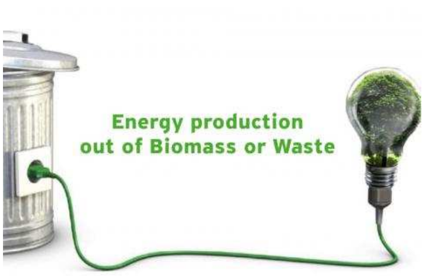
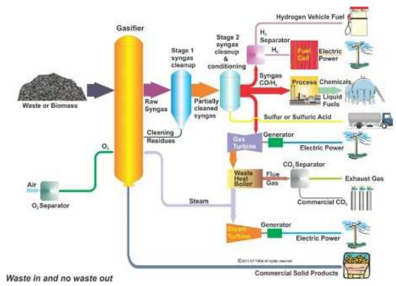
Doctoral Program in Energy, Chemical and Environmental Engineering

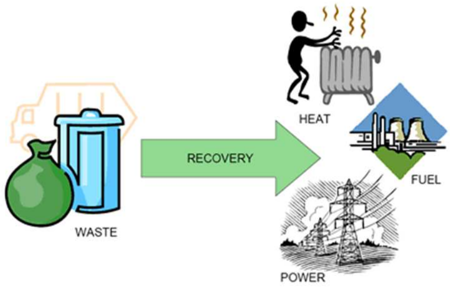
Workshop on conversion and utilization of biomass and wastes

(Seville, 28 November 2018)

Organization: Chemical and Environmental Engineering Department, University of Seville
Chair: Alberto Gómez-Barea (agomezbarea@us.es),
Secretar: Israel Pardo (rpardo@us.es)
Web: http://institucional.us.es/docenequiamb/
Venue: Sala Larrañeta (planta ático), Escuela Técnica Superior de Ingenieros, Sevilla. Camino de los Descubrimientos S/N. Sevilla, SPAIN (ETSI)







Summary

Reputed experts on outstanding topics in the field will give keynotes/lectures. The course is oriented for PhD students and young researchers willing to share their project results in a friendlier environment than conventional conferences. Some of the PhD students dealing with activities related to the conference topic will give an oral presentation and participate in the discussion.

There is no workshop fee (social activities not included).

** Jornadas celebradas dentro de las actividades de apoyo a la formación doctoral en el programa de doctorado de Ingeniería Energética Química y Ambiental de la US (+info: http://institucional.us.es/docenequiamb/index.php)*

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AGENDA

Wednesday 28th November	
9:00 - 9:05	**Welcome** Alberto Gómez Barea *Coordinator of Doctoral Program in Energy, Chemical and Environmental Engineering at University of Seville*
9:05 - 10:05	**Keynote 1** ***Fluidized bed conversion of waste: its possibilities for energy production*** Bo Leckner *Chalmers University of Technology, Sweden*
10:05 - 11:05	**Keynote 2** ***Agglomeration during fluidized bed combustion of biomass and waste, and sintering in CO2 capture units*** Fabrizio Scala *University of Naples*
11:05 - 11:35	Break
11:35 - 12:35	**Keynote 3** ***Liquid fuels production based on HTL*** Konstantinos Anastasakis *Aarhus University*
12:35 - 13:35	**Keynote 4** ***DME as a potential enabler for innovative concepts of solar-assisted gasification-based biorefineries*** Pedro Haro *University of Seville*
13:35 - 15:00	Lunch Break
15:00 - 16:00	**Keynote 5** ***Hydrogen production by biomass gasification assisted by solar energy*** Alberto Gómez Barea *University of Seville*
16:00 - 16:30	**Keynote 6** ***Characterization of contaminants in outlet streams of thermal processes and their valorization*** Vanessa Ferreira de Almeida *PhD student. University of Seville*
16:30 - 17:00	**Keynote 7** ***Transient model for biomass gasification in a fluidized bed: analysis of hot start-up and comparison with biomass combustion as backup system in CSP plants*** Montserrat Suárez Almeida *PhD student. University of Seville*

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FLUIDIZED BED CONVERSION OF WASTE: its possibilities for energy production

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It is not a simple task to make a generalised presentation on the conversion of municipal solid waste (MSW) and the possibilities of fluidized bed conversion (FBC) to recover energy from such waste. The presentation shows how the conditions change from time to time and from country to country. Besides, FBC is not at all important in available statistics over existing plants where grate firing dominates, and one finds gasification mostly in optimistic academic publications.

In the European Union Directives as well as in many local legislations, it is encouraged to extract as much useful energy as possible from MSW. This is a reasonably simple task if there is a demand for heat, because it is easy to produce heat in waste conversion plants. However, it is more difficult to produce electricity only; the danger for corrosion on steam tubes in a boiler limits the steam temperature, the upper temperature of a thermodynamic cycle, and the same reason for which there is no heating demand---a warm or hot climate --- affects the low-temperature level of the thermodynamic cycle, which is relatively high. These two temperature limitations reduce the efficiency of electric power production. The presentation discusses a number of ways to improve this situation and to increase the efficiency of electric power production, valid for FBC, but also, in most cases, for grate fired boilers. In some cases, gasification, mostly two-step oxidation, offers advantages, leading to considerably increased efficiencies. However, there are fuel restrictions: gasification requires an even flow of well-defined, dried fuel (Solid Recovered Fuel or Refuse Derived Fuel), while for FBC boilers, shredding and removal of metals and heavy objects (glass) is sufficient. For a grate-fired furnace, on the other hand, there is no need for fuel treatment, and this makes the waste destruction cheaper, although combustion is less controlled than in an FBC.

