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Highlights from Bioenergy Task 32: Biomass Combustion and Cofiring

Graz, Austria, 19 January 2-173-7 October 2016

Jaap Koppejan, task leader

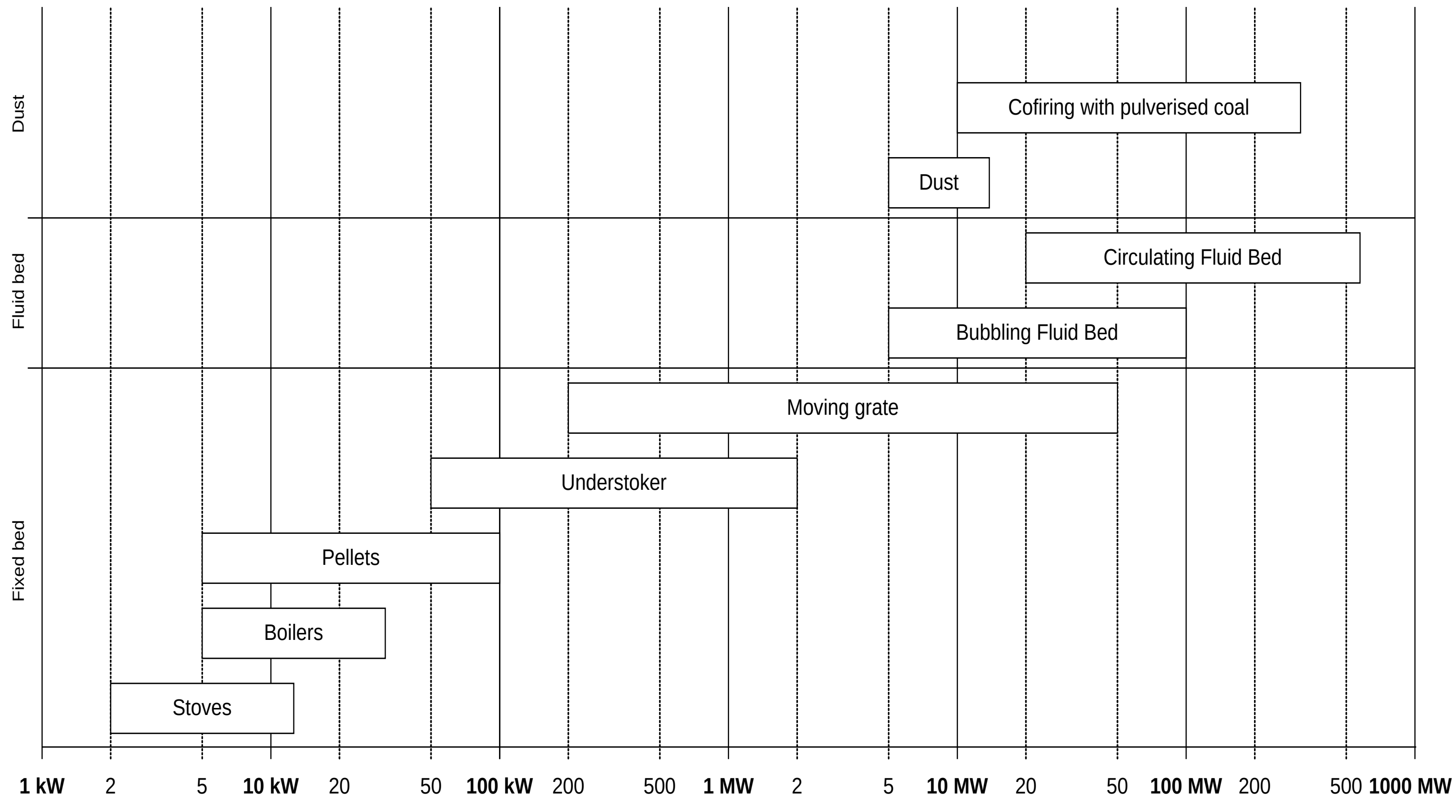
Kees Kwant, Operating Agent

IEA Bioenergy Task 32: Biomass Combustion and Cofiring

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

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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
- **The status of large scale biomass firing** - The milling and combustion of biomass materials in large pulverised coal boilers. W.R. Livingston, J. Middelkamp, W. Willeboer, S. Tosney, B. Sander, S. Madrali, M.T. Hansen, J. Koppejan and M.F.G. Cremers, 2016
- **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

