Highlights from Bioenergy Task 32: Biomass Combustion and Cofiring
Graz, Austria, 19 January 2-173-7 October 2016

Jaap Koppejan, task leader
Kees Kwant, Operating Agent

IEA Bioenergy Task 32: Biomass Combustion and Cofiring

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IEA Bioenergy task 32: Biomass Combustion and Cofiring

- Combustion expertise network, part of the IEA Bioenergy Technology Collaboration Programme
- Experts from 13 countries:
  - Austria, Belgium, Canada, Denmark, Germany, Ireland, Italy, Japan, Netherlands, Norway, South Africa, Sweden, Switzerland
- Working together in:
  - Cooperative projects
  - Meetings, Workshops, Conferences, Excursions
  - Cooperation with other Networks
- Reports etc. can be found on:
  - www.ieabioenergytask32.com
Combustion technologies are proven and here to stay

Role of Task 32: Generate and exchange key information for further market deployment
- Cost reduction (CAPEX + OPEX)
- Efficiency increase
- Increased fuel flexibility
- Better environmental performance
Workshops in our last triennium 2013-2015

- Biomass torrefaction
- CFD based furnace design
- Improved woodstove design
- High Temperature Corrosion
- Opportunities for biomass power generation in South Africa
- Key results of 2013-2015
Studies in our last triennium

- Status overview of Torrefaction Technologies - A review of the commercialisation status of biomass torrefaction, Marcel Cremers et. al., DNV-GL, Netherlands, 2015

- Advanced characterisation methods for solid biomass fuels, Ingwald Obernberger, Thomas Brunner, TU Graz, Austria, 2014


- Sensitivity of System Design on Heat Distribution Costs in District Heating, Thomas Nussbaumer and Stefan Thalmann, Verenum, Switzerland, 2015

- Status Report on District Heating Systems in IEA Bioenergy T32 member countries, Thomas Nussbaumer and Stefan Thalmann, Verenum, Switzerland, 2015

- Techno-economic evaluation of selected decentralised CHP applications based on biomass combustion with steam turbine and ORC processes, Alfred Hammerschmid, Bios Bioenergiesysteme GmbH, Austria, 2016
Status overview of Torrefaction Technologies - A review of the commercialisation status of biomass torrefaction, Marcel Cremers et. al., DNV-GL, Netherlands, 2016

- What is torrefaction
- Recent progress in R&D
- Actual status of commercialisation
- Challenges remaining

