### Black liquor and other biomass gasification and combustion (R&D at ETC)

Hassan Salman



## ETC, Piteå, Sweden



### **The ETC Bioenergy Laboratory**





## Key facts

- Independent non-profit research foundation (started in 1989)
- Founded by Piteå Municipality, Luleå University of Technology and the County Administrative Board of Norrbotten
- Formal ties with Luleå University of Technology (adjunct professorship and joint PhD students)
- Focus on bioenergy and biorefinery
- Both applied research (70%) <u>and</u> industrial problem solving and development {consulting} (30%)

## **Research areas at ETC**

- Black liquor gasification
  - CFD modelling
  - Atomisation and burner optimisation
  - Large scale experiments
- Biomass combustion
  - Particle emissions from combustion
  - Fuel characterisation
  - Equipment optimisation
- Biomass gasification
  - Cyclone gasification for CHP
  - Fixed bed for small scale applications
  - Entrained flow for syngas production
- Biorefinery processes
  - Catalytic conversion (syngas impurities, methanol, DME)
  - Lignin precipitation (with KIRAM and SmurfitKappa)
  - Bio-diesel from tall oil (together with Sunpine)
  - Pyrolysis oil (together with KIRAM)

## **Biorefinery research**

- Catalytic conversion of syngas
  - Methanol
  - DME
- Lignin precipitation from black liquor
- Biodiesel from tall oil
- Pyrolysis oil
- Hydrogen enrichment of syngas
  - Wind power and electrolysis

### The pulp mill of tomorrow is a bio-refinery

Part of the solution of the greenhouse problem Sustainable use of forest feed stocks with high added value



## **Direct biomass gasification**

#### • Enabling technology for:

- Combined heat and power production
- Synthetic fuels production

#### • Technologies at ETC:

- Fluidised bed gasification
- Cyclone gasification
- Fixed bed
- Entrained flow gasification
- Fuels:
  - Wood chips
  - Powder (wood, bagasse, etc.)

## Cyclon gasifier (500 kW)



Gas composition				
Component	Vol%			
H2	8,40			
N <sub>2</sub>	56,45			
СО	13,18			
CH <sub>4</sub>	5,48			
CO <sub>2</sub>	14,95			
C <sub>2</sub> H <sub>4</sub>	0,88			
C <sub>2</sub> H <sub>6</sub>	0,03			
$C_2H_2$	0,68			

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## Fluidised bed gasifier (5 kW)





# Ash agglomeration during slaughter wastes gasification





# Horisontal powder gasifier (150 KW)





## **Black liquor gasifier**



- Neighbor to Smurfit-Kappa Kraftliner pulp mill (Europe's largest)
- Built in the ETC laboratory, cost about 10 MUSD
- Owned and operated by Chemrec AB
- 3.5 MW thermal power (app. 1 ton black liquor/hour)



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# The Chemrec black-liquor gasifier (3500 kW)



## **Black liquor**

- By-product in pulp production
- Lignin (1/3), water (1/3), cooking chemicals and extractives (1/3)
- Can be pumped
- Heating value ~14 MJ/kg DS (Oil: ~42 MJ/kg)
- 40 TWh/year from Swedish pulp mills (corresponds to about 3 million tons of oil)



### ... is renewable energy

# Why is black liquor gasification interesting?

- Black liquor is the largest available biofuel source in Sweden (about 40 TWh/year)
- The black liquor energy can be converted with black liquor gasification and catalytic reactions into about 22 TWh/year of synthetic fuel
- 22 TWh/year corresponds to about 25% of today's consumption of petrol and diesel in Sweden
- The production cost is about the same as for fossil petrol and diesel before taxes
- The potential for cash flow increase at the pulp mills is therefore >30%
- However:
  - Black liquor is used for steam generation at the pulp mills
  - Pulp mills have extreme demands on availability
  - Any new process must be compatible with efficient pulp production

# ETC and black liquor gasification

- Coordinator for the national research program on black liquor gasification:
  - "BLG Program" 2004-2006 (36 MSEK)
  - "BLG II Program" 2007-2009 (40 MSEK)
- Host for the Chemrec 3.5 MW pressurised oxygen blown gasifier (DP-1)

# Partners in the BLG research program

- ETC (coordinator),
- Luleå University of Technology (LTU)
- Umeå University (UmU)
- Chalmers University of Technology (CTH)
- STFI
- Swedish Corrosion Institute (2004-2006)

## **Experience from DP1**



- More than 5 200 hours of operation (May 2007)
- Continuous operation Sep 2007 during 22 days stint
- Excellent syngas and green liquor quality
- Material behaviour as predicted

#### Typical results:

Component	H <sub>2</sub>	СО	CO <sub>2</sub>	CH <sub>4</sub>
Molar concentration	43%	30%	26%	1.6%

Gasifier pressure 30 bar

BL flow rate 20 t/d

(Design spec.)

Source: Chemrec 2008



### **CFD MODELING**



## LDA/PDA measurement of droplets





### **Burner optimisation**

Atmospheric

Pressurized #1 same massflow ratio Pressurized #2 same momentum flux ratio





#### In-situ measurements and advanced chemical analysis of gas and smelt composition

#### **Developing measurement probe**



### **Results of in-situ measurements**



**Reactor Pressure** 

# Methanol synthesis via Black liquor gasification

- New research project at ETC and part of Solander Science Park
- Cooperation between ETC and LTU and gas supply from Chemrec (DP-1)
- The project is financed by Energimyndigheten
- > Budget: 5.9 MSEK
- Equipments: 1 MSEK
- Senior researcher Olov Öhrman/ ETC, Ph.D student Caroline Häggström and Prof. Jonas Hedlund (Chemical technology, LTU)



## Next steps connected to BLG?

- 2007-2009: Continued process research in the BLG Program (app. 2 MUSD/year for research)
- 2007-2009: Bench scale experiments with synthesis of methanol/DME from real syngas
- 2008-2010: DME-plant, production of 4 ton/day from the Piteå DP1 gasifier
- 2009-2011: Semi commercial black liquor gasifier and synthesis plant for methanol/DME (60-80 ton/24h)
- 2010-....: Commercial plants in the 150-600 ton/24h scale in Sweden and abroad
- 2030: All Swedish pulp mills converted to BLG