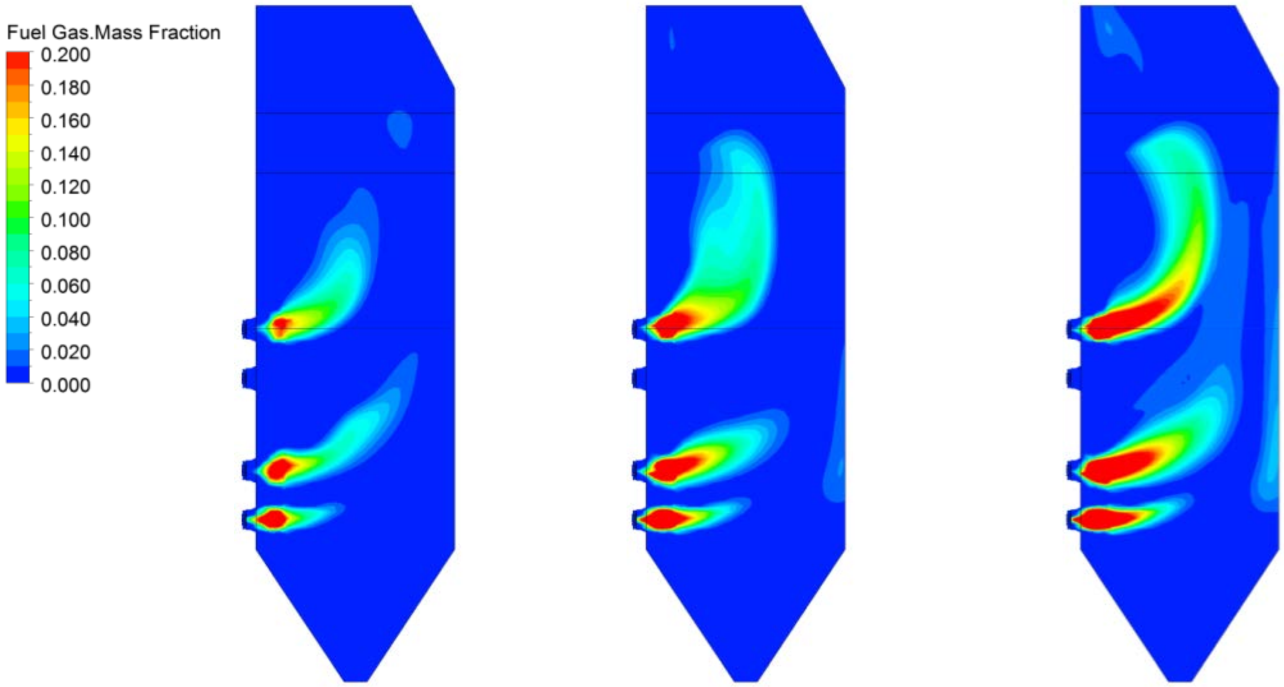
- What is torrefaction
- Recent progress in R&D
- Actual status of commercialisation
- Challenges remaining

- Webinar available!

Status of torrefaction initiatives as of early 2015

Developer	Technology	Location(s)	Production capacity (ton/a)	Scale and status Pilot scale: 0.05- 0.55 tph Demo scale: 0.5- 2 tph Commercial scale: > 2tph	Full integration (pre-treatment, torrefaction, combustion, heat cycle, densification)	Status
Clean Electricity Generation (UK)	Oscillating bed	Derby (UK)	30,000	Commercial scale	Yes	Available/operational
Horizon Bioenergy (NL)	Oscillating belt conveyor	Steenwijk (NL)	45,000	Commercial scale	Yes	Dismantled
Solvay (FR) / New Biomass Energy (USA)	Screw reactor	Quitman (USA/MS)	80,000	Commercial scale	Yes	Available/operational
Topell Energy (NL)	Fluidised bed	Duiven (NL)	60,000	Commercial scale	Yes	Mothballed
Torr-Coal B.V. (NL)	Rotary drum	Dilsen-Stokkem (BE)	30,000	Commercial scale	Yes	Available/operational
Airex (CAN/QC)	Cyclonic bed	Bécancour (CAN/QC)	16,000	Demonstration scale		Available/operational
Agri-Tech Producers LLC (USA/SC)	Screw reactor	Allendale (USA/SC)	13,000	Demonstration scale	Yes	Scheduled to be built
Andritz (AT)	Rotary drum	Frohnleiten (AT)	10,000	Demonstration scale	Yes	Out-of-service
Andritz (DK) / ECN (NL)	Moving bed	Stenderup (DK)	10,000	Demonstration scale		Unknown
BioEndev (SWE)	Dedicated screw reactor	Holmsund, Umea (SWE)	16,000	Demonstration scale	Yes	Available (2015)
CMI NESA (BE)	Multiple hearth	Seraing (BE)	Undefined	Demonstration scale		Unknown
Earth Care Products (USA)	Rotary drum	Independence (USA/KS)	20,000	Demonstration scale		Available/operational
Grupo Lantec (SP)	Moving bed	Urnieta (SP)	20,000	Demonstration scale		Unknown
Integro Earth Fuels, LLC (USA)	Multiple hearth	Greenville (USA/SC)	11,000	Demonstration scale		Unknown
LMK Energy (FR)	Moving bed	Mazingarbe (FR)	20,000	Demonstration scale		Unknown
River Basin Energy (USA)	Undefined	Laramie (USA/WY)	Undefined	Demonstration scale		Available/operational
Teal Sales Inc (USA)	Rotary drum	White Castle (USA/LA)	15,000	Demonstration scale		Available/operational
Torrec (FI)	Moving bed	Mikkeli (FI)	10,000	Demonstration scale		Available/operational
Agri-Tech Producers LLC (US/SC)	Screw reactor	Raleigh (USA/NC)	Undefined	Pilot stage		Available/operational
Airex (CAN/QC)	Cyclonic bed	Rouyn-Noranda (CAN/QC)	Undefined	Pilot stage		Available/operational
Airex (CAN/QC)	Cyclonic bed	Trois-Rivières (CAN/QC)	Undefined	Pilot stage		Available/operational
Arigna Fuels (IR)	Screw reactor	County Roscommon (IR)	Undefined	Pilot stage		Available/operational
CENER (SP)	Rotary drum	Aoiz (SP)	Undefined	Pilot scale		Available/operational
Terra Green Energy (USA)	Multiple hearth	McKean County (USA/PA)	Undefined	Pilot scale		Available/operational
Wyssmont (USA)	Multiple hearth	Fort Lee (USA/NJ)	Undefined	Pilot scale		Unknown
CEA (FR)	Multiple hearth	Paris (FR)	Undefined	Laboratory scale		Available/operational
Rotawave, Ltd. (UK)	Microwave	Chester (UK)	Undefined	Laboratory scale		Unknown
Bio Energy Development & Production (CAN)	Fluidised bed	Nova Scotia (CAN/NS)	Undefined	Unknown		Unknown

