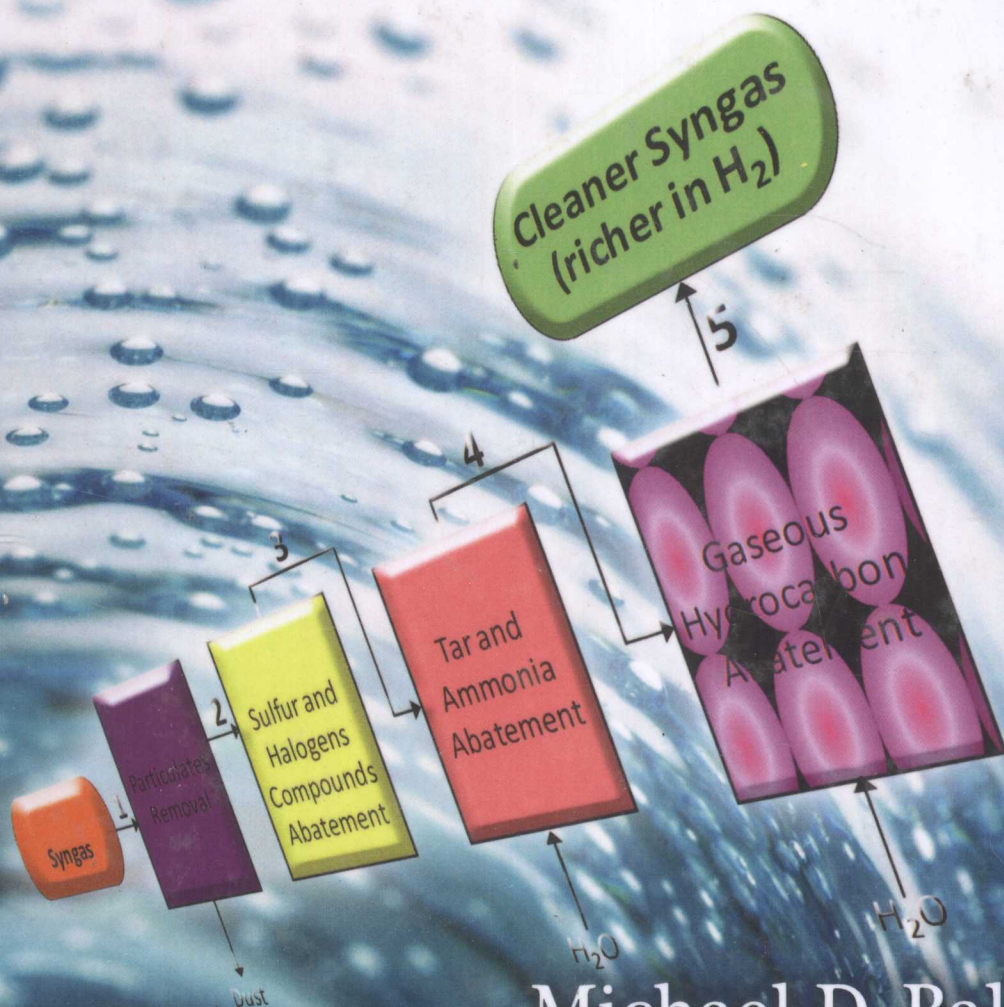


Gasification

Chemistry, Processes and Applications



Michael D. Baker
Editor

Energy Science, Engineering and Technology

NOVA

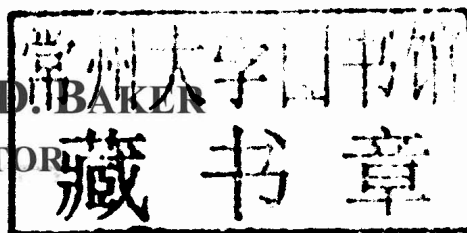
ENERGY SCIENCE, ENGINEERING AND TECHNOLOGY

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AND APPLICATIONS

MICHAEL D. BAKER

EDITOR



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New York

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GASIFICATION

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PREFACE

This new book presents current research in the study of the chemistry, processes and application of gasification processes. Topics discussed include experimental activities in a flexible gasification pilot plant; water gas shift and membrane reactor studies for the production of a hydrogen-rich stream in steam-oxygen gasification processes; the development of a dynamic model for a stratified downdraft wood gasifier; gasification of biomass for the production of syngas with reduced tar formation; the System Biomass Gasifier and its operation and the study of the catalytic effect of magnetite in the gasification of chars from lignite/rubber mixtures