- Webinar available!
## Status of torrefaction initiatives as of early 2015

<table>
<thead>
<tr>
<th>Developer</th>
<th>Technology</th>
<th>Location(s)</th>
<th>Production capacity (ton/a)</th>
<th>Scale and status</th>
<th>Full integration (pre-treatment, torrefaction, combustion, heat cycle, densification)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Electricity Generation (UK)</td>
<td>Oscillating bed</td>
<td>Derby (UK)</td>
<td>30,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Horizon Bioenergy (NL)</td>
<td>Oscillating belt conveyor</td>
<td>Steenwijk (NL)</td>
<td>45,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Dismantled</td>
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<tr>
<td>Solvay (FR) / New Biomass Energy (USA)</td>
<td>Screw reactor</td>
<td>Quitman (USA/MS)</td>
<td>80,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Topell Energy (NL)</td>
<td>Fluidised bed</td>
<td>Duiven (NL)</td>
<td>60,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Mothballed</td>
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<tr>
<td>Torr-Coal B.V. (NL)</td>
<td>Rotary drum</td>
<td>Dilsen-Stokkem (BE)</td>
<td>30,000</td>
<td>Commercial scale</td>
<td>Yes</td>
<td>Available/operational</td>
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<tr>
<td>Airex (CAN/QC)</td>
<td>Cyclonic bed</td>
<td>Bécanourg (CAN/QC)</td>
<td>16,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Scheduled to be built</td>
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<tr>
<td>Agri-Tech Producers LLC (USA/SC)</td>
<td>Screw reactor</td>
<td>Allendale (USA/SC)</td>
<td>13,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Out-of-service</td>
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<td>Andritz (AT)</td>
<td>Rotary drum</td>
<td>Frohleiten (AT)</td>
<td>10,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Unknown</td>
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<td>Andritz (DK) / ECN (NL)</td>
<td>Moving bed</td>
<td>Stenderup (DK)</td>
<td>10,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Available (2015)</td>
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<tr>
<td>BioEndev (SWE)</td>
<td>Dedicated screw reactor</td>
<td>Holmsund, Umea (SWE)</td>
<td>16,000</td>
<td>Demonstration scale</td>
<td>Yes</td>
<td>Unknown</td>
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<td>CMI NESA (BE)</td>
<td>Multiple hearth</td>
<td>Seraing (BE)</td>
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<td>Demonstration scale</td>
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<td>Earth Care Products (USA)</td>
<td>Rotary drum</td>
<td>Independence (USA/KS)</td>
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<td>Available/operational</td>
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<td>Grupo Lantec (SP)</td>
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<td>Urnieta (SP)</td>
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<tr>
<td>Integro Earth Fuels, LLC (USA)</td>
<td>Multiple hearth</td>
<td>Greenville (USA/SC)</td>
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<td>Demonstration scale</td>
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<td>LMK Energy (FR)</td>
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<td>Mazingarbe (FR)</td>
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<td>Demonstration scale</td>
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<td>Unknown</td>
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<td>River Basin Energy (USA)</td>
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<td>Laramie (USA/WY)</td>
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<td>Demonstration scale</td>
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<td>Available/operational</td>
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<td>Teal Sales Inc (USA)</td>
<td>Rotary drum</td>
<td>White Castle (USA/VA)</td>
<td>15,000</td>
<td>Demonstration scale</td>
<td>Unknown</td>
<td>Available/operational</td>
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<tr>
<td>Torrec (FI)</td>
<td>Moving bed</td>
<td>Mikkeli (FI)</td>
<td>10,000</td>
<td>Demonstration scale</td>
<td>Unknown</td>
<td>Available/operational</td>
</tr>
<tr>
<td>Agri-Tech Producers LLC (US/SC)</td>
<td>Screw reactor</td>
<td>Raleigh (USA/NC)</td>
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<td>Pilot stage</td>
<td>Unknown</td>
<td>Available/operational</td>
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<tr>
<td>Airex (CAN/QC)</td>
<td>Cyclonic bed</td>
<td>Rouyn-Noranda (CAN/QC)</td>
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<td>Pilot stage</td>
<td>Unknown</td>
<td>Available/operational</td>
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<tr>
<td>Airyna Fuels (IR)</td>
<td>Screw reactor</td>
<td>County Roscommon (IR)</td>
<td>Undefined</td>
<td>Pilot stage</td>
<td>Unknown</td>
<td>Available/operational</td>
</tr>
<tr>
<td>CENER (SP)</td>
<td>Rotary drum</td>
<td>Aoz (IR)</td>
<td>Undefined</td>
<td>Pilot scale</td>
<td>Unknown</td>
<td>Available/operational</td>
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<tr>
<td>Terra Green Energy (USA)</td>
<td>Multiple hearth</td>
<td>McKeen County (USA/PA)</td>
<td>Undefined</td>
<td>Pilot scale</td>
<td>Unknown</td>
<td>Available/operational</td>
</tr>
<tr>
<td>Wyssmont (USA)</td>
<td>Multiple hearth</td>
<td>Fort Lee (USA/NJ)</td>
<td>Undefined</td>
<td>Pilot scale</td>
<td>Unknown</td>
<td>Available/operational</td>
</tr>
<tr>
<td>CEA (FR)</td>
<td>Multiple hearth</td>
<td>Paris (FR)</td>
<td>Undefined</td>
<td>Laboratory scale</td>
<td>Unknown</td>
<td>Available/operational</td>
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<tr>
<td>Rotawave, Ltd. (UK)</td>
<td>Microwave</td>
<td>Chester (UK)</td>
<td>Undefined</td>
<td>Laboratory scale</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Bio Energy Development &amp; Production (CAN)</td>
<td>Fluidised bed</td>
<td>Nova Scotia (CAN/NS)</td>
<td>Undefined</td>
<td>Laboratory scale</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
</tbody>
</table>
Impact on flame shape in pulverised coal boilers