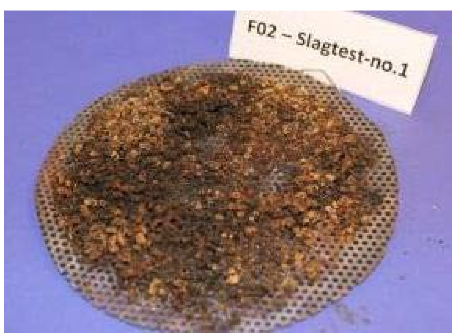
Impact on flame shape in pulverised coal boilers

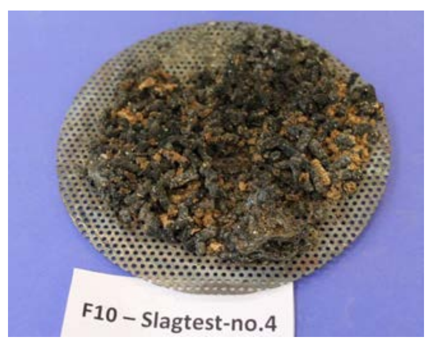


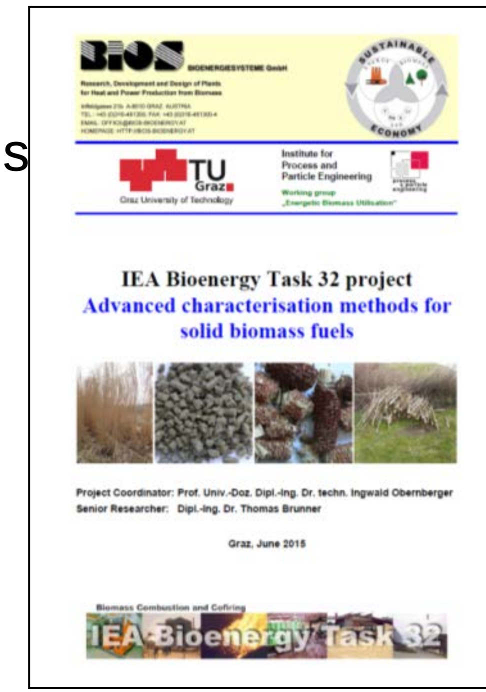
100% coal 50% coal/50% TWP 100% TWP

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

- 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





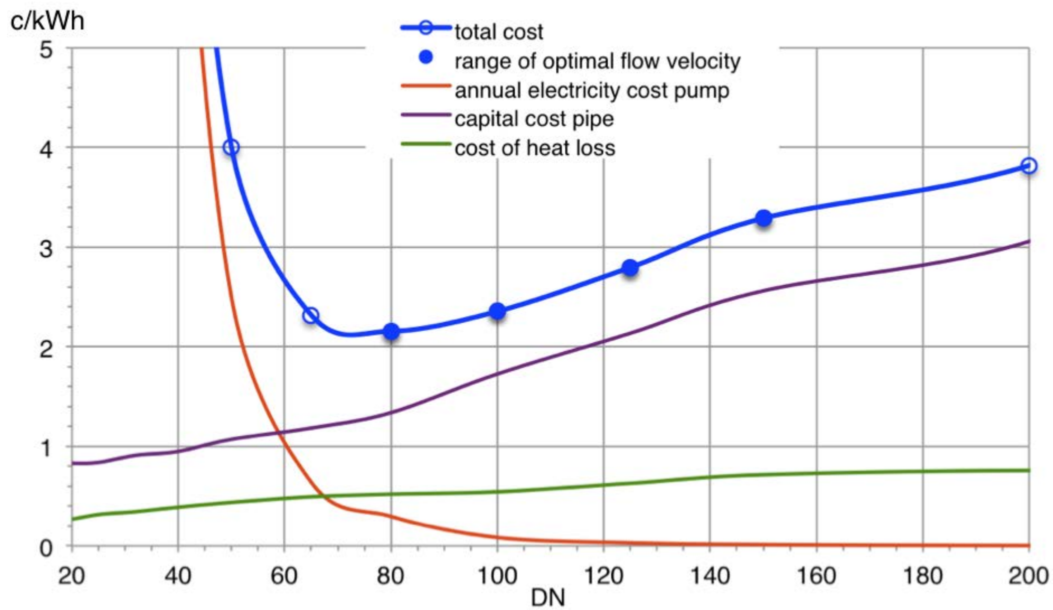


The status of large scale biomass firing - The milling and combustion of biomass materials in large pulverised coal boilers. W.R. Livingston, J. Middelkamp, W. Willeboer, S. Tosney, B. Sander, S. Madrali, M.T. Hansen, J. Koppejan and M.F.G. Cremers, 2016

