Rapport SGC 234

Biomass Gasifier Database

for Computer Simulation Purposes

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Summary

This report is an effort to summarize the existing data on biomass gasifiers as the authors have taken part in various projects aiming at computer simulations of systems that include biomass gasification. Reliable input data is paramount for any computer simulation, but so far there is no easy-accessible biomass gasifier database available for this purpose.

This study aims at benchmarking current and past gasifier systems in order to create a comprehensive database for computer simulation purposes. The result of the investigation is presented in a Microsoft Excel sheet, so that the user easily can implement the data in their specific model. In addition to provide simulation data, the technology is described briefly for every studied gasifier system. The primary pieces of information that are sought for are temperatures, pressures, stream compositions and energy consumption.

At present the resulting database contains 17 gasifiers, with one or more gasifier within the different gasification technology types normally discussed in this context:

- Fixed bed
- Fluidised bed
- Entrained flow

It also contains gasifiers in the range from 100 kW to 120 MW, with several gasifiers in-between these two values. Finally, there are gasifiers representing both direct and indirect heating. This allows for a more qualified and better available choice of starting data sets for simulations. In addition to this, with multiple data sets available for several of the operating modes, sensitivity analysis of various inputs will improve simulations performed.

However, there have been fewer answers to the survey than expected/hoped for, which could have improved the database further. However, the use of online sources and other public information has to some extent counterbalanced the low response frequency of the survey. In addition to that, the database is preferred to be a living document, continuously updated with new gasifiers and improved information on existing gasifiers.

Abbreviations and Definitions of Used Terms

BFB	Bubbling fluid bed
CFB	Circulating fluid bed
CHP	Combined heat and power
FT	Fischer-Tropsch
MSW	Municipal solid waste
kW_{th}, MW_{th}	Thermal power
kW_{el}, MW_{el}	Electric power
MC	Moisture content
SNG	Substitute Natural Gas (natural gas-mimicking gas produced using renewable sources)
SOFC	Solide oxide fuel cell
TRI	ThermoChem Recovery International, Inc.
VVBGC	Växjö Värnamo Biomass Gasification Centre AB

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1 Introduction

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The project, which was conducted during 2010, was initiated by Nordlight and financed by the member companies of the Swedish Gas Centre, SGC, gasification group. These include E.ON Gasification Development AB, Göteborg Energi AB, Öresundskraft AB, Kraftringen Produktion AB, Stockholm Gas AB, Vattenfall AB and Tekniska Verken i Linköping AB.

1.1 Background

In the gasification process a carbonaceous fuel, e.g. coal or biomass, is reacted with air or oxygen (and in some cases steam) to yield a gas. This is normally performed at temperatures between 500ºC and 1 400ºC and pressures ranging from atmospheric to 35 bar. This is performed for many reasons, reasons that will be studied in more detail in this text:

- Improved efficiency for electricity production, through combi-cycle
- Gas to be distributed in a more efficient manor than biomass/coal
- The gas can be used as a basis for fuel and/or chemical production

The first useful gasifier was constructed during the 1840s in France and the technology has been in development ever since. The intensity of the development, especially for fuel and chemical production, has to a large extent been dependent on the crude-oil price. Something that became very evident after the oil crisis during the 1970s, when intense development was commenced in Austria, Sweden, Finland and the US, aiming at producing substitutes for oil. During the 1990s the development focused toward the production of electricity and demonstration plants were built in Värnamo and in England, to mention a few examples. [1]

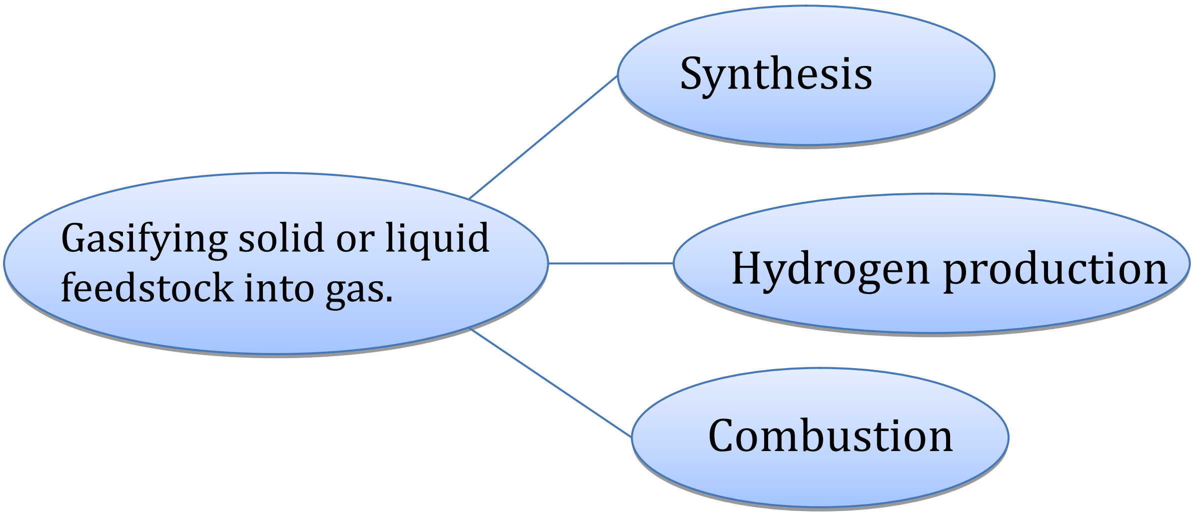

Figure 1 Summarisation of the most common utilisations of gasification.

In general, gasification technology has seen an increased level of development during times of high oil prices. Gasification research does not always follow a stable trend of the willingness to finance with the consequence that projects often are started up, only to be abandoned, sold or mothballed after a few years. Later years have brought new players to the field and there is today a wide range of technologies available, at different stages of development.

Players today can be found in Germany, Austria, Finland, Sweden, Denmark, the USA, Canada, the Netherlands, Italy, Portugal, Belgium, Switzerland and the UK, to mention a few.

Technologies vary but can usually be grouped into a few chief categories:

- Fluid bed – the gasifier is filled with a bed material such as sand or finely powdered minerals. The biomass is added directly to the bed material and is either combusted in the same chamber as the gasification reactions take place in (direct heating) or the bed material is transported from a combustion compartment to a gasifier compartment (indirect heating). The latter is an example of a circulating fluid bed (CFB), i.e. the oxidation medium (generally air or oxygen, steam is often also included in the mixture) carries the bed material from one chamber to another. If the bed material is stationary, but blown at a lower gas velocity it is referred to as a bubbling fluid bed (BFB). Different types of fluidised-bed gasifiers are depicted in figure 2.

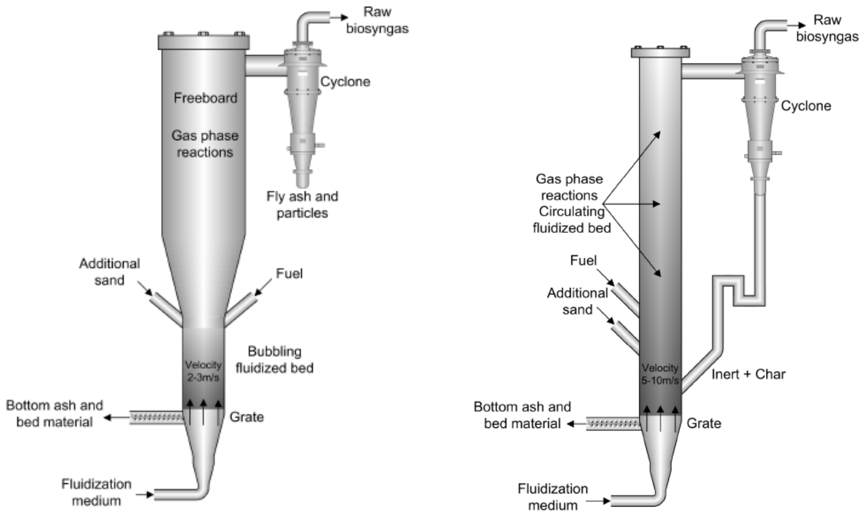

Figure 2 The different categories of fluidized bed gasification, bubbling bed and circulating fluidized bed [1].