Chapter 1 - World's energy demand is expected to continue to grow at large scale in emerging economies, due to the increase of world population and also due to increasing claims for high life quality. Though, in developed countries the rise of energy demands are predicted to grow at much lower levels, world's carbon dioxide (CO₂) emissions are expected to grow at an extent that may put in danger 'life as we know it.' Therefore, it is urgent to develop, demonstrate and implement alternative fuels sources and cleaner energy production technologies. It is predictable that developing countries, like China and India will increase the utilization of coal for energy production, thus the implementation of clean coal technologies, especially carbon capture and storage (CCS) are most needed.

Gasification is considered as a pre-combustion capture process, as by this process fuel is converted into syngas, which is afterwards converted into CO₂ and H₂. Thus, a H₂ rich fuel and free of carbon is produced while simultaneously CO₂ is captured producing a stream ready for storage. Gasification operating conditions may be optimized with the aim of reducing CO₂ emissions, while maintaining the heating value and the quality of syngas produced. Several materials with CO₂ capture ability may be added to the gasification bed to study their action. Another option is the use of oxygen instead of air producing a syngas without the dilution effect of nitrogen, which also simplifies CO₂ separation process.

The main challenges of current research work are to achieve high conversion of low grade coals and different types of wastes into syngas, with low contents of undesirable components, to simplify and decrease the cost of syngas cleaning and upgrading processes. Another important issue is syngas conversion into H₂ and the development of effective H₂ separation processes, which are both technically and economically viable. However, before these processes are ready to be implemented at industrial scale, further research and development activities are still needed and the demonstration at large scale of the known processes is fundamental. The integration of technologies under development in IGCC

(Integrated Gasification Combined Cycle) will be the main focus of the near future R, D&D (Research, Development & Deployment), as IGCC has high energy conversion efficiency.

This Chapter reviews the latest achievements in gasification processes and syngas cleaning and upgrading processes to produce a syngas with a wide range of applications, including effective H_2 separation processes to produce H_2 rich fuel and CO_2 capture. The stage of development of these subjects and the R, D&D needs before the full integration of the most promising ones are also analyzed.

Chapter 2 - In the field of hydrogen production through coal gasification for distributed power generation, Sotacarbo, an Italian limited company which operates in the field of clean coal technologies, is developing different research and development projects for the tuning of a coal-to-hydrogen process configuration. Toward this goal, a flexible pilot platform was built in 2007-2008, and it is currently in operation. In particular, the platform includes demonstrative and pilot air-blown fixed-bed gasifiers, the latter equipped with a flexible syngas treatment line for a combined power generation and CO_2 -free hydrogen production.

This chapter presents a detailed description of all the experimental equipment and the main results obtained during the first 700 hours of tests in the pilot unit. In particular, the optimum operating conditions with a low sulphur South African coal have been defined, with a syngas production of about $43 \text{ Nm}^3/\text{h}$ (from the gasification of 8 kg/h of coal), characterized by a lower heating value of 4.5 MJ/kg , and a high cold gas efficiency, of about 97%.

A series of experimental tests has also been carried out in order to assess the plant performance under different operating conditions and the effects of the main parameters, such as air/fuel and steam/fuel mass ratios and oxidant composition (air, eventually enriched in oxygen, or mixtures of oxygen and carbon dioxide). Moreover, a series of preliminary tests has been carried out in order to evaluate the gasification performance with a portion of high sulphur Sulcis coal or biomass (wood pellets) in the fuel blend.