- Low capital investments, high efficiency, high reliability and high CO_2 impact in ton CO_2/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

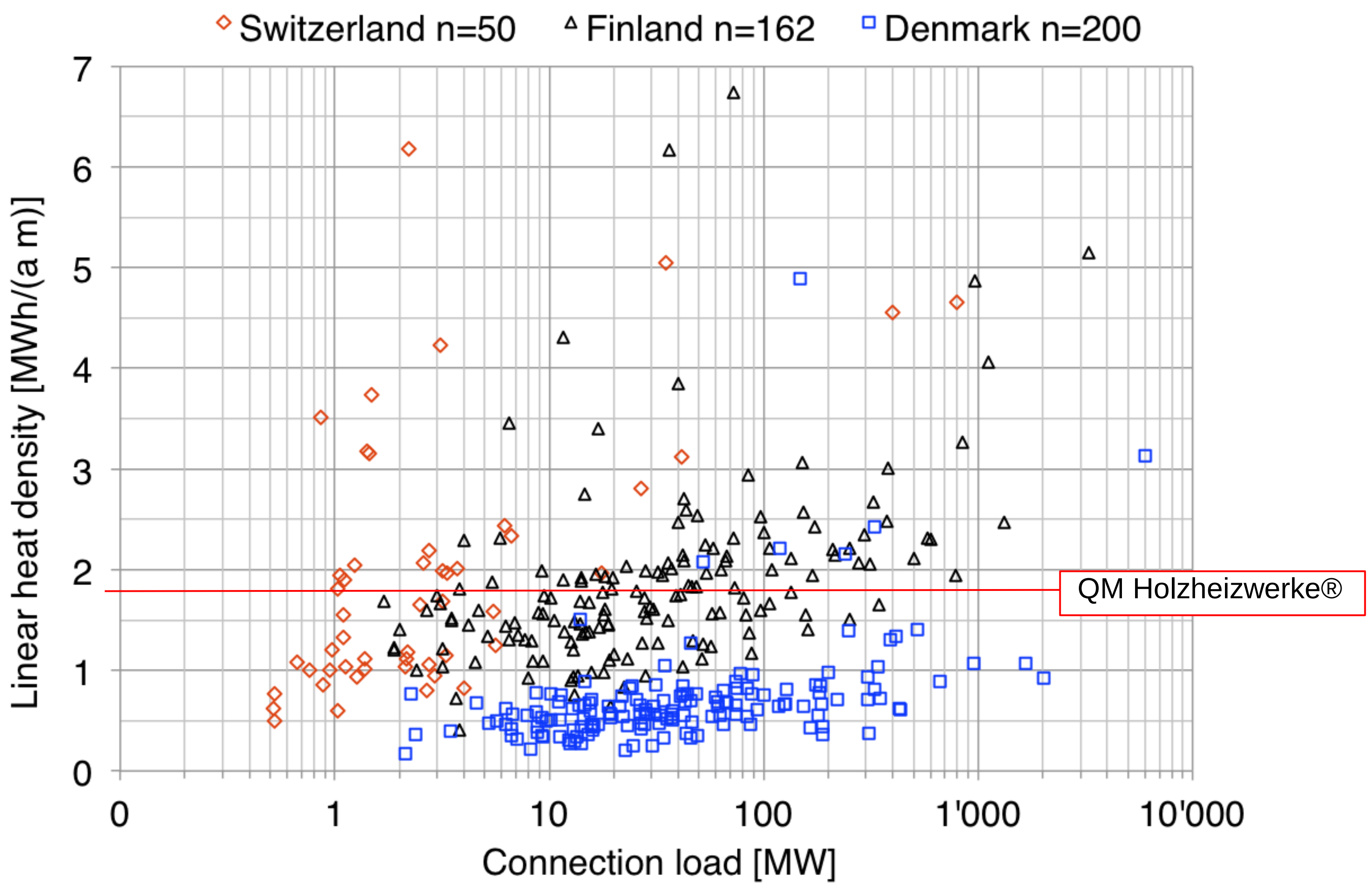
- Impact of capital costs, electricity prices, interest rates, fuel prices, insulation, supply and return temperatures, full load hours, etc on total costs of ownership
- Pipe diameter often chosen too large!



