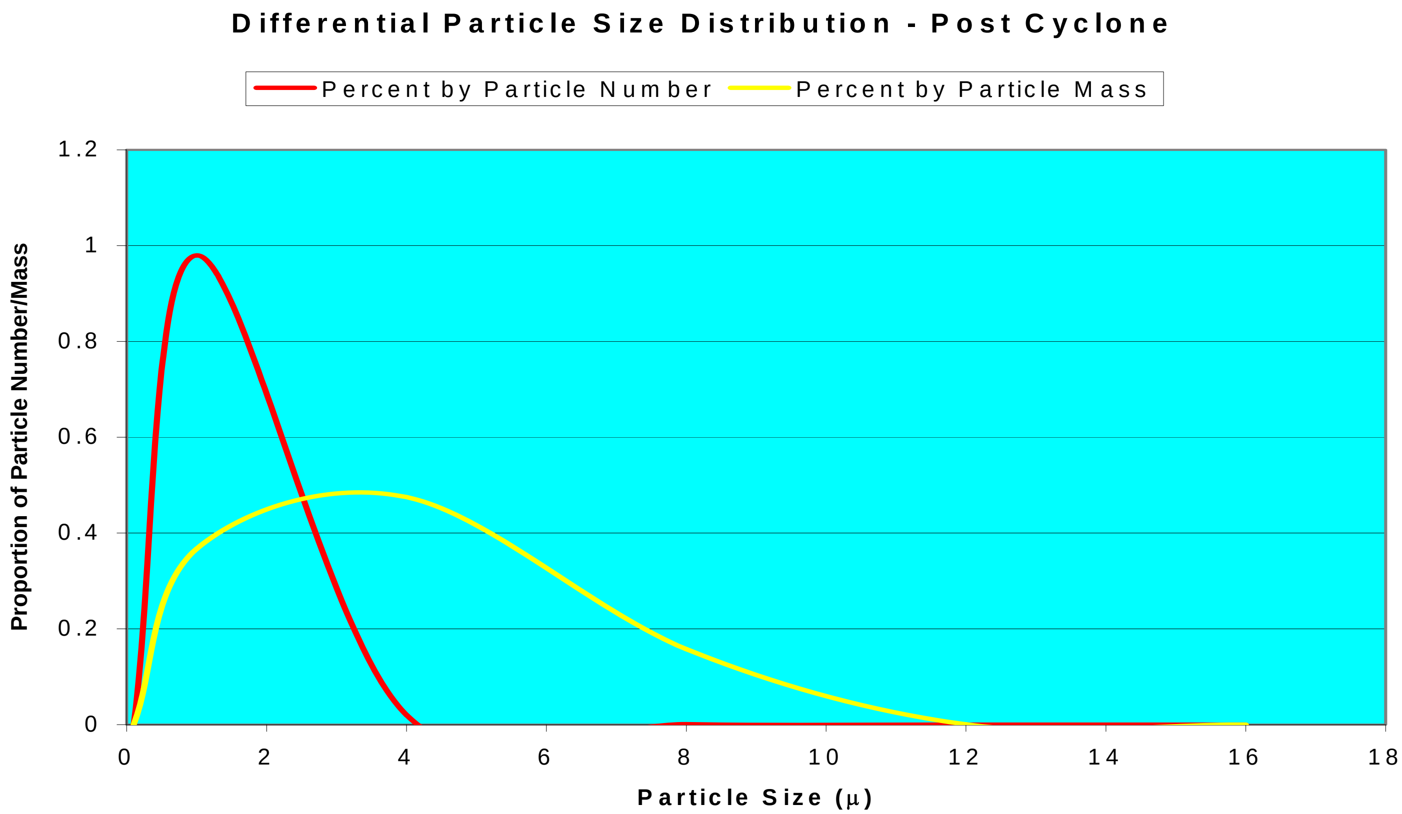


Figure 4*:* Chart of Contaminant Distribution Post Cyclone

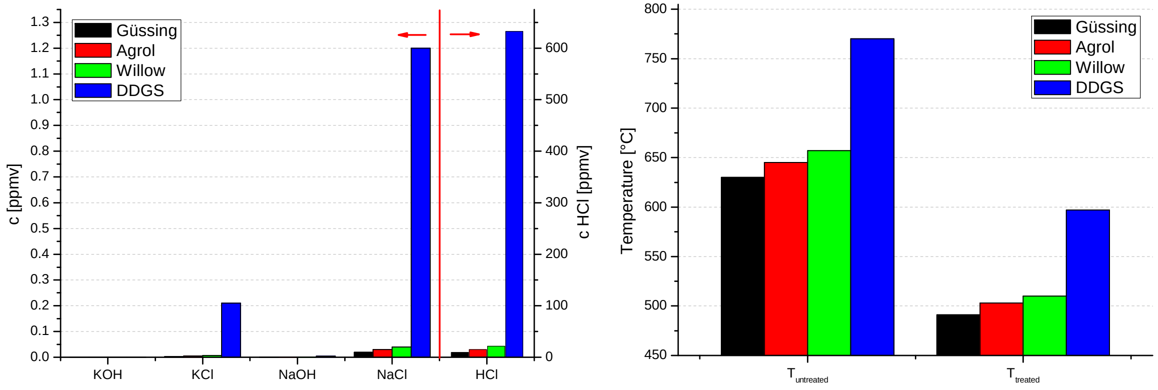


Figure 5: Achievable alkali concentrations (left) and resulting condensation temperatures (right) after alkali absorption by aluminosilicates