The experimental results obtained in syngas treatment processes show a very efficient removal of pollutants (in particular, a final concentration of sulphur compounds lower than 10 ppm, in volume, can be obtained, even with high sulphur coal in the fuel blend) and the possibility to reduce carbon dioxide emissions of about 90% by using a single-stage amine-based carbon capture system, which assures a CO_2 absorption efficiency of about 99%.

Finally, the guidelines of the future research activities are described in this chapter, with particular reference to the further optimization of both gasification and syngas treatment processes in different operating conditions

Chapter 3 - Gasification of different types of fuels with steam and oxygen produces a synthesis gas (syngas) which consists mainly of CO , H_2 , CO_2 and H_2O . Depending on the fuel and the operating conditions, the contents of CO and H_2 in the syngas usually range from 35 % to 55 % and from 20 % to 45 % respectively. If higher hydrogen contents are desired, the Water Gas Shift (WGS) reaction allows the conversion of CO to H_2 and CO_2 in presence of excess steam and a specific catalyst. This reaction is industrially carried out in two consecutive stages, first a high-temperature step for rapid CO conversion and then a low-temperature step for achievement of lower equilibrium CO contents.

A novel approach which is being investigated to increase the production of hydrogen in gasification processes is the use of a Water Gas Shift (WGS) membrane reactor in which a single high-temperature WGS catalyst is combined with a hydrogen selective membrane. In this system, the removal of hydrogen from the reaction chamber through the membrane drives the WGS reaction to the products side and thermodynamic equilibrium can be exceeded.

Catalyst and membrane must be carefully chosen and special attention must be paid to operating conditions in order to guarantee the correct performance of the system. In this work the performance of semi-commercial palladium membranes and two different high temperature WGS catalysts are described and the advantages of using a WGS membrane reactor for the production of H_2 in gasification processes versus a conventional WGS reactor are presented.

Chapter 4 - Gasification of different types of fuels with steam and oxygen produces a synthesis gas (syngas) which consists mainly of CO , H_2 , CO_2 and H_2O . Depending on the fuel and the operating conditions, the contents of CO and H_2 in the syngas usually range from 35 % to 55 % and from 20 % to 45 % respectively. If higher hydrogen contents are desired, the Water Gas Shift (WGS) reaction allows the conversion of CO to H_2 and CO_2 in presence of excess steam and a specific catalyst. This reaction is industrially carried out in two consecutive stages, first a high-temperature step for rapid CO conversion and then a low-temperature step for achievement of lower equilibrium CO contents.

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Chapter 5 - This paper describes the development and the predictions of a dynamic model for a stratified downdraft wood gasifier. The numerical model, which incorporates a two-step pyrolysis mechanism, uses mass and energy balances, together with information about rates of chemical reactions and physical transport processes, to describe the complex physical and chemical processes taking place in the gasifier. The model is capable of predicting the gas composition, primary and secondary tar contents, and gas and solid surface temperature profiles along the axis of the gasifier. The model predicts an outlet gas tar content of between 20 and 200 mg/Nm^3 for the range of input parameters used in the model simulation, assuming that prior to ignition the section of the gasifier below the ignition ports contains charcoal rather than wood. The stability of the reaction zones was also investigated and for stable operation it was found that the mass flux of supplied air needed to be in the range 0.158-0.167 kg/m^2s .

Chapter 6 - An analysis was carried out to determine the sensitivity of a dynamic model developed for a stratified downdraft wood gasifier to changes in input parameter values. The sensitivity of the model to small increments and decrements in three operating parameters and eight model parameters was investigated. The results show that a higher air supply rate increases the combustion zone temperature and reduces outlet tar levels. Changes of $\pm 20\%$ in air supply rate, initial particle diameter and solid-to-gas heat transfer coefficient led to changes in predicted reaction zone velocity of more than 50%. The final mass of condensable tars in the producer gas was predicted to change by more than 300% as a result of 20%

changes in the values of the following model parameters: solid-to-gas heat transfer coefficient, mass transfer coefficient and tar cracking reaction rates.