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

- 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



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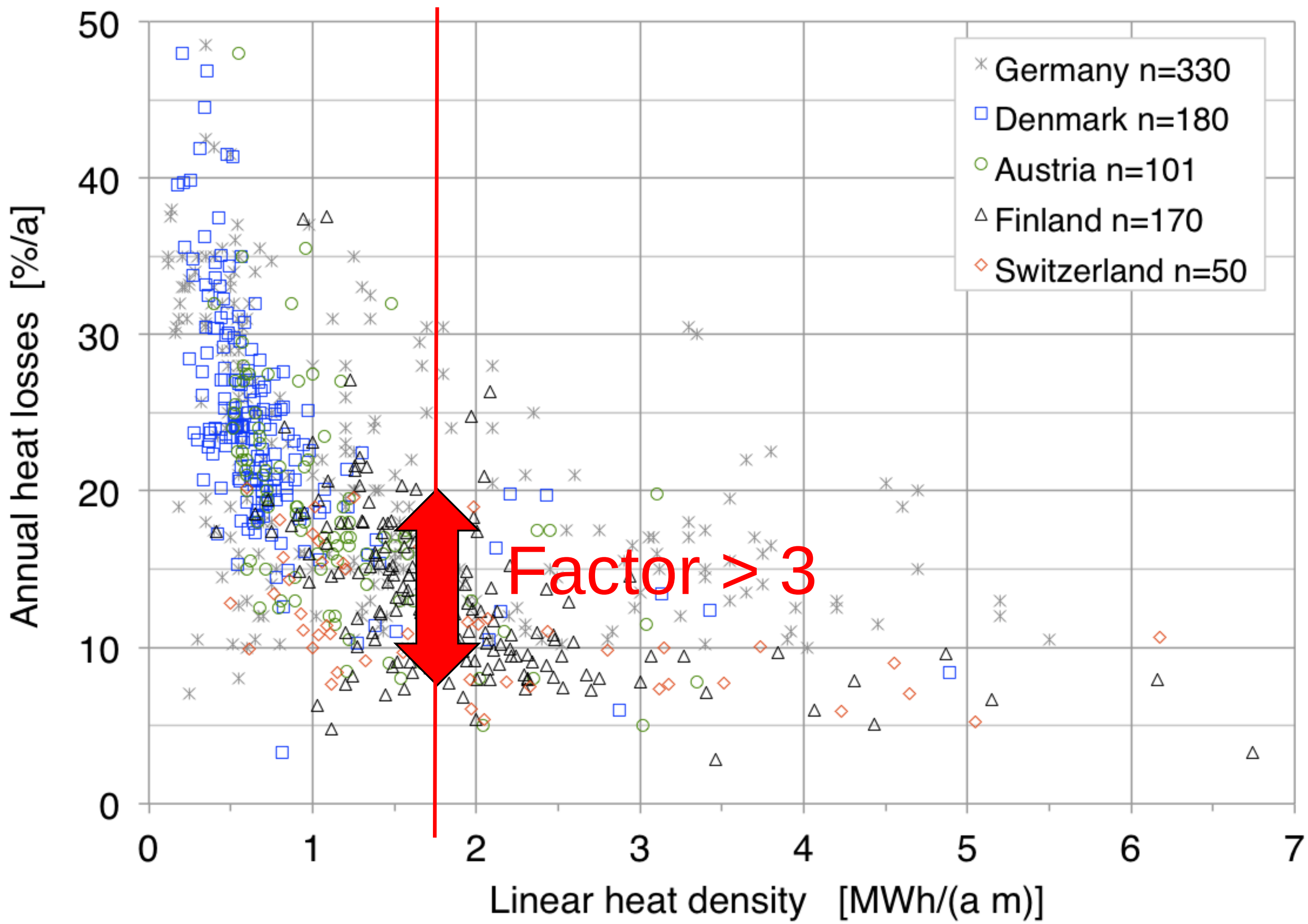
Heat Losses as function of Linear Heat Density



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 feasibilty under different conditions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SUSTAINABLE ENERGY BIOMASS ECONOMY

IEA Bioenergy Task 32 project

Techno-economic evaluation of selected decentralised CHP applications based on biomass combustion with steam turbine and ORC processes