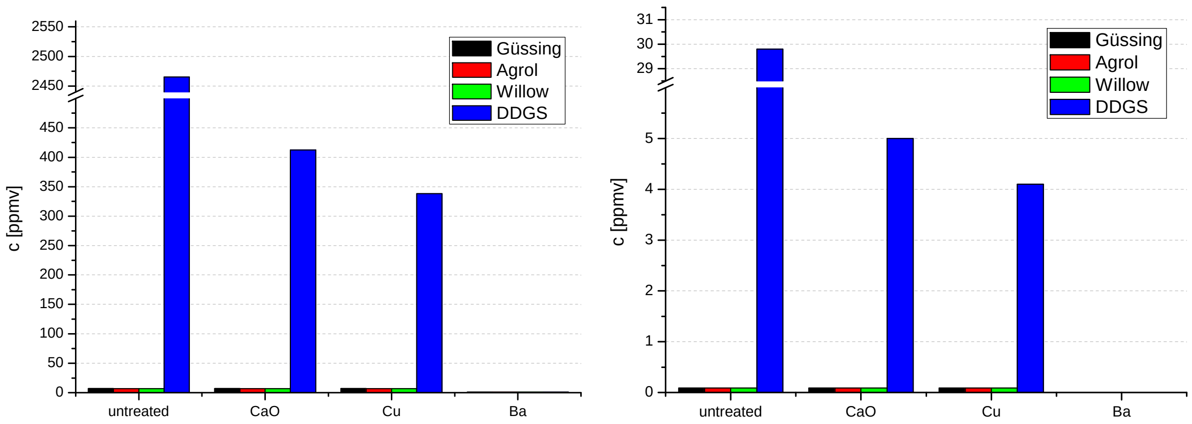


Figure 6: Achievable H_2S and COS concentrations before and after sulfur absorption by different sorbents

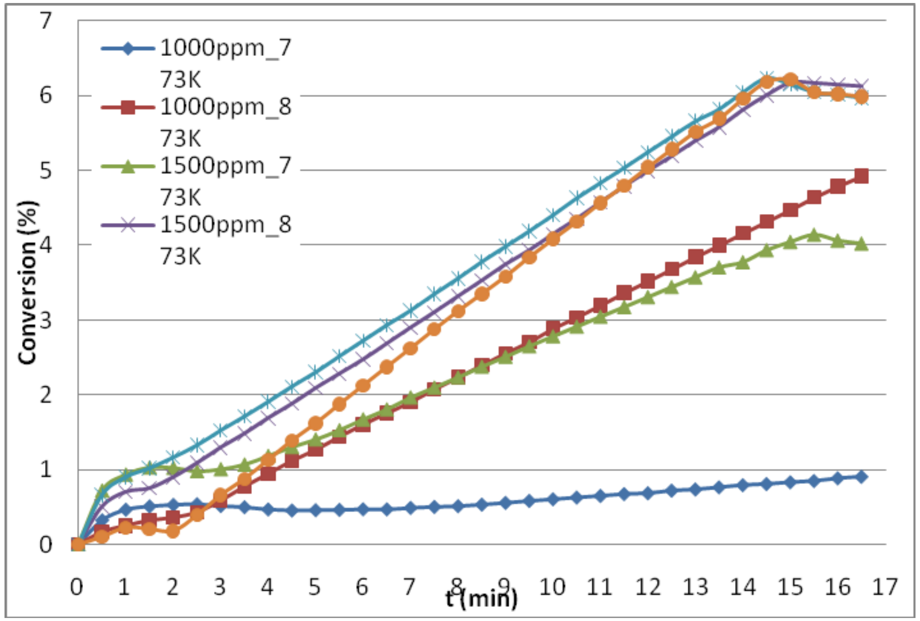


Figure 7: TGA graph for ZnO sulphidation using N_2 as carrier gas

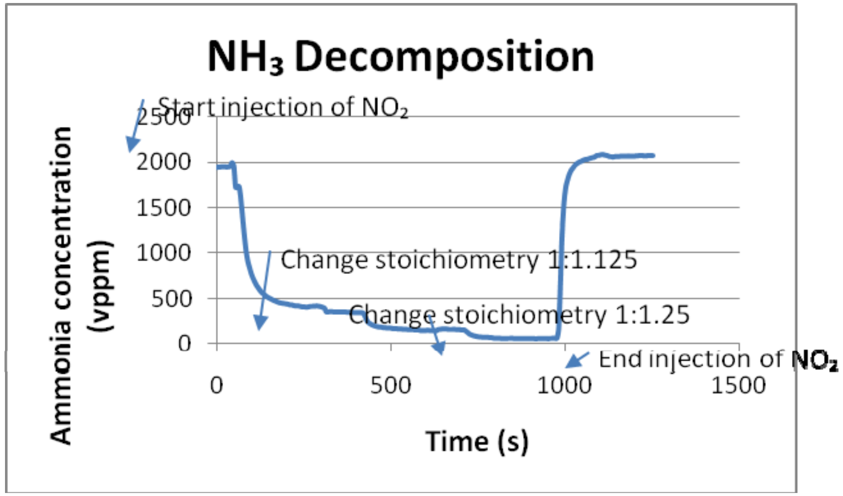


Figure 8: Ammonia concentration in the outlet for $V_2O_5/WO_3/TiO_2$ at 325 °C.