Chapter 7 - A pilot-scale downdraft gasifier was designed, fabricated and tested. The experimental data obtained from it were compared with the predictions of a dynamic model the development and analysis of which are described in previous papers. River red gum (*Eucalyptus camaldulensis*) wood blocks of two different sizes were used as gasifier feedstock. The gasifier was operated at inlet airflow rates of 7.5 to 27.6 kg/hr, with corresponding energy outputs ranging from 54 to 168 MJ/hr. An average cold gas efficiency of 70% was obtained. Two modes of operation were used. In the first mode, the section of the gasifier below the ignition port was filled with charcoal prior to start up and the remainder of the gasifier filled with wood; in the second mode, no initial charge of charcoal was used. Operating the reactor with wood fuel alone produced an outlet gas with a final tar content that was around 20 times higher than the average tar content values in gas produced when using an initial charge of charcoal. Transient temperature profiles, outlet gas compositions, and outlet tar contents predicted by the model were in generally good agreement with experimental values. However, the model predicted a more rapid increase in concentrations of H_2 and CO along the gasifier axis than was observed experimentally. There was good agreement between the predicted and experimentally observed rates and directions of reaction zone movement within the gasifier over the range of inlet airflow rates studied.

Chapter 8 - Among all the biomass conversion technologies, gasification has attracted increasing research interest in recent decades, as biomass gasification combined with gas turbine, internal combustion engines and gas burners has great potential for large-scale green power generation (through IGCC, integrated gasification combine cycle) at higher efficiencies than the conventional pulverized coal-fired power generation. Gasification of biomass can be achieved by partial oxidation of the feedstock using air, O_2 and steam or CO_2 , producing a low to medium-BTU syngas gas (4-15 MJ/Nm³), consisting primarily of CO , H_2 , CH_4 , CO_2 and trace higher hydrocarbons (C_2+C_3). However, a major challenge for biomass gasification is the high yields of tars that are composed mainly of aromatics and complex poly-aromatic hydrocarbons (PAHs). In an air-blown fluidized bed gasifier for instance, typical tar contents in the producer gas are between 0.5 to 100 g/m³. For many applications, with the exception of direct and immediate syngas combustion for heat or electricity production, these tar levels must be reduced, often to below 50 mg/m³. Tars can have significant negative effects on gasification with respect to efficiency and operation. Specifically, the production of tars instead of combustible gases reduces the gasification efficiency, and condensation and deposition of tars at temperatures below 350°C can lead to fouling and potential blockage of downstream equipment and piping. Although the biomass-derived syngas with tar can be effectively cleaned up with the wet scrubbing technology, hot gas clean-up technology, preferably employing using catalysts, to remove these contaminants at the "hot" state is advantageous with respect to energy efficiencies as it eliminates the need to cool the product gas and re-heat again for the syngas applications (internal combustion, gas engines, fuel cells and methanol synthesis, etc.). The hydrocarbons and tars formed during the gasification process could be removed/suppressed at a hot state through steam/dry reforming or cracking/hydro-cracking reactions using catalysts. This chapter overviews various biomass gasification technologies and tar formation during gasification, tar reduction technologies, and catalysts for biomass gasification and tar reduction.

Chapter 9 - Among alternative energy resources, biomass, such as wood wastes and sewage sludge, and waste plastics are very attractive due to its abundance, accessibility, and ease of use. The conversion of lignocellulosic biomass or waste plastics to a fuel or chemicals usually can take place with thermo-chemical conversion technologies. Among the thermo-chemical conversion processes, gasification is a complex combination of pyrolysis and oxidation reactions in the condensed and vapor phases. Under typical gasification conditions, oxygen levels are restricted to less than 30 % of that required for complete combustion. Gasification converts biomass or waste plastics to a uniform gaseous mixture that mainly comprises H_2 , CO , and CH_4 . The gaseous mixture is called producer gas. Producer gas can be used to run internal combustion engines to generate electricity, can be used as substitute for fuel oils in direct heat applications and can be used to produce chemicals which are useful as fuel, as well as chemical feedstock for industries.