Project Coordinator: Prof. Univ.-Doz. Dipl.-Ing. Dr. techn. Ingwald Obernberger

Senior Researcher: Dipl.-Ing. Alfred Hammerschmid

Junior Researcher: Dipl.-Ing. Michaela Forstinger

Graz, December 2015

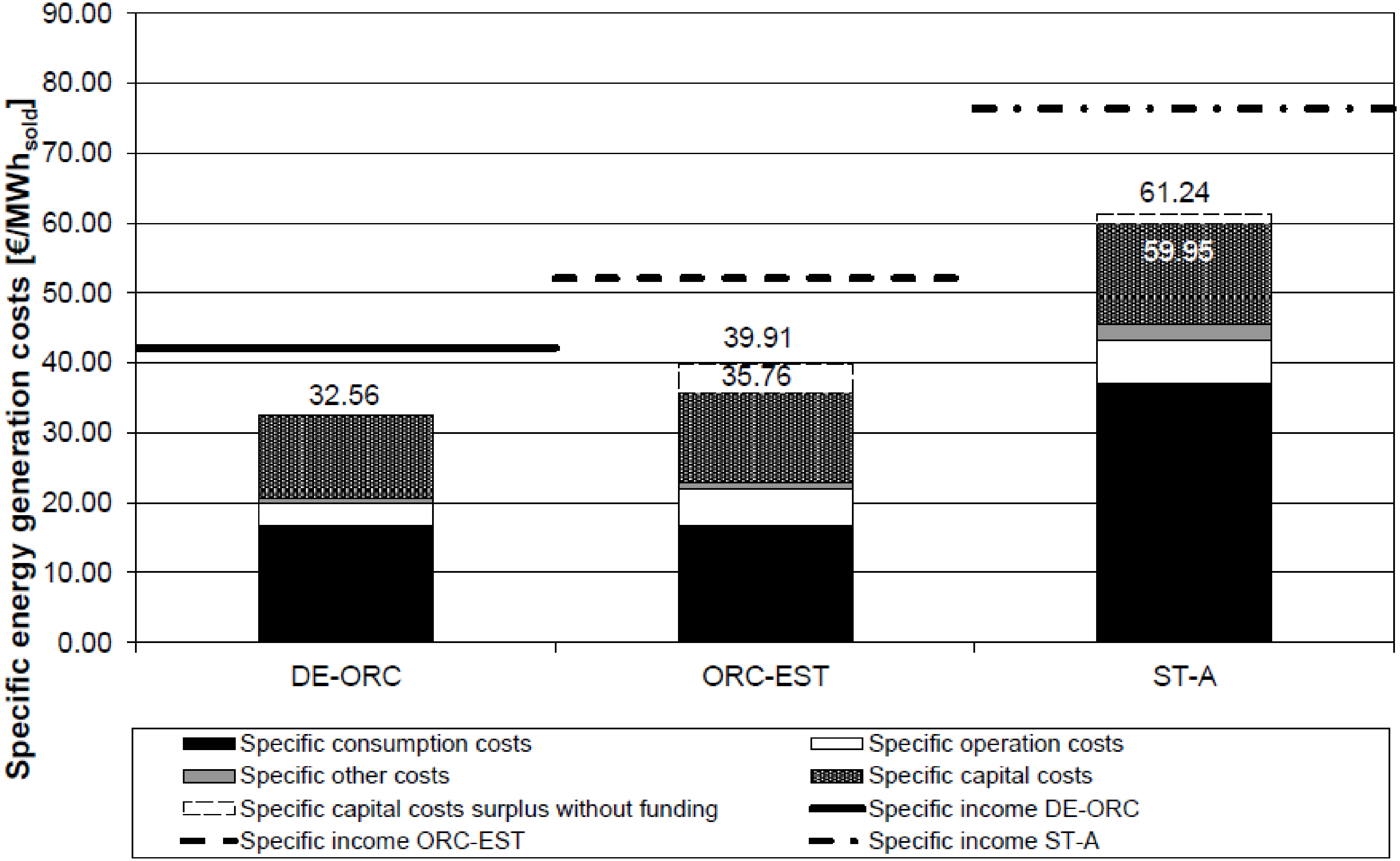
Biomass Combustion and Cofiring

IEA Bioenergy Task 32

Technical parameters

Parameter	Unit	DE-ORC	ORC-EST	ST-A
Combined heat and power plant (CHP)				
Fuel energy input CHP (nominal conditions)	[kW_{NCV}]	1,110	14,200	27,860
Electric capacity CHP gross (nominal conditions)	[kW_{el}]	130	2,400	5,700
Electric capacity CHP net (nominal conditions)	[kW_{el}]	90	2,050	5,000
Useful heat capacity CHP (nominal conditions)	[kW_{th}]	660	9,580	17,000
Full load operating hours CHP	[h/a]	7,500	5,140	7,807
Annual electric efficiency gross	[%]	10.8	16.5	22.3
Annual total efficiency	[%]	65.8	87.0	66.8
Electrical flow index	-	0.14	0.21	0.29
Specific electricity consumption CHP (total)	[kWh_{el}/MWh_{th}]	48.0	46.1	29.1
Specific electricity consumption (heat related)	[kWh_{el}/MWh_{th}]	20.0	20.9	18.0
Total electricity consumption CHP	[kWh_{el}/a]	299,520	3,145,000	4,000,000
Electricity consumption heat related	*[kWh_{el}/a]*	*105,300*	*1,170,000*	*1,674,000*
Electricity consumption - CHP surplus	*[kWh_{el}/a]*	*194,220*	*1,975,000*	*2,326,000*
Electricity production gross	[kWh_{el}/a]	975,000	12,336,000	44,500,000
Electricity sold	[kWh_{el}/a]	780,780	10,361,000	42,174,000
Total fuel energy input CHP	[kWh_{NCV}/a]	9,028,000	74,830,000	200,000,000
Fuel energy input heat related	*[kWh_{NCV}/a]*	*6,581,250*	*58,887,368*	*107,500,000*
Fuel energy input - CHP surplus	*[kWh_{NCV}/a]*	*2,446,750*	*15,942,632*	*92,500,000*
Heat production CHP	[kWh_{th}/a]	5,265,000	55,943,000	93,000,000
Distribution losses (network of pipes)	[%]	1.0	1.0	3.2
Useful heat (sold to clients)	[kWh_{th}/a]	5,212,350	55,383,570	90,000,000