- Fixed bed – there is no bed material present in the gasifier, only the biomass itself. This bed is also blown by an oxidant and this can be in updraft, downdraft or cross-draft direction, figure 3.

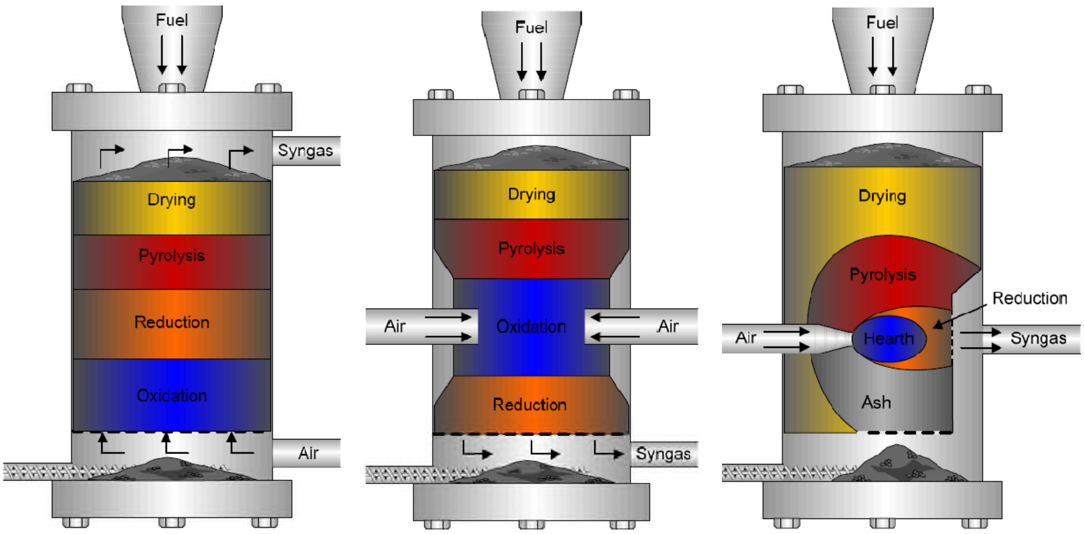

Figure 3 Different types of fixed bed gasifiers, from the left: updraft, downdraft and crossdraft [1].

- Entrained flow – the temperature is much higher than for the other types and the residence time is much shorter. The short residence time means the fuel needs to have a larger contact surface, i.e. be more finely ground or be a liquid. The high temperature reduces tar formation reactions but the system is not economically feasible in smaller sizes. Entrained-flow gasification gives high levels of H_2 and CO, which is sought for when bio fuels such as Fischer-Tropsch (FT) diesel is produced, figure 4.

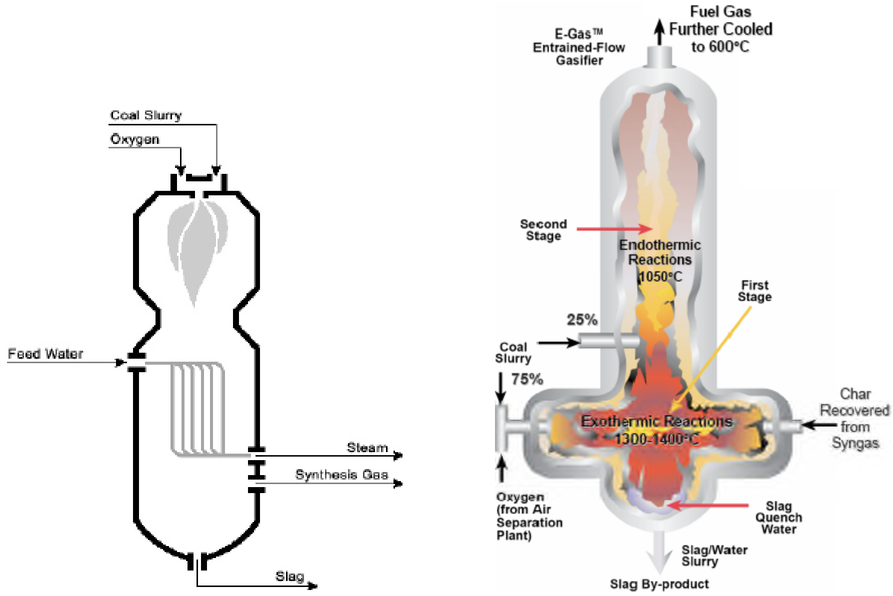

Figure 4 Different designs of entrained flow gasifiers, downstream and upstream gasifier [1].

The choice of oxidant has an important impact on the product gas which is obtained from the gasifier. If air is used, a larger fraction of the product gas consists of N_2, reducing the calorific value of the gas. This is a disadvantage in fuels production but just right when a gas engine is utilised to generate power. If a higher calorific value is important for the application, the N_2 needs to be avoided upstream the gasifier. Enriched air, pure oxygen or an oxygen carrier (e.g. metal oxide) can be used to supply the gasification reactions with oxygen. Yet another approach is to supply the heat by conveying a hot bed material from a combustion chamber to the gasification chamber such as in the indirect CFB gasifier method mentioned above. In this, air can be used instead of the more costly options with concentrated oxygen.