Gasification itself is very old technology, which flourished during the 2nd world war. Today, there is renewed interest in the gasification, due to the increased petroleum prices. The main advantage of gasification lies in that it is decentralized conversion system which can be operated even in a small scale.

In Korea, an average of 5 million tons/yr of wood waste is being generated of late, much of which has been treated simply through incineration and recycling, such as into wood pellets for boiler fuel. Therefore, the need for more efficient treatment of wood wastes has recently gained strong national recognition.

Meanwhile, plastics are widely used in everyday life, as well as in high-tech industries, as an indispensable ingredient. Consequently, the amount of waste plastics has also increased. Therefore, there is a growing need for waste plastics management. The traditional ways for the disposal of waste plastics have been either to bury it in landfills, or to burn it in incinerators. Landfill and incineration, however, are associated with serious environmental problems. Therefore, there is an increasing need to utilize waste plastics environmental friendly and economically.

In this regard, the present work gives detailed experimental results of gasification of forest wood waste (FWW), construction wood waste (CWW), dried sewage sludge (DSS), and post-consumed mixed waste plastics (MPW) in a newly developed two-stage gasifier. The aim of the research is to directly reduce the tar yield in the gasifier and to produce a high caloric producer gas. In accordance with the aim, this article reports the development of a producer gas composition according to experimental conditions, such as the reactor temperatures and the equivalence ratio, the role of activated carbon in tar removal, and the chemical and thermal characteristics of the tar

Chapter 10 - The chapter presents a detailed description of the System Johansson Biomass Gasifier and its operation; it also deals with the factors influencing the efficiency of fixed bed biomass gasifier systems since the latter gasifier is a fixed bed type. Basically, the fuel is fed into the reactor where the gasification process takes place resulting in the formation of syngas. Syngas is channeled through a system of pipes to the downstream processes that consists mainly of the purification unit where it is cleaned of impurities such as fine carbon particles. The gas is then used to drive the engine that drives the generator and generates electricity. The gasifier is mainly used for electricity generation. A 150kVA pilot project aimed at improving the socio-economic status of a rural community has been implemented. The project aims to provide low-cost electricity to stimulate the establishment of small businesses in the area.

Chapter 11 - The utilization of waste rubber is still a topical issue. It is proven by a number of studies devoted to its treatment, especially thermal, to the process conditions, the products as well as a description of the behavior of this material in pyrolysis and gasification, and kinetics of reaction of the rubber char with CO_2 . A realistic solution could be the co-gasification of waste rubber with lignite in the Integrated Gasification Combined Cycle. Recent experiments on the laboratory but predominantly commercial scale have demonstrated that waste rubber can without any technological difficulties thus be gasified at a content of 10% in a gasified mixture, in the short term at 20%. Higher content however causes an increase in the unburned carbon, whose content in ash grows significantly with the rising share of rubber in the mixture, as demonstrated in Fig. 1. The reason is apparently the significant difference between the reactivities of the lignite and rubber chars in the gasification zone of the generator, where the reactivity of the rubber char is low in comparison with the reactivity of the lignite char. The removal of the negative phenomenon of the unburned carbon would contribute to the more effective treatment of waste rubber, avert the losses of energy inserted into the process, improve the quality of the ash for its further use and facilitate the maintenance of the surface of the disposal site of the generator ash. From the environmental perspective, the possibility to treat greater volumes of waste rubber (e.g. waste-tire) than before is significant, whereas from the economic perspective it is important to avert energy losses. The author's operational experiments on the Lurgi gasifiers (Sokolov Coal A.S., Czech Rep.) have shown that if the content of the unburned carbon in the generator ash is for example 10.5%, then the loss of energy is 1.26% of the higher heating value introduced in the system at the input of the generator and that at a content of unburned carbon of 28.4% is already 4.39%, which are high to extreme losses. The question thus is how to lower the unburned carbon at higher shares of rubber in the gasified mixtures to an acceptable level or to the level reached at the gasification of the lignite alone. A possible solution is to lower the size of the particles of the treated rubber, e.g. from 40 mm to 15-20 mm (in the moving-bed gasifiers), and thus to increase the surface of the gasified particles, but this solution is not essential.