Energy generation costs



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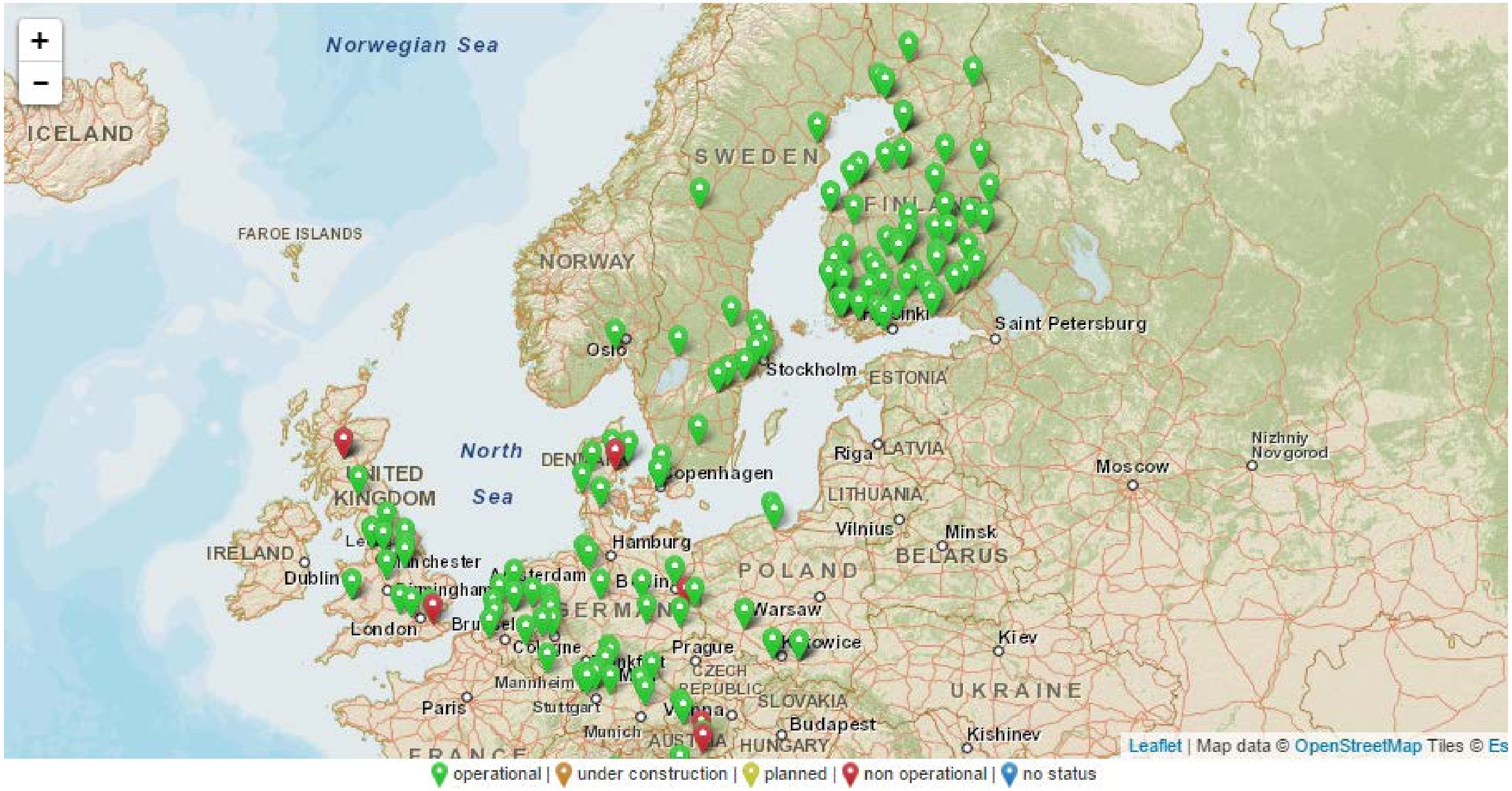
Cofiring database

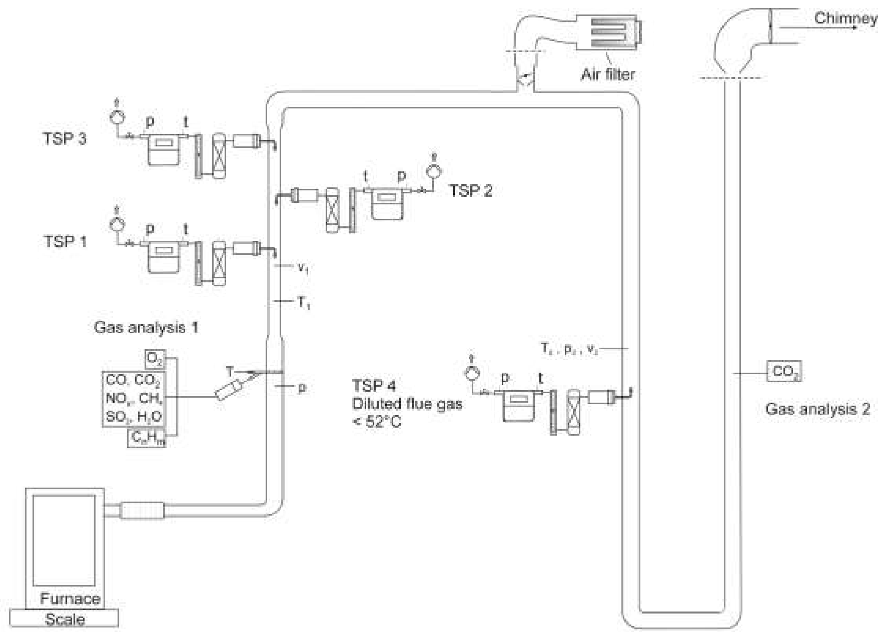
- Global overview of >250 larger boilers originally designed for fossil fuels, now using biomass