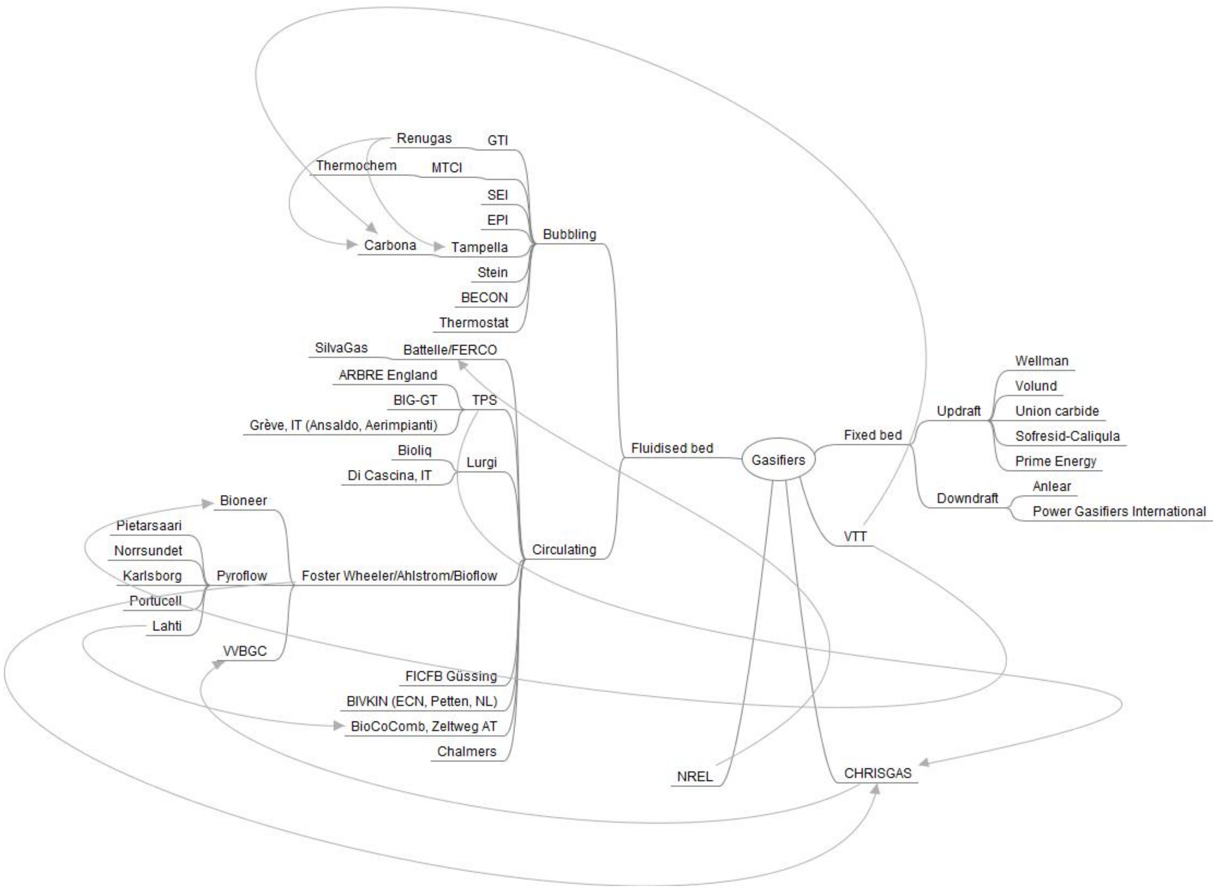

Figure 5 Mindmap gasifiers

1.2 Methods of Investigation

The primary sources of information used in the gasification database are:

- online data from conference slides and proceedings as well as project reports
- published data
- first-hand information from gasification companies and researchers

The intended purpose of populating the database with all necessary data to perform a heat and mass balance computer simulation requires a wide range of operational data to be collected. The use of online and published data restricts this collection to the data that the sender of this information chose to convey. This calls for the requirement of contacting the player in question and asking the right questions. A survey was therefore performed, aimed at the interesting companies and researchers.

The survey was conducted through phone and e-mail. In general, the interviewee was phoned up and asked for participation in the study. Thereafter, a questionnaire was sent and either filled out by the gasification player and returned, or filled out by the interviewer during a phone conversation. A third alternative has been to use material sent by the gasification player and thus fill out by the questionnaire. Table 1 (under section 2.2) shows method of data investigation for each gasification system.

1.3 Scope of Study

This purpose of this gasifier database is to supply anyone who wishes to perform computer simulations on systems containing a gasifier with reliable data including:

- temperatures
- pressures
- stream compositions
- energy consumption

With "computer simulations", it is referred to process flowsheeting, i.e. steady-state heat and mass balancing, sizing and costing calculations, using software such as Aspen Plus or HYSYS.

In order to further the understanding of the data supplied, brief information is also given for every gasifier system included in the database (Chapter 2). For a more comprehensive description of the various gasifier systems, handbooks [2], IEA (International Energy Agency) publications [3] or other reports are referred to.

2 Gasifier Directory

In this section, the studied biomass gasifier systems are depicted, with brief descriptions of technology and history for each system.

2.1 Selection Criteria

The first selection of gasifier systems was done through experience gained from work within the gasification field. A brainstorming session and further online research gave a comprehensive list, which was shortened through filtering using a number of criteria, including:

- Feedstock – the database is limited to biomass gasifiers, not for example waste, MSW or coal
- Scale – only systems of at least pilot scale ($\geq 100\ kW_{th}$) were taken into account
- Technological maturity – technologically immature systems were removed from the list
- Uniqueness - the news value of each system was also taken into account. If several identical systems existed, the first one completed was used.
- Availability of data – if the required information could not be found or supplied by the owner itself, the gasifier system was removed from the list
- Language barriers – during data collection, only sources in English, German and the Scandinavian languages were considered

2.2 Gasifier Listing

This section includes a list of the gasifiers which can be found in the database (Table 2). For a more comprehensive directory of gasifiers that were included but also considered but removed from the gasifier database, check APPENDIX.

Name of gasifier/project	Technology owner/developer	Location of gasifier	Source of information
Bioliq	Lurgi, Karlsruhe Institute of Technology	Germany	Online publications
BIONEER	VTT, BIONEER	Finland [6], Sweden [2]	Online publications
Chalmers	Chalmers Institute of Technology	Sweden	Online publications
CHEMREC	Energy Technology Center Piteå (ETC)	Sweden	Online publications
CHOREN	CHOREN Gmbh	Germany	Online publications
Cortus WoodRoll®	Cortus AB	Sweden	Survey reply
FIFCB	Technical University of Vienna	Austria	Scientific publications
Lahti	Foster-Wheeler	Finland	Online publications
MILENA	Energy Research Centre (ECN)	the Netherlands	Scientific publications
Nexterra	Nexterra System Corp.	Canada and the USA	Survey reply
PYROFORCE®	Pyroforce Energietechnologie AG	Switzerland and Austria	Survey reply
Rentech-Silvagas	Rentech	the USA	Online publications
Skive	Carbona	Denmark	Online publications
TRI (TermoChem Recovery International)	TRI	Canada and the USA	Survey reply
Viking	Technical University of Denmark (DTU)	Denmark	Scientific publications
Värnamo	VVBGC	Sweden	Scientific publications
Värö	Metso Power	Södra Cell Värö Pulp Mill in Sweden	Survey reply

Table 2 Gasifiers included in database.

More detailed information of each gasifier is given below.

Bioliq	
Developing Companies/Institutions	Forschungszentrum Karlsruhe (FZK)/Karlsruhe Institut für Technologie (KIT), Lurgi GmbH
Owner	FZK/Lurgi
Gasification Technology	High temperature entrained-flow gasification of pyrolysis oil, which is produced in a Lurgi fast pyrolysis process to "Biosyncrude"
Primary Purpose	Biomass to Fischer-Tropsch fuels, methanol, chemicals, SNG
Technology Status	Demonstration gasifier to be completed in 2011
Power Throughput	2 MW_{th} of demonstration unit
Location	Karlsruhe, Germany

In a joint development between Forschungszentrum Karslruhe (FZK) and Lurgi GmbH, a combined pyrolysis/entrained-flow gasification system has been developed. The idea is to produce a pyrolysis oil (name "BioSynCrude" by Lurgi) on a decentralised location upon which the energy density is increased, where after it is transported to a centralised entrained-flow gasification plant where it is gasified. Entrained-flow gasification is generally favoured by scale so this is a suitable approach to save on transports and energy. The collaboration project started in 2008 and in 2012 it is believed that the complete plant is operational. [4] [5]

Figure 6 The FZK pilot gasifier in Karlsruhe [4]

Bioneer	
Developing Companies/Institutions	Technical Research Centre of Finland (VTT), Bioneer Oy
Owner	Various
Gasification Technology	Updraft fixed bed
Primary Purpose	Lime kilns, district heating
Technology Status	Commercial system in operation but no new development
Power Throughput	4-6 MW_{th} input
Location	Kankaanpää, Kempele, Kauhajoki, Hämeenlinna, Parkano, Kitee, Jalasjärvi (Finland) and Lit and Vilhelmina (Sweden)

The development of an updraft gasifier for peat and wood was initiated at the Technical Research Centre of Finland (VTT) in the late 1970s. The idea was to replace imported fuels with domestic. The Finnish Ministry of Trade supported and sponsored the venture. During the mid 80s, the VTT conducted extensive tests with a variety of feedstocks, including wood, forest wastes, peat, straw, RDF pellet etc. at a pilot plant in Kankaanpää. Since 1984 Bioneer Oy manufactured and sold the gasifiers under the trademark Bioneer. Eight commercial plants were then built during the 80s, in Finland and Sweden. Yet another commercial plant was built in 1996 in Finland. [6]