Another approach is to find the effective catalyst of the gasification reaction. Alkali metal salts, especially potassium salts, including those presented in a high content potassium biomass, are considered as effective catalysts for gasification by steam and CO_2 . The most recently tested catalyst requires coal modified by a solvent extraction (HyperCoal), because this catalyst reacts with the mineral components of the coal. It is, however, an unfeasible variant for the given case. According to the authors experience with the Lurgi gasification process, it is possible to consider iron-based catalysts, which are effective, available and industrially used. For the authors experiments as model Fe catalyst a finely ground magnetite was selected for the laboratory tests. The experiments were conceived so that the chars from lignite and rubber without magnetite and with magnetite were prepared first in a rotary kiln. The comparative chars from rubber alone, lignite/polymers, lignite/celluloses and lignite/wood mixtures, and lignite alone were prepared in a similar way. They served for the comparison of their reactivity with the reactivity of the lignite/rubber chars and further for the more general determination of the impact of magnetite on the rate of the gasification reactions. The prepared materials were then gasified by steam and CO_2 and the rates of gasification measured at isothermal conditions. With lignite/rubber chars, the effective activation energy and pre-exponential factor of the gasifying reaction with CO_2 were further

evaluated using non-isothermal isoconversional kinetics, and these parameters were compared for the samples with and without magnetite.

The objective of the treatise is to describe the effect of magnetite on the rate of the gasification of the chars from the mixture of lignite and rubber, compare it with the effect determined with comparative chars and explain the impact of magnetite on the basis of non-isothermal isoconversional kinetics.

Chapter 12 - Carbon, slag chemistry, temperature, and partial pressure of oxygen affect material reactions in a gasification chamber. Corresponding thermodynamic parameters are critical as they determine the types of crystals that form in slags, weight fractions of the phases, and corrosive interactions between slags and refractory materials. The crystal formation then effectively changes physical characteristics of slags, impacting slag viscosity. In order to study interactions between slags and refractory materials, it is important to assess thermodynamic data for the slags and the timing of crystal formation as opposed to slag residence time in the gasification chamber. The current study focuses on the thermodynamic analysis of impurities contained in carbon feedstock used in gasification, its kinetic behavior, and the effects of carbon feedstock chemistry on the degradation of gasifier refractory materials. Utilizing qualitative and quantitative techniques (XRD, SEM-EDX/WDX, TEM-EDX and ICP-OES); a thermodynamic phase diagram encompassing industrial slags based upon coal/petcoke ash mixture compositions was constructed using equilibration conditions obtained in samples after 72 hours of exposure at 1500 °C in an atmosphere of 64%CO/36%CO₂. This CO/CO₂ ratio corresponded to a simulated gasification environment of $P_{O_2} = 10^{-8}$ atm. Mullite crystal was found in Al₂O₃ rich slags, while V₂O₃ crystal was present in slags with high V₂O₃ (content corresponding to slags with high petcoke content). No crystalline phases were observed in SiO₂ rich slags at low V₂O₃ content (slag with high content of coal ash).

The formation kinetics of crystals in coal/petcoke slags was also studied from 1200 – 1700 °C in an atmosphere of 64%CO/36%CO₂, and a Time-Temperature-Transformation diagram constructed. This diagram exhibited two distinct crystallization events; with higher than 10 wt.% additions of petcoke slag to coal slag promoting V₂O₃ crystallization in the slag above 1350 °C, and with additional crystalline phases such as V-rich spinel forming at temperatures lower than 1350 °C. Experimental results indicated that the V₂O₃ crystal would form in the slag as fast as 35 seconds.