100% coal  50% coal/50% TWP  100% TWP
Recommendation for using new characterisation methods to evaluate combustion behaviour of a fuel

1. Evaluate fuel based on fuel indices

2. Test runs in suitable batchwise or continuously operated lab-scale reactors using TDA, SEM-EDX, STA or TEC

3. Pilot-scale test run

- Low capital investments, high efficiency, high reliability and high CO₂ impact in ton CO₂/GJ biomass
- From 5-10% cofiring in 90’s to full conversion today
- Various detailed case studies and country overviews
- Differences in combustion behaviour manageable
- Main challenges related to safety in fuel handling and storage (separate T32 report available)
Sensitivity of System Design on Heat Distribution Costs in District Heating, Thomas Nussbaumer and Stefan Thalmann, Verenum, Switzerland, 2015

- Impact of capital costs, electricity prices, interest rates, fuel prices, insulation, supply and return temperatures, full load hours, etc on total costs of ownership

- Pipe diameter often chosen too large!
Evaluation of 800 district heating networks in Austria, Denmark, Finland, Germany and Switzerland

General:
- Heat production: strong economy of scale
- Heat distribution: diseconomy of scale.

Consequently: larger district heating systems as e.g. in Denmark are only economically feasible due to the large economy of scale in the generation unit.

Analysis of several Swiss DH systems: 80% of the line sections are oversized mostly by one or two nominal diameters. This results in heat distribution losses and costs of up to 20-30% higher than necessary.
Connection Load & Linear Heat Density

- Switzerland n=50
- Finland n=162
- Denmark n=200

Linear heat density [MWh/(a m)]
Connection load [MW]

QM Holzheizwerke®
Heat Losses as function of Linear Heat Density

Factor > 3
Techno-economic evaluation of selected decentralised CHP applications based on biomass combustion with steam turbine and ORC processes, Alfred Hammerschmid, Bios Bioenergiesysteme GmbH, Austria, 2016