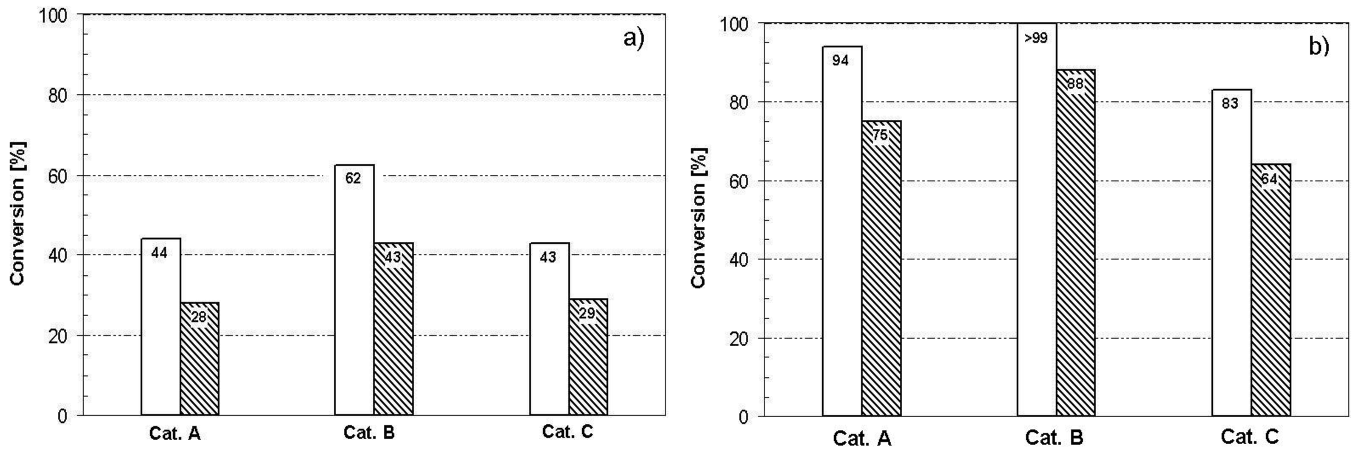


Figure 9: The conversion of CH_4 in the steam reforming of the pure model syngas (white bars) and in the presence of toluene (hatched bars) at 700°C, a) S/C = 2,8 b) S/C = 8,5.

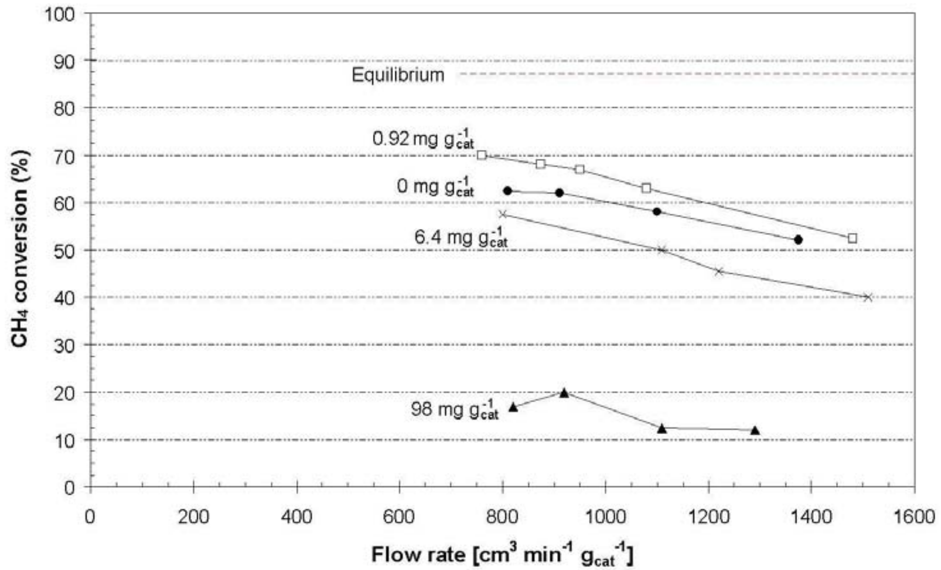


Figure 10: Effect of KCl deposition on the catalytic activity of GSG-05. Estimated amounts of salt are indicated in the Figure