Figure 7 VTT research gasifier [6]

Chalmers Pilot Gasifier	
Developing Companies/Institutions	Chalmers University of Technology, Göteborg
Owner	Chalmers University of Technology, Göteborg
Gasification technology	Indirect gasification, CFB (combustor) and BFB (gasifier)
Primary purpose	Research purposes: Increased stability of the gasification process Possibility to take full advantage of the low temperature heat demand connected to the drying Take advantage of the low alkali content in the char Production unit can produce heat and power even if the biofuel production has low availability
Technology history and status	2.2 (2-4) MW pilot plant
Power Throughput	0-4 MW_{th} input
Location	Göteborg, Sweden

Chalmers University of Technology in Göteborg, Sweden has since 2008 been engaged in research in the field of gasifying biomass. Their gasifier has been operational since the spring of 2008 and the technology is expected to have significant commercial potential [7]. If optimised the gasifier could make fuel for roughly 500 cars which makes it one of the largest research facilities for production of nitrogen free product gas from biomass.

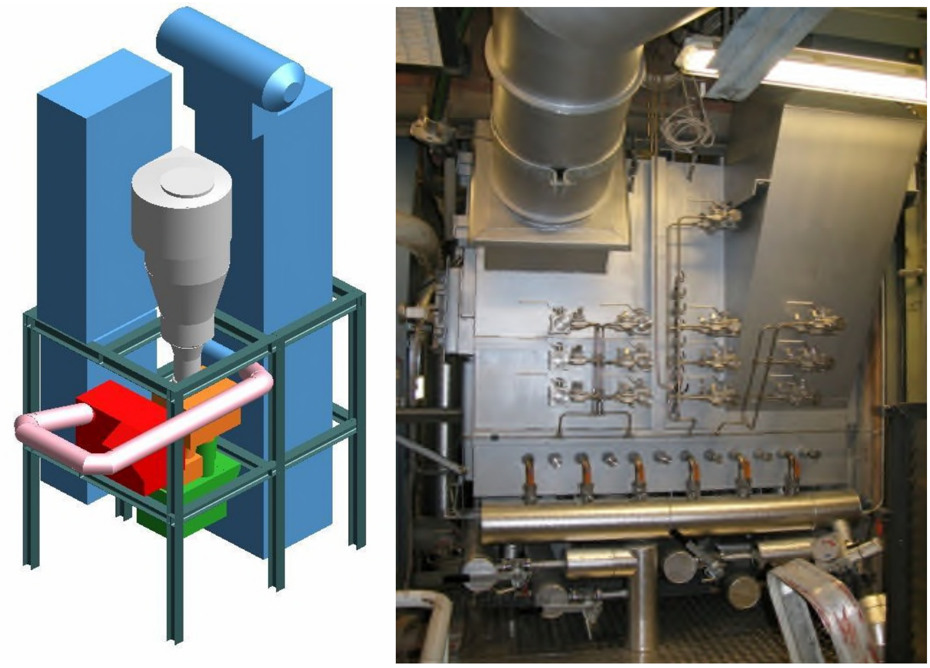

Figure 8 Chalmers Pilot Gasifier [7]

CHOREN

Developing Companies/Institutions	CHOREN
Owner	CHOREN (Freiberg, Germany)
Gasification Technology	Entrained flow, 3-step gasification - low temp (400-500 °C), high temp (1300-1550 °C), chemical quenching to 900 °C
Primary Purpose	Woody biomass to synthetic fuels, i.e. syngas via Fischer-Tropsch synthesis to diesel (SunDiesel®)
Technology Status	Alpha pilot plant finished 1997, then Beta plant of 45 MW constructed in 2009. The Sigma plant at 640 MW planned.
Power Throughput	45 MW_{th} input of demonstration plant
Location	Freiberg, Germany

CHOREN was founded in 1990 by four people under the name Umwelt- und Energietechnik Freiberg (UET) GmbH. They soon went into gasification and in 1998 the first Carbo-V Alpha pilot plant was constructed and trials begun. In 2004, 22 5000 hours of testing has been done, using many different kinds of feedstock.

The first industrial-size plant, a demonstration facility of 45 MW_{th}, was started in 2003 fist as a char production unit and later became a part of the synthesis gas production part of the beta plant. A synthetic fuels synthesis was added to the Alpha plant in 2003 and in the same year the first wood chips to synthetic automotive fuels were produced. This took place within a combined project with German Federal Ministry of Economics and Labour. Partners DaimlerChrysler AG and Volkswagen AG joined the project. Shell was previously also a partner but sold their stocks to the remaining owners in 2009. An integrated gasifier and fuel production facility went operational in 2009 and is called the beta unit, using some parts from the char production unit earlier developed. The next step, the SIGMA plant at 640 MW_{th} is currently under planning.

In January of 2010, the French group CNIM (Constructions Industrielles de la Méditerranée SA) contracted CHOREN's services to build a 45 MW_{th} plant in France.

Figure 9 The CHOREN BETA plant

Cortus WoodRoll®	
Developing Companies/Institutions	Cortus, partners GEP Group, Kanthal, Caldersys, ÅF, AB Torkapparater
Owner	Cortus AB
Gasification Technology	Indirectly heated downdraft entrained flow gasifier
Primary Purpose	CHP
Technology Status	Pilot phase. Demonstration plant, on stream "within 12 months from finalised financing"
Power Throughput	Pilot 500 kW_{th}, then demonstration 5 MW_{th} output (thereafter commercial unit at 25 MW_{th})
Location	Stockholm, Sweden

Stockholm-based Cortus AB sells renewable, cost-efficient and CO_2-neutral energy gas supply to process industries with the need of combustion at high temperatures. The business is based in the patented WoodRoll® process. The WoodRoll technology produces a clean synthesis gas which is free from condensable residues and nitrogen aggregates. Essentially, WoodRoll fixes this problem by separating the drying, pyrolysis and gasification into three separate steps and by using indirect heated gasification. [8]

Cortus' aim is to reach 10% of process industries market in Europe by 2020. Expansion will focus in the Nordic countries as well as the EU and North America, where the long term business model is well accepted. They will also introduce our solution to the power industry for distributed combined heat and power. An increased interest has been identified, especially from the Baltic countries. The first commercial installation is underway at a Swedish limestone-product producer in Köping, starting with a 5 MW demonstration plant and expanding to 25 MW after 2 years. [8]

FICFB	
Developing Companies/Institutions	PSI, Vienna University of Technology, Repotec, CTU, AE Energietechnik, Renet-Austria
Owner	Güssinger Fernwärme Ges.m.b.H.; EVN AG, and a research organisation TU Vienna
Gasification Technology	Indirect gasification, CFB (combustor) and BFB (gasifier)
Primary Purpose	Generation of heat and power, production of FT liquids and SNG, power generation in SOFC (solide oxide fuel cell)
Technology Status	Demonstration
Power Throughput	8 MW_{th} input
Location	Güssing, Austria

The FICFB (Fast Internally Circulated Fluidised Bed) was developed to achieve a product gas with high calorific value (up to 15 MJ/Nm^3) and with a very low level of nitrogen. The predecessors of the demonstration unit includes one lab scale test rig of 10 kWth thermal input and three different pilot plants – the first one at 100 kWth was run between 1995 and 1999, the second (with an improved design) also at 100 kWth, started operation in 1999. The third pilot was very similar to the second one, only with a slight separation modification. With the result of the second pilot, the demonstration unit at 8 MWth was built. It is possible to use catalysts in the bed material – it can be regenerated in the combustion zone. [9]