- Detailed technical and economical analysis of three CHP plants on scales of 0.13, 2.4 and 5.7 MWe
- Competitiveness of heat related part and electricity related part of the investment separately investigated
- Sensitivity analysis allows the reader to examine feasibility under different conditions
# Technical parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>DE-ORC</th>
<th>ORC-EST</th>
<th>ST-A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined heat and power plant (CHP)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel energy input CHP (nominal conditions)</td>
<td>[kWh\textsubscript{NCV}]</td>
<td>1,110</td>
<td>14,200</td>
<td>27,860</td>
</tr>
<tr>
<td>Electric capacity CHP gross (nominal conditions)</td>
<td>[kWh\textsubscript{el}]</td>
<td>130</td>
<td>2,400</td>
<td>5,700</td>
</tr>
<tr>
<td>Electric capacity CHP net (nominal conditions)</td>
<td>[kWh\textsubscript{el}]</td>
<td>90</td>
<td>2,050</td>
<td>5,000</td>
</tr>
<tr>
<td>Useful heat capacity CHP (nominal conditions)</td>
<td>[kW\textsubscript{u}]</td>
<td>660</td>
<td>9,580</td>
<td>17,000</td>
</tr>
<tr>
<td>Full load operating hours CHP</td>
<td>[h/a]</td>
<td>7,500</td>
<td>5,140</td>
<td>7,807</td>
</tr>
<tr>
<td>Annual electric efficiency gross</td>
<td>[%]</td>
<td>10.8</td>
<td>16.5</td>
<td>22.3</td>
</tr>
<tr>
<td>Annual total efficiency</td>
<td>[%]</td>
<td>65.8</td>
<td>87.0</td>
<td>66.8</td>
</tr>
<tr>
<td>Electrical flow index</td>
<td>-</td>
<td>0.14</td>
<td>0.21</td>
<td>0.29</td>
</tr>
<tr>
<td>Specific electricity consumption CHP (total)</td>
<td>[kWh\textsubscript{el}/MWh\textsubscript{th}]</td>
<td>48.0</td>
<td>46.1</td>
<td>29.1</td>
</tr>
<tr>
<td>Specific electricity consumption (heat related)</td>
<td>[kWh\textsubscript{el}/MWh\textsubscript{th}]</td>
<td>20.0</td>
<td>20.9</td>
<td>18.0</td>
</tr>
<tr>
<td>Total electricity consumption CHP</td>
<td>[kWh\textsubscript{el}/a]</td>
<td>299,520</td>
<td>3,145,000</td>
<td>4,000,000</td>
</tr>
<tr>
<td>-Electricity consumption heat related</td>
<td>[kWh\textsubscript{el}/a]</td>
<td>105,300</td>
<td>1,170,000</td>
<td>1,674,000</td>
</tr>
<tr>
<td>-Electricity consumption - CHP surplus</td>
<td>[kWh\textsubscript{el}/a]</td>
<td>194,220</td>
<td>1,975,000</td>
<td>2,326,000</td>
</tr>
<tr>
<td>Electricity production gross</td>
<td>[kWh\textsubscript{el}/a]</td>
<td>975,000</td>
<td>12,336,000</td>
<td>44,500,000</td>
</tr>
<tr>
<td>Electricity sold</td>
<td>[kWh\textsubscript{el}/a]</td>
<td>780,780</td>
<td>10,361,000</td>
<td>42,174,000</td>
</tr>
<tr>
<td>Total fuel energy input CHP</td>
<td>[kWh\textsubscript{NCV}/a]</td>
<td>9,026,000</td>
<td>74,830,000</td>
<td>200,000,000</td>
</tr>
<tr>
<td>-Fuel energy input heat related</td>
<td>[kWh\textsubscript{NCV}/a]</td>
<td>6,581,250</td>
<td>58,887,368</td>
<td>107,500,000</td>
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<tr>
<td>-Fuel energy input - CHP surplus</td>
<td>[kWh\textsubscript{NCV}/a]</td>
<td>2,446,750</td>
<td>15,942,632</td>
<td>92,500,000</td>
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<tr>
<td>Heat production CHP</td>
<td>[kWh\textsubscript{th}/a]</td>
<td>5,265,000</td>
<td>55,943,000</td>
<td>93,000,000</td>
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<tr>
<td>Distribution losses (network of pipes)</td>
<td>[%]</td>
<td>1.0</td>
<td>1.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Useful heat (sold to clients)</td>
<td>[kWh\textsubscript{th}/a]</td>
<td>5,212,350</td>
<td>55,383,570</td>
<td>90,000,000</td>
</tr>
</tbody>
</table>

**IEA Bioenergy**

www.ieabioenergy.com
Energy generation costs

![Energy generation costs graph](image)

IEA Bioenergy

www.ieabioenergy.com
Cofiring database

- Global overview of >250 larger boilers originally designed for fossil fuels, now using biomass
Work in progress
Status of PM emission measurement methods and new developments

- By Claudia Schön, Hans Hartmann (TFZ Straubing)
- Comparison of different methods for particle sampling and analysis, describing influencing parameters
- Providing recommendations for suitability of various methods for different applications
Policy paper with background report on the health impact of combustion aerosols

- By Thomas Nussbaumer, VERENUM
- Covering particle emissions from various biomass fired stoves and boilers.
- Policy paper available, background report to be finalised early 2017
Policy recommendation for small scale biomass combustion