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Agglomeration during fluidized bed combustion of biomass and waste, and sintering in CO2 capture units

Fabrizio Scala

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Particle agglomeration in fluidized bed systems has been observed in several industrial processes. The most extensively reported case is concerned with the fluidized bed combustion of biomass and waste, containing significant amounts of low-melting compounds (typically alkali metals) in the ash. The occurrence of bed agglomeration in such systems implies the unscheduled shut down of the reactor and costly maintenance operations. This presentation tries to summarize the present status of understanding of the mechanisms leading to agglomeration, as well as the influence of the different operating variables on this phenomenon. In addition, because of their great practical importance, the possible early detection techniques and operational countermeasures are also briefly described.

A second temperature-related phenomenon, which has been typically reported in CO2 capture units using calcium-based sorbents (Calcium Looping, Sorption-Enhanced Gasification), is the decay of the sorbent carbon dioxide capture capacity due to particle sintering. This phenomenon, which the sorbent particles undergo especially during the high-temperature calcination stage, determines a continuous decrease of the sorbent pore area and reactivity, and modifies the mechanical properties of the particles. As a consequence, a make-up of fresh sorbent must be used to compensate for the purge of "spent" (deactivated) sorbent, implying higher process costs. The mechanisms, influence of operating variables, and possible countermeasures on sorbent sintering are here discussed.

Liquid fuels production based on HTL

Konstantinos Anastasakis

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A lot of attention has recently been put into foreground for scaling up hydrothermal liquefaction (HTL) reactors from batch–lab scale, to continuous-pilot scale. During the past 5 years, a number of research groups and private ventures around the world have developed and demonstrated a series of continuous HTL systems. However, there are still process challenges to overcome, such as slurry pumpability, energy efficiency, carbon conversion, product separation, etc. Aarhus University (AU) is in the unique position to have one of the most advanced HTL reactors currently running around the world. The reactor incorporates a patented oscillating flow technology leading to an increase in turbidity in the plug-flow reactor and hence to an increase in reaction rates and conversion. In addition, heat recoveries of over 80% are able to be achieved by the heat exchanger system. This study presents results and experiences from the Aarhus University pilot scale HTL reactor with a capacity of 100 L/h, during HTL of three different biomass feedstocks. Miscanthus, spirulina and sewage sludge were selected as model feedstocks to represent 2nd generation, 3rd generation and waste biomass feedstocks, respectively.

The selected feedstocks have different compositions and structures and were selected in order to demonstrate the versatility of HTL systems in handling different feedstocks. A special emphasis is given on the rector design and performance as well as on the utilization of sewage sludge in a wastewater treatment facilities context.

DME as a potential enabler for innovative concepts of solar-assisted gasification-based biorefineries

Pedro Haro

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Dimethyl ether (DME) has been subject of intense research in the last two decades. A number of advantages have been described for its use as fuel (substitute of natural gas –domestic use– and diesel –transportation– along with intermediate for synthetic gasoline production) and to a lesser extent as commodity for the chemical industry (olefins production). There are two approaches to produce DME from biomass/wastes, both cases involving the production of synthetic gas (syngas). The first approach (conventional and with a high TRL) involves the conversion of the syngas into methanol (fully commercial) and the dehydration of the methanol into DME (fully commercial). However, this approach offers poor flexibility for the production of the syngas and requires intense gas conditioning. Therefore, this approach has not been able to further development in the last decade (e.g. DME plant in Lulea). The second approach (with a low TRL) involves the synthesis of DME from syngas in a single reaction step. Despite the advantages of the approach, deactivation of the catalyst is fast and productivities are moderate. Reactor designs are based on trickle-bed devices, where strong heat and mass transfer limitations have been reported. Therefore, neither this approach has been developed much further than a few pilot plant experiences (e.g. Kingsport plant). Considering the integration of solar energy in a biorefinery, the experience gained in the single-step synthesis of DME offers an interesting opportunity. Even though solar-assisted gasification concepts are aimed to provide a constant syngas composition and flow, it is an advantage to have a reactor that can operate at a moderate flexibility. In addition, there is room for synergies in the integration of the biorefinery. This presentation aims to prompt a discussion on the role of DME as a target compound in designing new concepts of solar-assisted biorefineries.

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Hydrogen production by biomass gasification assisted by solar energy

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Presently hydrogen is produced from reformation of fossil fuels, and a renewable carbon-neutral energy source like biomass and solar energy are considered promising options. Steam gasification of biomass is a highly endothermic process and all the concepts proposed up to date are based on partial burning of the fuel.