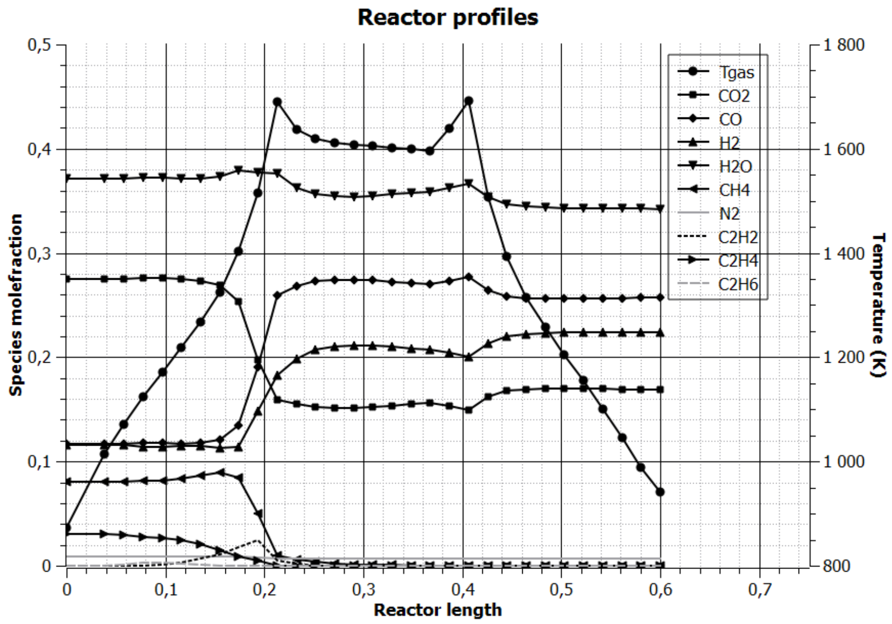


Figure 11: Typical temperature and concentration profiles during simulation

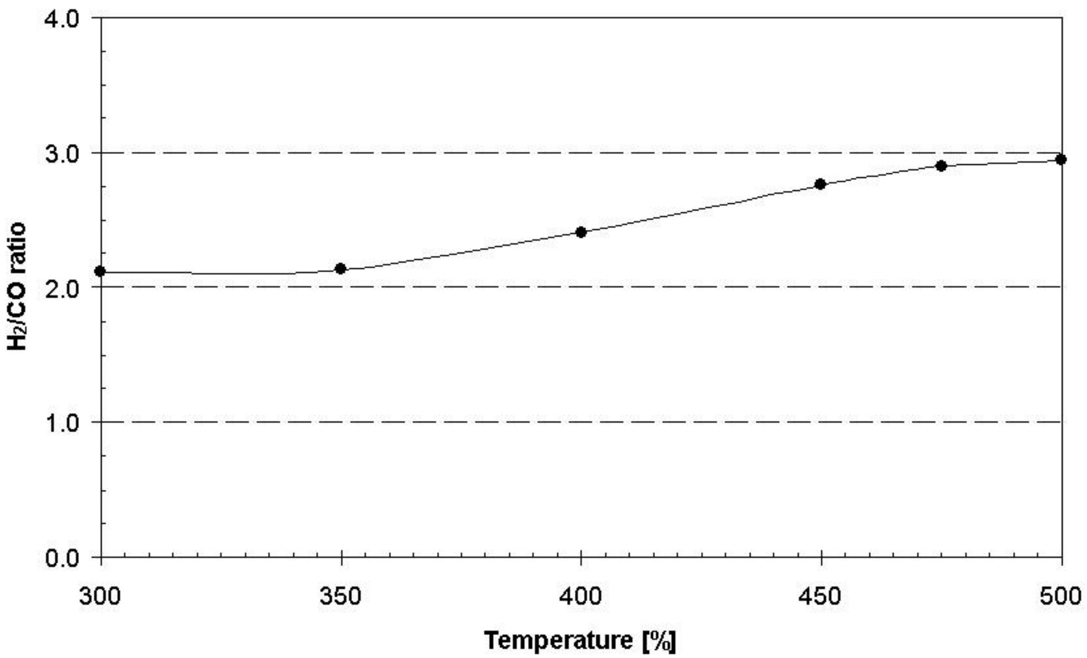


Figure 12: The variation of H_2/CO ratio with the WGS reaction temperature

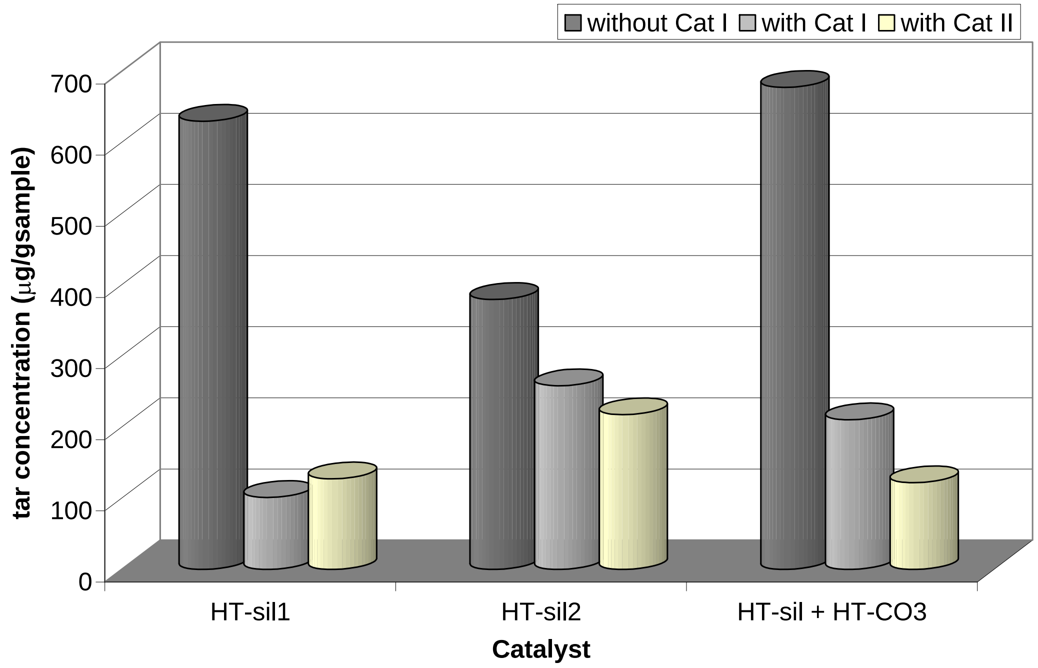


Figure 13: Tar content in the gas before and after the catalytic reactor

4.1 Use and dissemination of foreground

Section A (public)

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES									
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Is/Will open access[3] provided to this publication ?
1	Detection of Soot Using a Resistivity Sensor Device Employing Thermophoretic Particle Deposition	Doina Lutic & Mehri Sanati	Journal of Sensors	Article ID 421072, 6 pages; http://www.hindawi.com/journals/js/2010/421072.html	Hindawi Publishing Corporation	New York, USA *and* Cairo Egypt	*2010*	*pp. 1-6*	yes
2	A Potential Soot Mass Determination Method from Resistivity Measurement of Thermophoretically Deposited Soot	Azhar Malik & Mehri Sanati	Aerosol Science and Technology	Volume 45	Taylor & Francis	London, UK	2011	pp. 1-11	NO
3	Influence of soot particle aggregation on time-resolved laser-induced incandescence signals	Jenny Rissler & Mehri Sanati	Applied Physics B: Lasers and Optics	Volume 102	SPRINGER	North America, Europe, Asia	2011		No
4	An experimental model system using organic and inorganic compounds for examination of fine particles formed at biomass gasification	Patrik Nilsson & Mehri Sanati	Biomass Conversion and Biorefinery	Submitted in Volume 1, 2011	SPRINGER	North America, Europe, Asia	2011		No