- Proper operation of the combustion devices by users
- Appropriate standardisation of biomass fuels, combustion devices, type-tests, and measurement technologies
- Enforcement of regulations on energy standards and on air quality
- Design guidelines and quality management for the planning, implementation and monitoring of biomass combustion plants.
- An international exchange of experience between all stakeholders from research, industry, energy economics, and national authorities can assist this process.
D1 Strategic study for renewable heat

- Highlight the potential of biomass in smart renewable heating systems in different countries
- Show to policy makers how this can play a role in the green transition (in terms of job creation, economic growth, climate change and mitigation).
- The project will result in
  - a strategic report
  - case study leaflets.
- Available in 2018
D2. Strategic Study on Bioenergy Hybrids

- Joint project, coordinated by Illka Hannula, VTT
- Future role of bioenergy hybrids in energy supply system
- Preliminary roadmaps for countries or regions aiming towards sustainable future-proof energy system.
- Three status reports available on bioenergy hybrid technologies in Austria, Finland and Germany
- Two workshops held

- See http://task41project7.ieabioenergy.com/
D3 Best practise report of biomass combustion based CHP

- By Christoph Schmidl, BE2020+
  - Good examples of proven CHP technologies (steam turbines, ORC)
  - Innovative CHP concepts (gas/hot air turbines, Stirling engines, TEG, etc)
- To be finished by the end of 2017
D5. Reports on real life emissions of boilers and stoves

- Two separate reports on real life emissions from boilers and stoves
- Contents also discussed in yesterday’s workshop
D6. Workshop on developments in biomass cofiring

- To be organised with WPA 2017 conference in Canada, 18 Sept 2017
D7. Review on options for better ash utilisation

- Goal: promote specific pathways/recipes for utilizing the ash
- Readers: policy makers and traders
- Participants:
  - Marcel Cremers, (DNV-GL, Netherlands)
  - Angelo Saraber (Vliegasunie, Netherlands)
  - Brent Boyko (OPG, Canada)
  - Morten Tony Hansen (EAEA, Denmark)
  - Christoph Schmidl (BE2020+, Austria)
  - Roberta Roberto (ENEA, Italy)
  - Sebnem Madrali, Paul Hazlett, Kirsten Hannam (CANMET, Canada)
  - Claes Tullin, Kent Davidsson (SP, Sweden)
  - Sebastian Zimmerling, Hans-Joachim Feuerborn (VGB, Germany)
  - Jovita Juodaityte, Naushaad Haripersad (ESKOM, South Africa)
- Finished in 2017
D9 Workshop on SRF utilisation options

- Organisation with T33, T36 and ERFO
- Scope is a comparison of pathways for solid recovered fuels
- Probably in conjunction with EUBCE in Stockholm, June 2017
Joint project on biomass fuel pretreatment

Project strategy:

- Demonstrate to market actors and policy makers how advanced pretreatment technologies can make bioenergy supply chains more fuel flexible, efficient and cost effective

Deliverables:

1. 7 carefully identified case studies
2. Two technology databases
3. Policy report
Activity 1: Case studies

CS1 Biomass torrefaction as alternative to wood pellets for cofiring

CS2A: Pretreatment of forest residues in Finland, Ireland and Australia

CS2B Pretreatment of wood process residues.

CS3: Pretreatment of SRF/RDF for waste gasification

CS4: Thermal biomass pretreatment for dry liquefaction

CS5: Steam explosion for full conversion from coal to biomass

CS6: Sugar cane trash and palm oil mill residue leaching
D11 Inter task project on bio-ccs

- Led by Arasto Antti, VTT
- **Sustainability and GHG impact of Bio-CC(U)S**, GHGT13, Lausanne, Nov 14-18, 2016
- Summary available on [http://task41project5.ieabioenergy.com/](http://task41project5.ieabioenergy.com/)
BIOCCS needs to be implemented a.s.a.p.

- Norway announced that it will build three full scale CCS projects: cement, WtE and fertiliser production
- Main issues: technology demonstration & gaining experience, public acceptation, funding
Thank you!

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