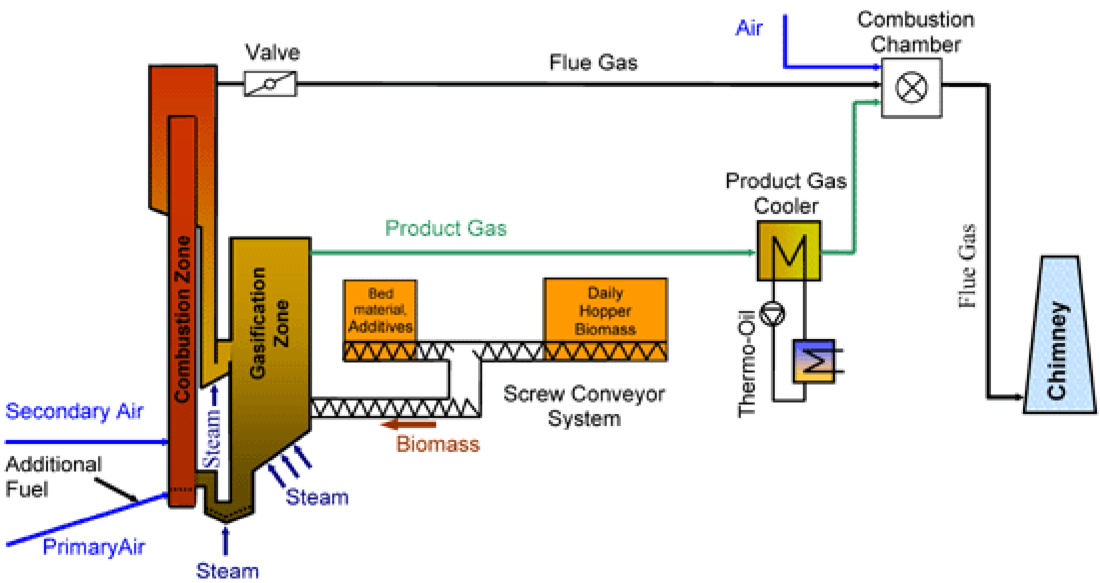

Figure 10 Schematics of the FICFB demonstration plant [9]

Harboøre	
Developing Companies/Institutions	Babcock and Wilcox Vølund
Owner	Babcock and Wilcox Vølund
Gasification Technology	Updraft counter-current moving bed gasifier
Primary Purpose	CHP
Technology Status	commercial
Power Throughput	3.5 MW_{th} input
Location	Harboøre, Denmark

Danish boiler manufacturer Ansaldo Vølund Energy built the Harboøre updraft counter-current moving bed gasifier between 1988 and 1992. The updraft technology was chosen to include the drying step in the unit, and to achieve a high carbon conversion. Other benefit would include high heating value of the product gas and low dust content. [3]

The plant was actually constructed for district heating only at first but was in 1997 optimised for gasification. Gas cleaning, waste water cleaning and gas engines were installed during 1997-2002, thereafter commercial operation commenced. The technology has also been transferred to a plant in Yamagata in Japan, which began operation in 2007. Since then two more Japanese plants have been added to the list. [2] [10]

Figure 11 The B&W Vølund gasifier in Harboøre [3]

Lahti	
Developing Companies/Institutions	Foster-Wheeler
Owner	Lahden Lämpäpövoima Oy
Gasification Technology	Atmospheric CFB
Primary Purpose	Heat and power to the local community, auxiliary system to the conventional boiler
Technology Status	Commercial
Power Throughput	60 MW_{th} input
Location	Kymijärvi Power Plant, Lahti, Finland

The FW CFB gasification technology was developed in the early 1980s, the driver for development being very high oil prices. The first commercial-scale CFB gasifiers, using 17 to 35 MW of dry waste wood as feedstock, were delivered for the pulp and paper industry in the mid 1980s, enabling oil to be substituted in the lime kiln process. During the 1990s, a gasification process producing raw gas from a variety of biomass and recycled fuels to be co-combusted in a pulverized coal (PC) boiler was developed. Additionally, three commercial-scale atmospheric CFB/bubbling fluidized-bed (BFB) gasifiers with fuel inputs from 40 to 70 MW were supplied during the years 1997-2003. [11]

In 1997-1998, a 60 MWth atmospheric Foster Wheeler CFB biomass gasifier was installed at the 200 MWth fossil fuel fired Kymijärvi power station, without any significant commissioning problems. The product gas is used in the boiler and the gasifier is flexible when it comes to type of fuel and with an availability of >95%. [3] [12]

Figure 12 The Kymijärvi plant with the gasification unit on the side of the construction [11]

MILENA	
Developing Companies/Institutions	ECN (Energy Research Centre of the Netherlands
Owner	ECN
Gasification Technology	Indirect gasification, BFB (combustor) and CFB (gasifier)
Primary Purpose	CHP and SNG (Substitute Natural Gas)
Technology Status	Pilot phase running since 2008, demonstration unit planned
Power Throughput	Pilot: 0.8 MW_{th} input. Demonstration unit: 10 MW_{th} input
Location	Lab and pilot at ECN? Demonstration unit in Alkmaar, the Netherlands

The Energy research Centre of the Netherlands (ECN) has developed a biomass gasification technology, called the MILENA technology. The MILENA gasification technology has a high cold gas efficiency and high methane yield, making it suitable for gas engine application or upgrading of the gas into Substitute Natural Gas (SNG). [13], [14] [15]

ECN aims at the development of large scale SNG production and sees the gas engine as an intermediate application necessary for reaching the large scale application. The MILENA Bio-CHP technology will be introduced on a 10 – 30 MWth scale. To achieve both these goals, a waste processing company in the Netherlands (HVC Alkmaar) joined ECN to make the step from pilot scale to demonstration and commercial scale. The progress for the demonstration plant has so far reached basic engineering (August 2010). [13], [14]

The development of this technology started in the laboratory with a 5 kg/h (25 kWth) indirect gasifier. This first MILENA has been operated for about 2000 hours and is actively used for different testing purposes. In 2008 ECN finished the construction of the 800 kWth pilot gasifier MILENA. [13]

The pilot installation is coupled to ECN's technology to remove tar (OLGA) which is a necessary step for the CHP and the SNG applications. [13]

Several commercial parties have shown interest in commercialising the technology. A 50 MWth SNG demonstration plant is scheduled to be started in 2015. [13], [14]

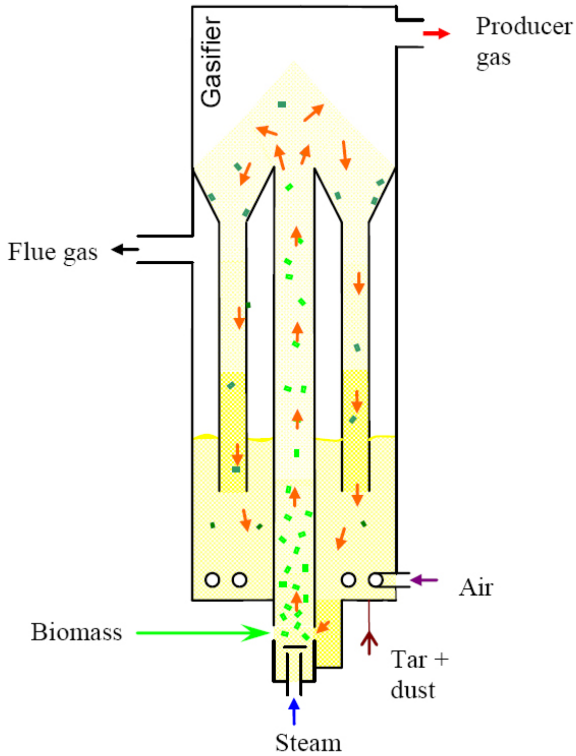

Figure 2 Schematics of the MILENA gasifier [14]