[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

	processes								
5	Methodology for Sampling and Characterizing Internally Mixed Soot-Tar Particles Suspended in the Product Gas from Biomass Gasification Processes	Azhar Malik & Mehri Sanati	Energy & Fuel	Submitted	ACS publication	Washington, DC 20036, USA	2011		No
6	Theoretical Evaluation of Feedstock Gasification Using H2/C Ratio and ROC as Main Input Variables	Michael Stemmler &Michael Muller	Ind. Eng. Chem. Res	Volume 49	ACS publication	Washington, DC 20036, USA	2010	pp.9230-9237	No
7	Thermodynamic analysis and kinetics model of H2S sorption using different sorbents	X.M. Meng & W. de Jong	Environmental Progress & Sustainable Energy	Volume 28, Issue 3	John Wiley & Sons	USA, Canada, Australia, Europe, Asia	2009	pp. 360-371	No
8	In bed and downstream hot gas desulphurization during solid fuel gasification	X.M. Meng & W. de Jong	Fuel Processing Technology	Volume 91, Issue 8	Elsevier	North America, Europe, Asia	August 2010	pp. 964-981	No
9	Reforming Syngas From Biomass Gasification: The Effect of Tar and Alkali Components	E. Wangen, E.A. Blekkan	Topics in Catalysis	Submitted	Springer		2011		No

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[4]	Main leader and Title	Title of conference	Date	Place	Type of audience[5]	Size of audie-nce	Countries addressed
1	*Conference*	Magnus Lindskog, Azhar Malik, Mehri Sanati; Lab-Scale Development of a High Temperature Aerosol Particle Sampling Probe for Field Measurements in Thermochemical Conversion of Biomass	The Fifth International Conference on Thermal Engineering Theory and Applications	May 10-14, 2010	Marrakesh; Morocco	University, Industries, and local government official	*~150*	World Golden Tullp Farah Hotel: Marrakesh; Morocco
2	*Conference*	Azhar Malik, Patrik Nilsson, Espen Wang; Edd Blekkan and M. Sanati; Investigation of catalyst deactivation by deposition of size selected soot particles	NOSA, Nordic Aerosol Conference	November 12-13, 2009	Lund/Sweden	University, Industries, and local government official	~100	Europe Lund University, Department of Design Sciences Faculty of Engineering P.O. Box 118 SE-221 00 Lund, Sweden
3	*Conference*	Magnus Lindskog, Azhar Malik, Mehri sanati; Lab-Scale Development of a High Temperature Aerosol Particle Sampling Probe for Field Measurements in Thermochemical Conversion of Biomass	NOSA, Nordic Aerosol Conference	November 12-13, 2009	Lund/Sweden	University, Industries, and local government official	~100	Europe Lund University, Department of Design Sciences Faculty of Engineering P.O. Box 118 SE-221 00 Lund, Sweden
4	*Conference*	Jenny Rissler, Patrik Nilsson and Mehri Sanati; Online particle density measurement of combustion aerosol with the Aerosol mass analyser (APM)	NOSA, Nordic Aerosol Conference	November 12-13, 2009	Lund/Sweden	University, Industries, and local government official	~100	Europe Lund University, Department of Design Sciences Faculty of Engineering P.O. Box 118 SE-221 00 Lund, Sweden
5	*Conference*	Jan Brandin and Per Tune; Modeling of Reverse-Flow Partial-Oxidation Process for	The Fifth International Conference on	May 10-14, 2010	Marrakesh; Morocco	University, Industries, and local	~150	World Golden Tullp Farah Hotel: Marrakesh;

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias ('multiple choices' is possible.

		Gasifier- Product Gas Upgrading	Thermal Engineering Theory and Applications			government official		Morocco
6	Symposium	Espen Standal Wangen, Azhar Malik, Mehri Sanati, Edd A. Blekkan; On the steam reforming of producer gas in the production of clean bio-syngas.	Norwegian Catalysis Symposium 2009; NTNU and Norwegian Science Foundation	November 2009	Trondheim; Norway	University, Industries	~50	Norway Auditorium R8, Realfagbygget (Science building), Høgskoleringen 5, Gløshaugen, Trondheim; Norway
7	Seminar and Mehri Sanati was keynotes speaker	Mehri Sanati; Investigation of different process configuration based on energy conservation in synthesis step in production of vehicle fuels from biomass (GreenSyngas).	Fachagentur Nachwachsende Rohstoffe (FNR) Expert Discusssion	27-28 August 2008	Güstrow; Germany; arranged by Fachagentur Nachwachsende Rohstoffe (FNR) / Agency for Renewable Resources Department of Public Relations - Bioenergy Consulting Service	University, Industries, and local government official	~30	Germany and Sweden Hotel "Kurhaus am Inselsee"; Güstrow; Germany
8	Conference	Meng X., de Jong W., Verkooijen A.H.M; Prediction of sulphur compounds distribution in gasification products of biomass fuels.	17th European Biomass Conference & Exhibition from Research to Industry and Markets	29 June-03 July 2009	Hamburg, Germany	University, Industries, and European government official and Politician	~3500	World CCH - Congress Center Hamburg - 1 Marseiller Straße, Hamburg, Univiertel, 20355
9	ACS meeting	Wangen E. S., Trehjørningen K. R., He L., Chen D., and Blekkan E. A; Reforming raw synthesis gas from wood gasification.	21st North American Catalysis Society Meeting	June 7 to 12, 2009	San Francisco, USA, North America	University, Industries	~100	North America and Europe San Francisco, California, at the Hyatt Regency Hotel located directly on the Embarcadero waterfront
10	Conference	J. Rissler, J. Pagels, P. Nilsson, M. Sanati, Mass-mobility relationship of soot generator and diesel soot	European Aerosol Conference 2009, Karlsruhe, Germany	August 6-11, 2009	Karlsruhe; Germany	University, Industries, and European government official and Politician	~1000	World University of Karlsruhe; Germany
11	Conference	H. Abdulhamid, A. Malik, J. Pagels, M. Sanati A Reliable Method for Generation of Size Selected Soot using Aerosol Technology and Detection by	European Aerosol Conference 2009, Karlsruhe, Germany	August 6-11, 2009	Karlsruhe; Germany	University, Industries, and European government official and	~1000	World University of Karlsruhe; Germany