Finally, an evaluation of the interfacial reactions between synthetic slags (average coal and petcoke slag chemistry) and refractory materials (90 wt.% Cr₂O₃ – 10 wt.% Al₂O₃ and 100 wt.% Al₂O₃) was conducted utilizing a Confocal Scanning Laser Microscope. Ground slag samples at specific locations on refractory coupons were heated at 1500 °C in a 64%CO/36%CO₂ gas mixture using a gold-image heating chamber. Characterization of the slag/refractory interface by the SEM-EDX indicated that slag penetration occurred into porous areas of the refractory microstructure, and that refractory dissolution into slag occurred through the refractory surface and in the porous areas penetrated by slag, which promoted de-bonding of refractory material. It was noted that VO_x-containing crystalline phases precipitated at the slag/refractory interface in coal/petcoke slag mixtures. Chemical spalling of the Cr-containing refractory grains along with chemical dissolution of the grain in the slag facilitated surface degradation of the refractory.

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Chapter 1

**ANALYSIS OF GASIFICATION VIABILITY AS A
PRE-COMBUSTION CCS OPTION,
VIA THE PRODUCTION OF A H₂ RICH FUEL
WITH CO₂ CAPTURE**

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ABSTRACT

World's energy demand is expected to continue to grow at large scale in emerging economies, due to the increase of world population and also due to increasing claims for high life quality. Though, in developed countries the rise of energy demands are predicted to grow at much lower levels, world's carbon dioxide (CO₂) emissions are expected to grow at an extent that may put in danger life as we know it. Therefore, it is urgent to develop, demonstrate and implement alternative fuels sources and cleaner energy production technologies. It is predictable that developing countries, like China and India will increase the utilization of coal for energy production, thus the implementation of clean coal technologies, especially carbon capture and storage (CCS) are most needed.

Gasification is considered as a pre-combustion capture process, as by this process fuel is converted into syngas, which is afterwards converted into CO₂ and H₂. Thus, a H₂ rich fuel and free of carbon is produced while simultaneously CO₂ is captured producing a stream ready for storage. Gasification operating conditions may be optimized with the aim of reducing CO₂ emissions, while maintaining the heating value and the quality of syngas produced. Several materials with CO₂ capture ability may be added to the gasification bed to study their action. Another option is the use of oxygen instead of air producing a syngas without the dilution effect of nitrogen, which also simplifies CO₂ separation process.

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The main challenges of current research work are to achieve high conversion of low grade coals and different types of wastes into syngas, with low contents of undesirable components, to simplify and decrease the cost of syngas cleaning and upgrading processes. Another important issue is syngas conversion into H_2 and the development of effective H_2 separation processes, which are both technically and economically viable. However, before these processes are ready to be implemented at industrial scale, further research and development activities are still needed and the demonstration at large scale of the known processes is fundamental. The integration of technologies under development in IGCC (Integrated Gasification Combined Cycle) will be the main focus of the near future R, D&D (Research, Development & Deployment), as IGCC has high energy conversion efficiency.

This Chapter reviews the latest achievements in gasification processes and syngas cleaning and upgrading processes to produce a syngas with a wide range of applications, including effective H_2 separation processes to produce H_2 rich fuel and CO_2 capture. The stage of development of these subjects and the R, D&D needs before the full integration of the most promising ones are also analyzed.

Keywords: pre-combustion CCS, gasification, hot syngas cleaning, steam reforming, water gas shift (WGS) reaction, membrane H_2 separation, chemical looping (CL).

1. INTRODUCTION - THE ROLE OF SYNGAS TOWARDS ZET

International Energy Agency (IEA) predicts that the world's energy demand will continue to grow, between 2005 and 2030 by about 55% (IEA, 2009), due to the growth of world population and also because of increasing demand for greater life quality, especially in developing countries, like China and India. Consequently, carbon dioxide (CO_2) emissions will continue to grow, especially in emerging economies, whose contributions to CO_2 release is predicted to increase from 39%, in 2005, to over 50%, in 2030 (IEA, 2009). If the right measures are not taken, CO_2 emissions from energy sector will be, in 2050, around 130% higher than those verified in 2005 (IEA, 2008). Due to the negative consequences in climate change and in worldwide economics, CO_2 emissions from energy production have to be reduced. Hence, clean coal technologies, particularly carbon capture storage (CCS) are most needed, especially in countries where coal use is growing faster.