Nexterra	
Developing Companies/Institutions	Nexterra Systems Corp. (Vancouver, Canada)
Owner	varies
Gasification Technology	Updraft fixed bed gasifier
Primary Purpose	Heat and power
Technology Status	Commercial
Power Throughput	30 MW_{th} or 10 MW_{el} (for cogeneration) output
Location	Several plants in North America, including Oak Ridge (Tennessee, USA), Vancouver (British Columbia), Columbia (North Carolina, USA), Prince George (British Columbia), Victoria (British Columbia), New Westminster (British Columbia), Heffley Creek Plywood Mill near Kamloops (British Columbia), in Canada if not otherwise stated

Nexterra develop, manufacture and deliver advanced gasification systems that enable customers to self-generate heat and power at industrial and institutional facilities using waste fuels. The technology is claimed to be based on a new generation of gasification technology suitable for “inside-the-fence” thermal and cogeneration applications. Nexterra has proven gasification solutions available for the forest industry, institutional (e.g. universities, hospitals, government facilities) and power generation where locally sourced wood waste can be found. Future applications include systems that operate on coal and other low cost fuels. [16] [17]

Figure 3 Nexterra gasifier at Heffley Creek Plywood Mill [17]

PYROFORCE® Holzvergasungs-KWK-System	
Developing Companies/Institutions	Pyroforce Energietechnologie AG, CTU (gas cleaning)
Owner	Pyroforce Energietechnologie AG (Switzerland)
Gasification Technology	2-zone downdraft fixed bed gasifier
Primary Purpose	CHP
Technology Status	Commercial
Power Throughput	150 kW_{el} output per gasifier unit, parallel operation of 4 and 8, respectively in current commercial plants
Location	Güssing, Austria and Nidwalden, Switzerland

Pyroforce Energietechnologie AG (PYROFORCE®) is a Swiss company founded in 1974 under the name Hydrotest Ingenieurunternehmung AG. They went into gasification in 1996 through a governmental project and have developed the technology since then. The Nidwalden and the Güssing facilities both went into operation in the beginning of 2008. The plant in Güssing has no operator at the moment and is thus not in operation. Combined, the systems have about 20 000 accumulated operating hours. Future plans include expansion in the UK and in Germany. [18] [19]

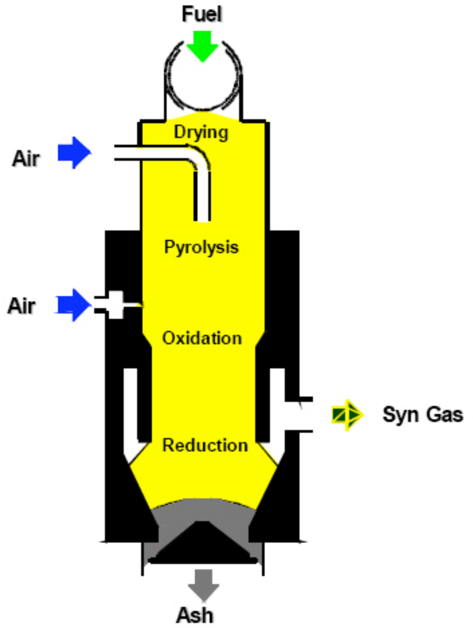

Figure 4 Schematic of the PYROFORCE gasifier

Figure 5 The Nidwalden plant in Switzerland [19]

Rentech-SilvaGas	
Developing Companies/Institutions	Battelle Columbus Laboratory, FERCO, DOE, NREL, Rentech
Owner	Rentech (Denver, Colorado, USA)
Gasification Technology	CFB gasifier at 24 tpd
Primary Purpose	Forestry and agricultural waste, algae and energy crops to synthetic fuels and/or power production
Technology Status	Commercial operation
Power Throughput	
Location	Burlington, Vermont, USA

Located at the McNeil Power Station in Burlington, the Vermont Gasification Project served as a development platform for the SilvaGas process – originally developed and tested as a part of the U.S. Department of Energy's (DOE) Biomass Power Program. FERCO (Future Energy Resources) bought the rights to the process in 1992. The plant was finalised in 1997 and extensive testing has been conducted since then. This program was funded to about $100 million from DOE and private investors. Other partners were National Renewable Energy Laboratory (NREL) and Battelle Columbus Laboratory. Rentech bought the SilvaGas technology in 2009. Now the technology is offered together with Rentech's fuel synthesis technology. [20] [21]

Figure 6 SilvaGas in Burlington, USA [21]

Skive	
Developing Companies/Institutions	Carbona, Tampella, Enviropower, IGT, VTT, GE Jenbacher
Owner	I/S Skive Fjernvarme
Gasification Technology	Biomass Gasfication Gas Engine (BGGE) plant; Low pressure BFB gasifier with one cyclone, based on the U-gas technology from 1989 (IGT)
Primary Purpose	CHP connected to district heating network
Technology Status	Demonstration unit
Power Throughput	20 MW_{th} input, 5.4 MW_{el} and 11.5 MW_{th} output
Location	Skive, Denmark

The Skive demonstration plant was commissioned in 2007-2008. The project is financed on commercial basis but subsidiaries are given by the US Department of Energy (DOE), the EU and the Danish Energy Agency (DEA). The plant will supply the plant owner Skive Fjernvarme with 70% of its district heating demand but also generate 40 GWh_e annually. [22]

Carbona is a subsidiary of pulp and paper technology company Andritz Oy, which also possesses CFB technology. VTT (also participant of the NSE Biofuels and the BIONEER technology) supplied with tar reformer technology. [22] [23]

Figure 7 The Carbona gasifier facility in Skive, Denmark [23]

TRI Steam Reformer	
Developing Companies/Institutions	TRI (ThermoChem Recovery International, Inc.)
Owner	TRI (licenses parts of the technology from MTCI)
Gasification Technology	Indirect bubbling fluidised bed gasifier with steam reformer followed by partial oxidation of char – customisable H2/CO ratio
Primary Purpose	Production of biofuels, biochemicals, power, heat, steam
Technology Status	Commercial operation of black liquor gasifier and further development of biomass gasification in pilot
Power Throughput	~20 MW_{th} black liquor (100 tpd)
Location	Commercial plant in Ontario, Canada. Pilot plant at in Durham, NC, USA. Two biomass gasification demonstration plants in final engineering phase to be constructed in Wisconsin, USA (100 and 200 MWth input, respectively)

MTCI/ThermoChem are the original developers of the technology and TRI was started with a license from them in 1996. Since then TRI have made many modifications and further development and have integrated the gasifier with a steam reformer, which they called 'TRI Steam Reformer'. The Maryland-based (USA) TRI has a commercial black liquor gasification plant running in Ontario, Canada. There is currently research carried out to perform biomass gasification in their pilot plant in North Carolina. Two new biomass gasification plants with a thermal input of ~100 MWth and 200 MWth, respectively are in the final engineering phase. These will be used to gasify dry forest residuals for the production of FT liquids. [24] [21]

The current system targets 250-2000 tpd of feed but there are plans to develop the technology for the 5-250 tpd range as well. More trials using other feedstock will increase the flexibility of the system. [25]

Figure 8 TRI's commercial black liquor gasification facility in Ontario, Canada (Picture courtesy of Norampac and TRI)

Viking or LTCFB	
Developing Companies/Institutions	Technical University of Denmark (DTU)
Owner	Technical University of Denmark (DTU)
Gasification Technology	Low-temperature circulating fluid bed
Primary Purpose	Research
Technology Status	Pilot
Power Throughput	500 kW_{th} output
Location	DTU, Kgs. Lyngby, Denmark

The Viking gasifier is developed by the Biomass Gasification Group at DTU and is an unmanned, automated and essentially tar free gasifier for heat and electricity production based on the two stage fixed-bed gasification process, where pyrolysis and char gasification takes place in separate reactors [26], and fueled by wood chips.