		Sensor Device				Politician		
12	Conference	A. Malik, M. Lindskog, P. Nilsson, M. Sanati; Development of a High Temperature Aerosol Particle ;Sampling Probe for Field Measurements in Thermochemical Conversion of Biomass	International Aerosol Conference 2010,	29 July -3 August, 2010	Helsinki, Finland	University, Industries, and European government official and Politician	~2000	World University campus in Helsinki
13	Conference	J. Rissler, J. Pagels; P. Nilsson; A. Malik; M. Sanati, On-line particle density measurements of combustion aerosols with the DMA-APM system and comparison with aggregation theory;	International Aerosol Conference 2010,	29 July -3 August, 2010	Helsinki, Finland	University, Industries, and European government official and Politician	~2000	World University campus in Helsinki
14	Symposium	X.M. Meng, W. de Jong; Primary Results of Dry Distiller'S Grains with Solubles Gasification in A 100kwth Steam-Oxygen Blown Circulating Fluidized Bed GasifieR;	the 8th International Symposium on Gas Cleaning at High Temperatures; GCHT-8	22-25August, 2010	Taiyuan, China	Scientific Community	~200	World Shanxi Yingze Hotel Taiyuan; China
15	GREENSYNGAS Presentation	X.M. Meng, W. de Jong; GREENSYNGAS	Poster on ET website	2008	TUD, Netherlander	University staff		Holland Delft; Holland
16	Conference	X.M. Meng, Thermodynamic Analysis and Kinetics Model of H2S Sorption Using Different Sorbents	TC Biomass 2009 Chicago, IL; The international conference on thermochemical conversion sciences	September 16-18; 2009	Chicago; USA	Scientific Community	~200	Sheraton Chicago hotel & Tower; USA
17	Nordic Symposium	Espen Wangen	Production of biomass derived synthesis gas by catalytic steam reforming.	29-31 August 2010.	Nordic Symposium on Catalysis, Marienborg, Denmark	Scientific Community	100	Europe
18	Seminar	Espen Wangen	Catalytic steam reforming for the production of biomass derived synthesis gas.	7-8 June 2010.	Renewable Energy Research Conference. Trondheim, Norway.	Scientific Community	50	Norway
19	Symposium	Espen Wangen	The Effect of Soot Deposition on Catalytic Activities in the Steam Reforming of a Simulated Producer Gas.	30 May – 3 June 2010	Novel Gas Conversion Symposium. Lyon, France.	Scientific Community	500	World

20	Symposium	Espen Wangen	On the steam reforming of producer gas for the production of clean bio-syngas.	30 November 2009	Norwegian Symposium on Catalysis. Trondheim, Norway	Scientific Community	75	Norway
21	ACS meeting; Submitted	Espen Wangen	Reforming Syngas From Biomass Gasification: The Effect of Tar and Alkali Components From the Biomass	June 5-10, 2011	22nd North American Catalysis Society Meeting Detroit, MI, USA	Scientific Community	1000	World

Part B2

Please complete the table hereafter:

Provision of commercial material and scale-up of advanced research concepts

Johnson Matthey's (JM) long before without explaining what it was—I thought it was a co-author, as it stood in a caption. Maybe explain it and also PA when they first appear? Role in the GreenSyngas project has been predominately one of material sample supply to the various partners. Over the course of the past 36 months, JM has provided absorbents, reforming catalysts (both base and precious metal) and water-gas shift catalysts to ULUND, NTNU, UNIBO, FZJ and TUM in a timely manner, enabling these partners to carry out their own tests as part of the project.

Another related objective to material supply was the scale-up of any promising materials that were proven to be better than those supplied by JM in the project. However, in the project timeframe, although interesting materials other than JM-supplied ones were investigated in WPs 4, 5 and 6, the results did not justify further work to be done on the scale-up activities. Furthermore, as the original plan for testing promising materials involving a sidestream from the Güssing CHP plant did not come to fruition, there was no requirement to pursue manufacturing scale-up activities on the tar-reforming and water-gas shift catalysts to supply this activity, either.

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	NEW ABSORBENTS	NO		CANDIDATE MATERIAL FOR ALKALINE CAPTURING	BIOENERGY INDUSTRY OR CHEMICAL AND PETROCHEMICAL INDUSTRIES	2012 IF THERE IS AN INVESTMENT COMPANY WILLING TO PRODUCE THE MATERIAL	NO MATERIALS PATENT IS PLANNED FOR 2011	FZJ, JULICH (OWNER)
	NEW ABSORBENTS	NO		CANDIDATE MATERIAL FOR SULFUR CAPTURING	BIOENERGY INDUSTRY OR CHEMICAL AND PETROCHEMICAL INDUSTRIES	2012 IF THERE IS AN INVESTMENT COMPANY WILLING TO PRODUCE THE MATERIAL	NO MATERIALS PATENT IS PLANNED FOR 2011	FZJ, JULICH (OWNER)
	NEW ABSORBENTS	NO		CANDIDATE MATERIAL FOR CHLORINE CAPTURING	BIOENERGY INDUSTRY OR CHEMICAL AND PETROCHEMICAL INDUSTRIES	2012 IF THERE IS AN INVESTMENT COMPANY WILLING TO PRODUCE THE MATERIAL	NO MATERIALS PATENT IS PLANNED FOR 2011	FZJ, JULICH (OWNER)
	NEW ONLINE TAR CHARACTERISATION TECHNIQUE	NO		Equipment; laser-induced fluorescence measurement technique online tar characterisation in produced gas	BIOENERGY INDUSTRY OR CHEMICAL AND PETROCHEMICAL INDUSTRIES	2012 IF THERE IS AN INVESTMENT COMPANY WILLING TO DEVELOP AND COMMERCIALISED THE ONLINE ANALYTICAL TAR MEASUREMENT TECHNIQUE	NO EQUIPMENT PATENT IS PLANNED FOR 2011	TUM (OWNER)