It has been identified that allothermal steam gasification with the use of an external energy source is ideal to supply the energy requirements, but no feasible technological solutions have been found yet. At laboratory scale the heat is provided by external electrical heaters, and no feasible way has been found to scale up the prototypes developed. The use of solar energy could provide a feasible renewable heat source to the process but no methods have been found up to now to combine solar energy with steam gasification of biomass with upscaling capability.

Hydrogen from water splitting by thermochemical cycles are extremely attractive method to produce hydrogen but it needs very high-temperature solar energy and strong technical difficulties have been found to develop the process even at laboratory scale. In spite of the huge research effort made during last two decades, the process is still under very low stage of development and scaling up of these concepts are uncertain.

Hybridization of biomass/coal conversion and high-temperature solar energy has received attention in the last few years. The main concepts proposed have been based mainly in combustion systems assisted by solar energy. Despite the theoretical interest identified, no technological attempts have been tried to combine these two renewable sources to produce hydrogen with CO2 capture using solar energy.

In this presentation the mechanisms of biomass gasification with steam and published work to identify important experimental variables for optimizing H2 output are addressed. Challenges related to process operability are discussed, including sorbent durability and incomplete conversion of sorbent and fuel. Hydrogen from water splitting are briefly reviewed and several hybridization options to combine solar and biomass gasification are suggested. Finally, a new concept based on chemical looping gasification (CLG) using CaO-based sorbent assisted by concentrated solar radiation (CSR) is presented.

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Characterization of contaminants in outlet streams of thermal processes and their valorization

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The concern about the environment has increased considerably in the past few decades, changing our view on wastes management. Therefore, research has been focusing on wastes energy recovery, in an attempt of avoiding greenhouse gases (GHG) emissions and moving towards a circular economy. Pyrolysis, gasification and combustion are suitable technologies for the use of wastes as fuels, because they decrease solids volume, while producing a gas and/or liquid that can be used to generate thermal energy, electricity, fuels and/or chemicals. Waste-derived fuels usually contain higher amounts of Cl, S, N and inorganics than woody biomasses, which represents a challenge for this type of processes. Inorganics behavior under thermal conversion is of great interest since: (i) the downstream cleaning processes depends on the element amount in the fuel and its volatility, (ii) their concentration in the solid residue affects the residue final disposal/application and (iii) they may affect the process operation (i.e. due to sintering formation). Thus, inorganics are quantified both in the fuel and in the solid products. Temperature, atmosphere, reactor type and additives all influence the behavior of these elements during thermal conversion, and our research has been dedicated on determining inorganics partitioning under different conditions using waste-derived fuels. Nevertheless, elements volatilities may be hard to determine in fluidized bed (FB) tests, because the exact final mass of the solid residue is unknown. Therefore, a method was developed to estimate the solid residue mass during FB, enabling the calculation of elements volatilities. Furthermore, the results of inorganics partitioning under several conditions allow the prediction of these elements concentration in the solid residue. This way, it is possible to select the optimum technology and operation conditions for the solid residue utilization or disposal, considering the normative in force. In this presentation, the results of process conditions influence on inorganic elements partitioning from different fuels – Dried Sewage Sludge (DSS), Refuse-Derived Fuel (RDF) and wood – are discussed, as well as elements volatilities calculated using the above-mentioned method. Finally, the characteristics of pyrolysis/gasification/combustion solid residues and the relevant aspects for their application (i.e. as soil amendment) are reviewed.

Transient model for biomass gasification in a fluidized bed: analysis of hot start-up and comparison with biomass combustion as backup system in CSP plants

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Standalone Concentrating Solar Power (CSP) plants suffer from intermittent energy output due to day/night cycles and reduced irradiation periods during winter resulting in high economic penalties. Hybridization of CSP plants (with fossil fuels, biomass or even wind and geothermic) comes to solve this problem providing these systems with higher flexibility.
Although hybridization with natural gas (NG) has been the most common over the years, the global trend is in favor of renewable energies and to the detriment of hybridization with fossil fuels. Biomass is a renewable energy that can be easily stored and managed so it is considered as one of the most interesting technologies for hybridization.
Borges Termosolar (Lleida, Spain) is the first-of-its-kind CSP-Biomass power plant, having two dual (Biomass-NG) grate boilers integrated in the solar side. NG is burned as back-up fuel when wet biomass comes to the plant and during transient and boilers ramping up. It has been reported that 10 % out of the generated power comes from NG. Reduction of this share can be made by the implementation of biomass technologies with higher flexibility.
The use of biomass by generating a syngas in a fluidized bed (FB) followed by the syngas burning in a gas boiler is analyzed as a potential alternative to direct combustion. Particularly, the comparison of the flexibility of the two processes as backup solution to CSP-Biomass power plants is analyzed. This presentation outlines the overall results of the study made to compare both alternatives. Firs the results from a model developed to simulate the ramping up of a FB biomass gasifier is presented. The model predicts the time it takes to the system to reach the steady-state after the sunset, when the biomass unit is started-up to supply the gas to the boiler. Later the comparison with the option of direct burning of biomass in the boiler is made, assuming typical times of biomass furnaces.