DTU has continued their work and developed a 500 kW (Low-Temperature Circulating Fluid Bed, LT-CFB) gasifier for fuels with high alkali contents e.g. straw, pig manure and chicken litter. [27; 28]

Figure 20 The Viking gasifier [28]

Värö	
Developing Companies/Institutions	Götaverken, Tampella, Kvaerner, Metso Power
Owner	Metso Power
Gasification Technology	Atmospheric circulating fluid bed
Primary Purpose	Generation of syngas to be burned in the lime kiln
Technology Status	Commercial operation
Power Throughput	35 MW_{th} input
Location	Södra Cell Värö Pulp Mill, Sweden

The Värö gasifier was installed in 1987 at the Södra Cell Pulp Mill In southwestern Sweden. It was designed by Götaverken in Göteborg, who had experience from atmospheric CFB gasification. Due to low oil prices during the early 1990's, the gasifier was not operating. Tampella Power and Vattenfall founded the company Enviropower in 1992 which was later bought by Metso Power. New development began in 2002, with the primary purposes to supply heat to the lime kiln and generate power. Waste gasification, fuel drying and new technologies for gas cleaning were/are also tested. [29] [30]

The gasifier now has a role in the lime cycle of the pulping process and has over 90 000 hours of operating time.

Figure 21 The Metso Power gasifier at Södra Cell Värö Pulp Mill [30]

Värnamo	
Developing Companies/Institutions	Sydkraft, TPS, Foster-Wheeler, Electricité de France, Energi E2, TK Energy, Linnaeus University, Lund University etc.
Owner	VVBGC (Växjö Värnamo Biomass Gasification Centre AB)
Gasification Technology	Pressurised circulating fluid bed
Primary Purpose	First built for heat and power, now conversion to production of green fuels
Technology Status	Demonstration plant, waiting for financing (August 2010)
Power Throughput	18 MW_{th} input
Location	Värnamo, Sweden

The Värnamo facility was built as an IGCC (Integrated Gasication Combined Cycle, i.e. heat and power generation) plant by Sydkraft (now E.ON) in 1992. Sydkraft conducted research aimed at CHP production until it was mothballed in 2000. Various research groups have since performed a number of different pre-studies with respect to different biomass feedstock, but only in the later years the interest for green chemicals and fuels has increased. [31] [32]

The Swedish Energy Agency has throughout the process shown interest in the gasifier and partly financed it. The European Union also supported a large development project (CHRISGAS), under which much research and development took place 2004-2009. The future of the plant is at the time of writing unclear with respect to financing and operation. A reconstruction of the Värnamo gasifier would cost about a third of the construction of a new facility, approximately 450 MSEK (~47 MEUR). [33]

Figure 22 The Värnamo facility from the air [33]

3 Presentation of Data

The data collected is presented in the Excel file that can be downloaded with the report. As this Excel file uses macros written in Excel VBA, these have to be activated before running the program. In Excel 2007 the program will ask whether to allow macros or not, Figure 9.

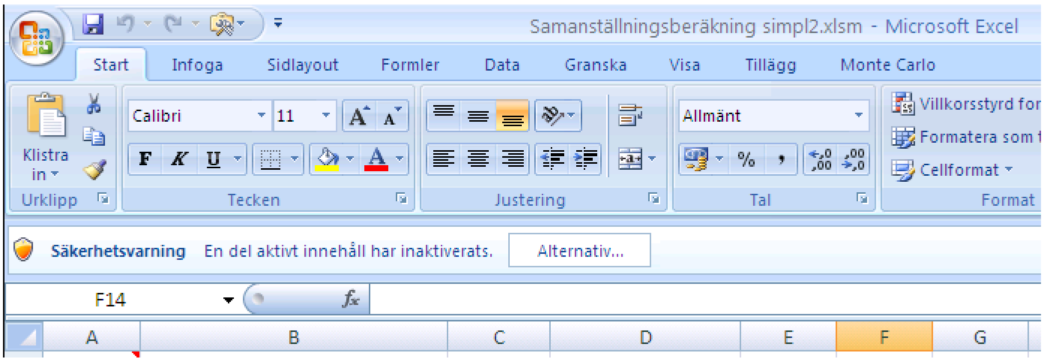

Figure 9 Safety warning in Excel.

To change the safety settings, click ”Alternativ” whereafter a dialog box will open, figure 24.

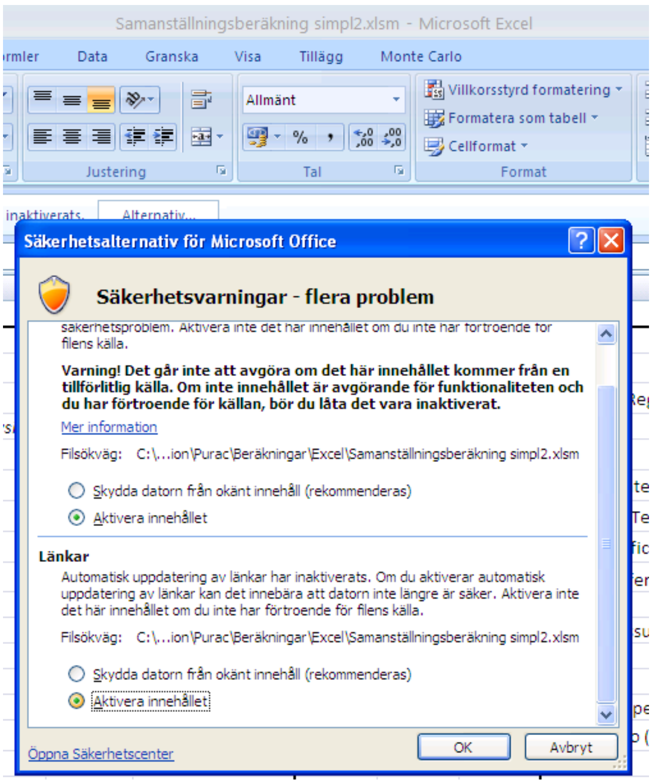

Figure 10 Safety warning with “activate contents” selected.

In the dialog box the two boxes which activate the content is checked where after OK is clicked. When these settings have been changed, the program is ready for use.

The Excel sheet is configured with a fist tab named front, containing general information about the project and links to the individual gasifiers. The next tab, Index, contains a sorting function in which the list of gasifiers can be tailored with respect to certain operating conditions. The conditions or selection criteria that can be used are the following:

- Mode of heating (direct or indirect)
- Size (MW_{th})
- Type of gasifier (fixed bed, fluidised bed or entrained-flow)

The program uses the drop-down lists available for selecting the criterion for each individual search, if N/A is chosen the criterion is not applied in the search. After selecting new values, the "sort"-button has to be pressed for the search to be made, Figure 11.