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
[7] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	NEW ONLINE TAR CHARACTERISATION TECHNIQUE	NO		Equipment; Excimer Laser-Induced fragmentation Fluorescence technique online alkaline characterisation in produced gas	BIOENERGY INDUSTRY OR CHEMICAL AND PETROCHEMICAL INDUSTRIES	2012 IF THERE IS AN INVESTMENT COMPANY WILLING TO DEVELOP AND COMMERCIALISED THE ONLINE ANALYTICAL ALKALINE MEASUREMENT TECHNIQUE	NO EQUIPMENT PATENT IS PLANNED FOR 2011	TUM (OWNER)
	HIGH TEMPERATURE CLEANING DEVICE	NO		EQUIPMENT; COMBINATION OF OPTIMISED CYCLONE AND FILTER ELEMENT, EQUIPMENT	BIOENERGY INDUSTRY AND COMPANIES WITH PROFILE OF GAS CLEANUP SYSTEM SUCH AS PORVAIR (UK) AND PAUL SHOEOMACHER (GERMANY, USA) AND CHEMICAL AND PETROCHEMICAL INDUSTRIES	THE HIGH TEMPERATURE CLEANUP DEVICE IS STILL CONSIDERED AS A BOTTLENECK IN BIOENERGY DEVELOPMENT. THE PROPOSED CONCEPT IN GREENSYNGAS ASSUMED TO BE A TECHNICALLY AND ECONOMICALLY FEASIBLE CONCEPT. THE CONCEPT SHOULD BE DEMONSTRATED AND SCALE-UP BY PORVAIR IN THIS PROJECT OR	THE CONCEPT HAS BEEN PATENTED BY PORVAIR IN EARLIER APPLICATION CONCERNING CLEAN-UP OF GAS FROM FOSSIL FUEL RELATED PROCESS AND GAVE EXCELLENT RESULTS. THE CONCEPT NEEDS TO BE DEMONSTRATED IN BIOENERGY APPLICATION.	PORVAIR (UK)

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
						A GRANTED NEW EC PROJECT.		
	HIGH TEMPERATURE FINE PARTICLE SAMPLING PROBE	NO		EQUIPMENT: COMBINATION OF OPTIMISED SAMPLING PROBE INCLUDING ONLINE REAL TIME COMMERCIAL MEASUREMENT TECHNIQUES	BIOENERGY INDUSTRY AND COMPANIES WITH PROFILE OF PARTICLE MEASUREMENT EQUIPMENT; TSI (USA); DEKATI (FINLAND); GRIMM (GERMANY)	THE HIGH TEMPERATURE FINE PARTICLE SAMPLING PROBE HAS BEEN DEMONSTRATED AT DOWNSTREAM OF CLEANING DEVICE AT TUD. THE DEVELOPED DEVICE IS NEED IN MEASURING PERFORMANCE OF CLEANING SYSTEM.	THE CONCEPT HAS NOT BEEN PATENTED BY ULUND. IT CAN BE A FUTURE PATENT IF THE CONCEPT WILL BE DEMONSTRATED WITH THE DEVELOPED CLEANUP DEVICE BY PORVAIR.	LUND UNIVERSITY (SWEDEN)
	REGENERATIVE METHANE REFORMING AND	NO		METHODOLOGY, NEW CONCEPT IN BIOENERGY BUT THE DEVICE HAS BEEN USED IN CHEMICAL AND PETRO INDUSTRIES	BIOENERGY, CHEMICAL AND INDUSTRIES WITH REFINERIES PROFILE, SUCH AS, BP, STATOIL AND ETC	THE CONCEPT EXHIBITED CAPABILITY FOR METHANE REFORMING, HOWEVER NO INVOLVEMENT OF THE CATALYST AND CAN BE UTILIZED IN PROCESSING OF PRODUCT GAS WITH HIGH CONCENTRATION OF METHANE AND PRESENT OF	IT IS PLANNED TO BE PATENTED IN APPLICATION OF BIOENERGY, IF AN INVESTMENT COMPANY IS WILLING TO ASSIST IN COMMERCIALISATION	LUND UNIVERSITY

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
						SULPHUR		
	OXIDATION OF NH_3 WITH NO_2 : REVERSE SELECTIVE CATALYTIC REDUCTION EXPERIMENT	NO		METHODS: NOVEL DEVELOPED TECHNOLOGY	BIOENERGY, CHEMICAL AND INDUSTRIES WITH REFINERIES PROFILE, SUCH AS, BP, STATOIL AND ETC	NOVEL METHOD FOR REMOVAL OF AMMONIA IN PRODUCED GAS FROM BIOMASS GASIFIER. AMMONIA CONSIDERED BEING POISON FOR CATALYTIC DOWNSTREAM PROCESSING. THE METHOD HAS BEEN VERIFIED IN BENCH SCALE EXPERIMENT	IT IS PLANNED TO BE PATENTED IN APPLICATION OF BIOENERGY IF AN INVESTMENT COMPANY IS WILLING TO ASSIST IN COMMERCIALISATION	LUND UNIVERSITY
	CANDIDATE CATALYST MATERIALS DEVELOPED BY PARTNERS	NO		MATERIALS; DOWNSTREAM UPGRADING OF PRODUCT GAS	BIOENERGY, CHEMICAL AND CATALYST PRODUCING COMPANY, SUCH AS JM, TOPSO, BASF	MORE LAB-SCALE AND PILOT SCALE EXPERIMENTAL IS REQUIRED	NO, IT NEEDS MORE WORK ON THESE MATERIALS	NTNU AND UNIBO
	SIMULATION CONCERNING FLOWSHEETING	NO		METHODS	REVIEW OF THE RESULTS PROVIDE BENEFIT IN PRODUCTION ROUTES OF CHEMICAL, BIOFUELS AND ENERGY, BIOENERGY COMPANIES, CHEMICAL AND	DEPEND ON THE COMPANIES WILINESS IN BIOENERGY DEVELOPMENT	NO PATENT	JM