Pre-combustion capture or gasification is a possible option to capture carbon from the fuel before combustion and to produce a hydrogen rich fuel and a CO_2 stream for storage. Moreover oxy-gasification uses oxygen instead of air to produce a syngas without the dilution effect of nitrogen, which also simplifies CO_2 separation process. Some research gasification studies have been concentrated in developing gasification processes with lower CO_2 emissions, either by optimizing gasification conditions, such as gasification temperature, gasifying agent type and composition, especially the ratios between gasifying agents and solid fuel. Another option consists of adding to the gasification bed CO_2 capture materials.

The production of syngas without or with minor contents of undesirable compounds, like tar, NH_3 , H_2S and HCl , is one of the great challenges of nowadays gasification processes, especially when low grade coals or wastes are co-gasified. The need of using alternative fuels to decrease the dependency on imported oil has led several countries to study the possibility of using poor quality fuels and wastes, which has imposed new challenges to co-gasification

and syngas cleaning processes. The most recent issue is the development of effective syngas cleaning processes to remove undesirable compounds and to produce a syngas with a wide range of end-uses.

Syngas produced from coal and natural gas may be converted into transportation fuels, through chemical synthesis by Sasol and Mobil processes. Another possibility is the production of syngas from biomass wastes, but the use of wastes that may contain undesirable elements will require an improvement of clean-up processes. The European Union has encouraged the production and use of biofuels in transportation sector and has been financing research project in these areas, which has motivated R&D (Research and Development) activities.

After syngas cleaning and improvement processes, its main components are CO , H_2 and CO_2 . CO can be converted into H_2 and CO_2 , by water gas shift (WGS) reaction. Although WGS reaction is a well known process, nowadays researchers have the challenge of applying known processes to syngas with different origins that consequently, may have adverse components. Another area of interest is the development of new catalysts that may increase WGS reaction conversion at milder conditions of temperature and pressure and with lower cost catalysts. Due to the potentialities of WGS reaction to achieve CO_2 capture, a huge amount of publications have appeared lately, reporting the performance of new catalysts.

Another challenge of current gasification processes studies is to achieve high conversion of syngas into CO_2 and H_2 and to develop an effective H_2 separation processes, both technically and economically viable. Hence, a H_2 rich stream is produced, while a CO_2 flow may go to storage. Consequently, coal and different types of wastes may be converted into H_2 , through gasification and syngas, thus these technologies may be considered as ZET (zero emissions technologies).

H_2 demand has increased, due to its industrial utilization and also due to its potentialities for energy production, either through combustion or as raw material in fuel cells. Therefore many researchers have concentrated their efforts in developing and testing new membranes for pure hydrogen production with high efficiencies. In this chapter the main developments in this area are reviewed. The integration of these technologies under development in IGCC (Integrated Gasification Combined Cycle) will be the main focus of the near future R, D&D (Research, Development & Deployment), as IGCC has high energy conversion efficiency.

The cost of power generation with CCS is higher than those of existing processes, when CO_2 is not captured. Hence, today's challenge is the development of processes that are less energy demanding and with lower costs. Thus, a great effort has been done in improving chemical looping processes and many researchers have focused their activities in applying the chemical looping process to gasification and CO_2 capture. This issue is also analyzed in this chapter.

One easier way of achieving CO_2 emission reduction is by increasing biomass use as fuels to enlarge biomass contribution to world's energy production. Biomass co-gasification technologies may play an important role in the future, due to their capacity to convert biomass waste into bioenergy and biofuels. Many researchers have stated the potentialities of gasification process and some developed technologies have been tested proved in operating industrial installations. However, more research is still needed in this area and mainly the demonstration of some of the developed processes at large scale is much required.