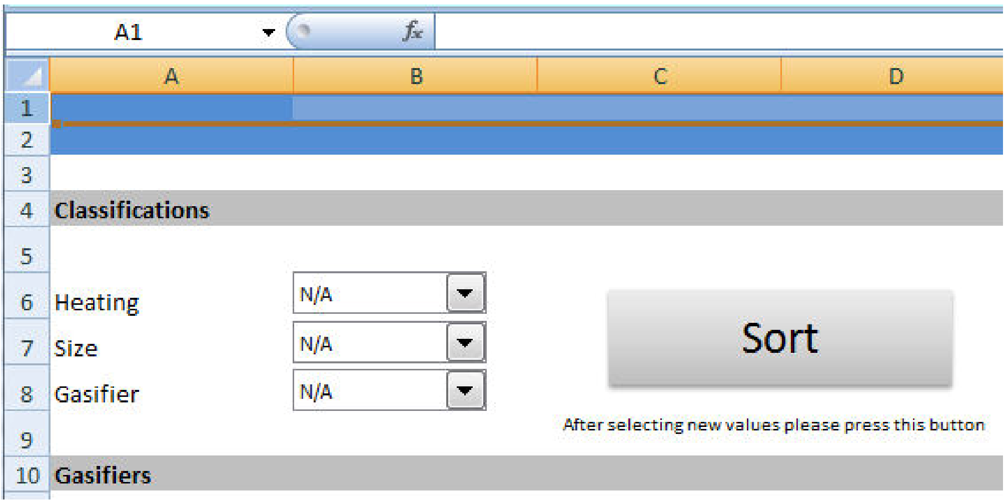

Figure 11 The index tab with the "sort" button.

When the button has been pressed, a list of the gasifiers matching the search criteria will be presented and by clicking the names on the list, the information of each gasifier will be accessed. Individual tabs for each gasifier are present in the database or Excel file in which each gasifier project is described including size, technology type, gas compositions etc.

4 Conclusions

The current database contains one or more gasifiers within the different gasification technology types normally discussed in this context:

- Fixed bed
- Fluidised bed
- Entrained flow

It also contains gasifiers in the range from 100 kW to 120 MW, with several gasifiers in-between these two values. Finally, there are gasifiers representing both direct and indirect heating. This allows for a more qualified and better available choice of starting data sets for simulations. In addition to this, with multiple data sets available for several of the operating modes, sensitivity analysis of various inputs will improve simulations performed.

However, there have been fewer answers to the survey than expected/hoped for, which could have improved the database further. However, the use of online sources and other public information has to some extent counterbalanced the low response frequency of the survey.

In addition to that, the database is preferred to be a living document, continuously updated with new gasifiers and improved information on existing gasifiers. The survey is appended to this report and any company/gasification operator can fill it out and submit it to:

info@sgc.se

or

Swedish Gas Centre AB
Scheelegatan 3
SE-212 28 Malmö
SWEDEN

And the information will be entered into the database and a new version uploaded to the SGC-website.

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Appendix

Gasifier
Bioliq/LURGI
Bioneer (VTT)
Carbona
Chalmers
CHEMREC
CHOREN
Cortus WoodRoll®
Enerkem
FERCO/Silvagas (Rentech)
FIFCB Güssing
Foster-Wheeler
HoST
Lahti
MEVA
MILENA
Mälarenergi
Nexterra
PYROFORCE®
Rentech-Silvagas
Research Triangle Inst
Skive
The University of Utah
ThermoChem/MTCI
TPS
Viking
Värnamo
Värö (Metso)
Vølund
Xylowatt
DTU

Gasifier Database for Computer Simulations

May the 27th, 2010

Dear Sir or Madame,

In cooperation with the Swedish Gas Centre (SGC), Nordlight aim to develop a wider base of knowledge in the area of gasification and its neighboring processes by creating a Gasification Database. This should include information about energy and mass balances etc for different types of gasifiers. It will be used as a database for research within the field and targets to be of great support for computer-based simulations especially. Much of the time in these projects are today spent on gathering reliable data and through this project we will aid researchers so that more knowledge can be created at a longer term.

The result will be made available online as an MS Excel® sheet. The exact URL for this will be published when the work is completed.

We are kindly asking you to participate in this study by supplying us with specified information about your gasifier system. Attached, you will find a list of key data, which we please ask you to fill out and return to us as soon as possible, but preferably at the latest on June the 18th, 2010.

For questions, please contact me through the contact information provided below.

Best regards,

Jens Hansson

Nordlight AB

Direct tel & sms: +46 73 396 93 60
E-mail: jens.hansson@nordlight.com
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Visiting address: Norra Fiskehamnen, Limhamn, Sweden

The assignment of **SGC** is to co-ordinate Swedish industrial interest in R&D concerning gas fuel technology. This is done on a "non profit"-base. The Swedish government represented by Swedish Energy Agency participates in financing the R&D-program. SGC was established in 1990 and is owned by E.ON Gas Sverige AB, E.ON Sverige AB, Göteborg Energi AB, Lunds Energikoncernen AB, Öresundskraft AB and The Swedish Gas Association. SGC has a staff of 6 and an annual turnover of approximately 2,2 MEuro.

Nordlight is a R&D based company focusing on biomass gasification technology. Prior and present work covers pulp and paper mill process integration, where forest raw materials are utilised in novel processes to produce green chemicals and biofuels.

Gasifier System Questionnaire

Name of Gasifier/Project ______________________

Developing Company(s)/Institute(s) ____

Background/History ____

____

Technology Description ____

____

Future Plans ____

____

Applications ____

____

Process Maturity and Scale______________________ (e.g. Pilot, Demonstration or Commercial)

Operating Hours: ______________

Please circle or underline your alternative. Where number input is required, consider the units of choice suggestions.

Heating	Direct	Indirect		
Gasifier type	No Bed Material	Fixed Bed	Bubbling Fluid Bed	Circulating Fluid Bed
Type of bed material	Sand	Dolomite	Olivine	Other, ___________
Gas flow direction	Up-draft	Down-draft	Cross-draft	Other, ___________
Operating Pressure	Atmospheric		Pressurised, ___ bar (g)	
Operating Temperature	_____ °C			

Upstream Supporting Equipment ____

Downstream Supporting Equipment ____

Gasifier Input

Feedstock	Woody biomass	Coal	Other, __________
Moisture Content	_____ %		
Approximate Size	_____ ____		
Energy Content, LHV	_____ kJ/kg		
Input Rate	_____ kg/s		
Input Rate Oxidant(s)			
Oxygen input	_____ kg/s		
Air input	_____ kg/s		
Steam	_____ kg/s of pressure _____ and temperature _____		
Other, ___________	_____ kg/s corresponding to ____ kg/s pure oxygen or ___% pure oxygen		
Power Input	_____ kW		

Gasifier Output

Outlet Gas Composition
(Composition preferably in mass% on wet basis - if dry basis is used, please specify the water content in the outlet gas below.)

	Range	Typical	
H_2	_________%	____ %	
CO	_________%	____ %	
CO_2	_________%	____ %	
CH_4	_________%	____ %	
C_2H_4	_________%	____ %	
C_2H_6	_________%	____ %	
C_3H_8	_________%	____ %	
C_{4+}	_________%	____ %	
H_2O	_________%	____ %	
N_2	_________%	____ %	
other ____	_________%	____ %	(Others could include tar content, naphthalene, benzene, H_2S, NH_3, alkali etc)
other ____	_________%	____ %	
other ____	_________%	____ %	
other ____	_________%	____ %	

Water content ____ (mass%, kg/s or vol%) *if composition on dry basis is used above*

Outlet gas (LHV) lower heating value _____kJ/kg
Outlet gas temperature _____ °C
Outlet gas pressure _____ bar (g) *or the unit of your preference*
Mass/volume flow _____ kg/s or Nm^3/s
Product efficiency = LHV_{prod}/LHV_{in} _____

Bottom Ash Flow ____ kg/s
Fly Ash in Product Stream ____ kg/s or ____ mg/m^3

Further comments ____

____

____

Your contact information, for possible further questions and follow-up and to send the final report:

Name ________________________________

E-mail address ________________________________

Telephone ________________________________

Thank you for your contribution towards a sustainable future!

Svenskt Gastekniskt Center AB

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www.sgc.se ● info@sgc.se