Type of Exploitable Foreground[6]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
					PERO CHEMICAL AND ENGINEERING COMPANIES, SUCH AS LURGI (GERMANY); MAROBENI (ITALY)			

EXPLOTATION of the achievements; Flowsheeting based on the partner's outcome of research was evaluated by JM and the results are published in the third periodic reporting. The numbers of publication and dissemination activities are in line with the planned publication plant. The project has been disseminated as popular science by BIL SWEDEN. The exploitations of results will be prioritised by industrial partners in GREENSYNGAS and other relevant European industry. The main achievement for exploitation activities in GREENSYNGAS consist of the following; flowsheeting provide knowledge to bring BIOENERGY closer to the market; high temperature cleaning device consider to be a bottleneck in BIOENERGY development, the suggested technology in GEREENSYNGAS give one step closer to the commercialization; reforming stage is also a difficult operation units in the downstream processing; in GEENSYNGAS we put emphasis to evaluate the commercial reforming units that were already been experienced in fossil fuel field and the results give knowledge in commercialization aspect of reforming units. The GREENSYNGAS website has been improved and a non-profit organization has joined the consortium through an undertaking contract and facilitates general dissemination to society.

The catalytic system needs to be tested on the downstream of suggested high temperature gas cleanup system by PA in order to guarantee the removal efficiency of catalytic poisoning prior to the entry in catalytic systems that utilize in upgrading steps. Further R & D needs to bring the suggested cleanup system by Porvair to the bioenergy market.

The results expected from the GreenSyngas project represent a great knowledge and experiences required to solve troublesome of cleaning step, and likewise very challenging, stage of the development in three process configurations. The regenerative concept for downstream processing (non catalytic system) provide knowledge that maybe a post reforming step will be required prior to the reforming step. The post reforming step takes care of the hydrocarbons that give rise to the soot formation. Soot act as a poisoning agent in catalytic deactivation and the elimination of the sources for soot formation helps to avoid catalytic decay process. The obtained knowledge in GREENSYNGAS addresses to a number of novelties that need to be investigated in future projects.

4.2 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	**213628**
Title of Project:	Advanced Cleaning Devices for Production of Green Syngas
Name and Title of Coordinator:	Mehri Sanati, Professor

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? ☐ If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	***No***
RESEARCH ON HUMANS	
Did the project involve children?	
☐ Did the project involve patients?	
☐ Did the project involve persons not able to give consent?	
☐ Did the project involve adult healthy volunteers?	
☐ Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
Did the project involve Human Embryos?	
Did the project involve Human Foetal Tissue / Cells?	
Did the project involve Human Embryonic Stem Cells (hESCs)?	
Did the project on human Embryonic Stem Cells involve cells in culture?	
Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
☐ Did the project involve processing of genetic information or personal data (eg. health, sexual	

lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
☐ Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
☐ Did the project involve research on animals?	
☐ Were those animals transgenic small laboratory animals?	
☐ Were those animals transgenic farm animals?	
☐ Were those animals cloned farm animals?	
☐ Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
☐ Did the project involve the use of local resources (genetic, animal, plant etc)?	
☐ Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	NO
☐ Research having the potential for terrorist abuse	NO

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	1	
Work package leaders	2	6
Experienced researchers (i.e. PhD holders)	7	15
PhD Students	2	4
Other	4	

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men: totally 12 and 7 of them are men	

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?

○ Yes
➢ No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	X	○	○
❑ Set targets to achieve a gender balance in the workforce	○	○	X	○	○
❑ Organise conferences and workshops on gender	○	○	X	○	○
❑ Actions to improve work-life balance	○	○	X	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

X No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

X No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

X No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

X Main discipline[8]:2

X Associated discipline[8]:1.3 Associated discipline[8]: 1.4

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*

X Yes
○ No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No
○ Yes- in determining what research should be performed
X Yes - in implementing the research
X Yes, in communicating /disseminating / using the results of the project

[8] Insert number from list below (Frascati Manual).

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	X ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- X Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- X Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- X Yes – as a **primary** objective (please indicate areas below- multiple answers possible): Energy
- X Yes – as a **secondary** objective (please indicate areas below - multiple answer possible): Environment
- ○ No

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level? ○ Local / regional levels ○ National level ○ European level X International level	
H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals? 10 and a whole specific Energy journal for	**10 and a whole specific Energy journal for result of GREENSYNGAS**
To how many of these is open access[9] provided?	**1**
How many of these are published in open access journals?	**1**
How many of these are published in open repositories?	
To how many of these is open access not provided?	**9**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access X other[10]: ……………	
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*	**No**

16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**NO**
	Registered design	**No**
	Other	**1**

17. How many spin-off companies were created / are planned as a direct result of the project?	**NO**
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

X	Increase in employment, or	X	In small & medium-sized enterprises
❑	Safeguard employment, or	❑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*

[9] Open Access is defined as free of charge access for anyone via Internet.
[10] For instance: classification for security project.

Difficult to estimate / not possible to quantify	X

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

X Yes ○ No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

X Yes ○ No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	❑	Coverage in specialist press
❑	Media briefing	X	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	X	Coverage in international press
❑	Brochures /posters / flyers	X	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	X	English
❑	Other language(s)		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]