Work in progress

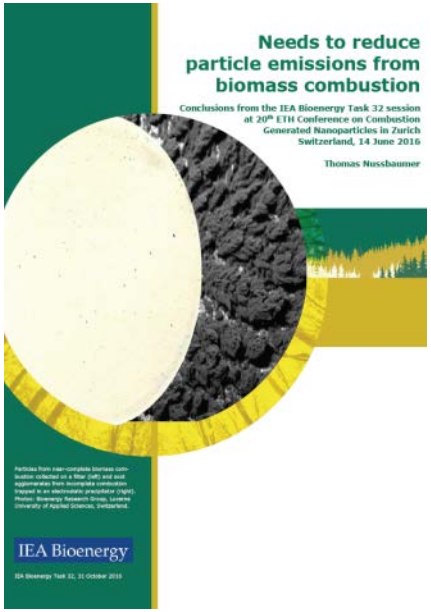
Status of PM emission measurement methods and new developments

- By Claudia Schön, Hans Hartmann (TFZ Srtraubing)
- 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

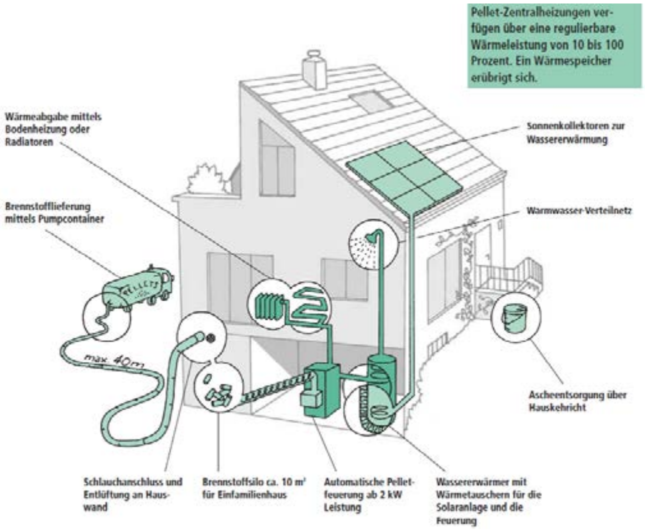


Policy recommendation for small scale biomass combustion

- 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

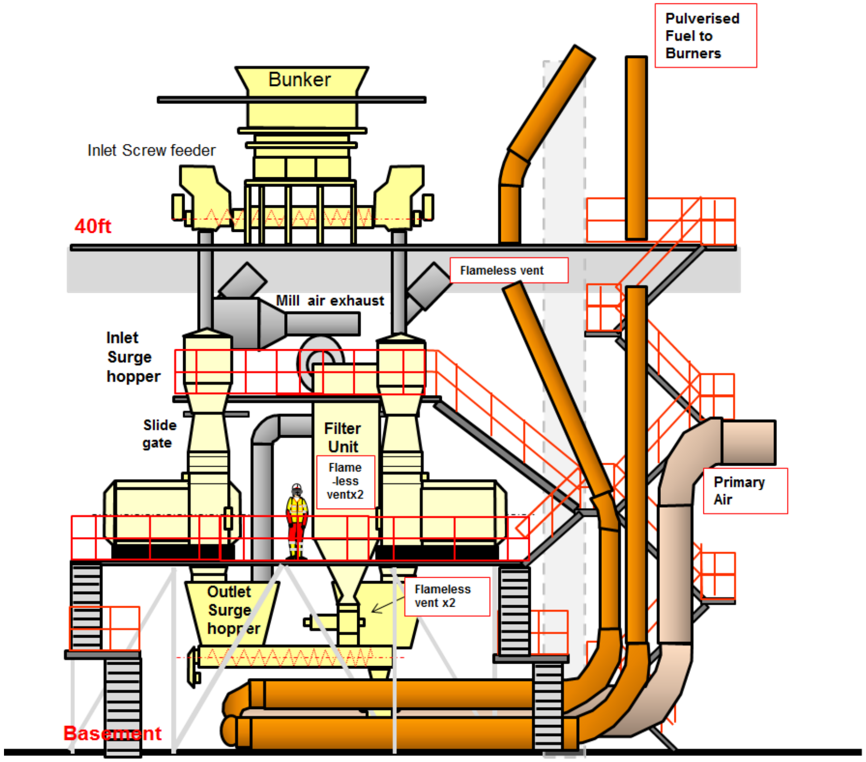
- By Christoph Schmidl, BE2020+
  - Good examples of proven CHP technologies (steam turbines, ORC)
  - innovative CHP concepts (gas/hot air turbines, Stirling engines, TEG, etc)
- To be finished by the end of 2017

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
- ***Applicable Bio-CCUS concepts for member states 2030–2050 – Technological and financial aspects of Bio-CC(U)S***, May 2016, Oslo
- **Sustainability and GHG impact of Bio-CC(U)S,** GHGT13, Lausanne, Nov 14-18, 2016
- Summary available on http://task41project5.ieabioenergy.com/

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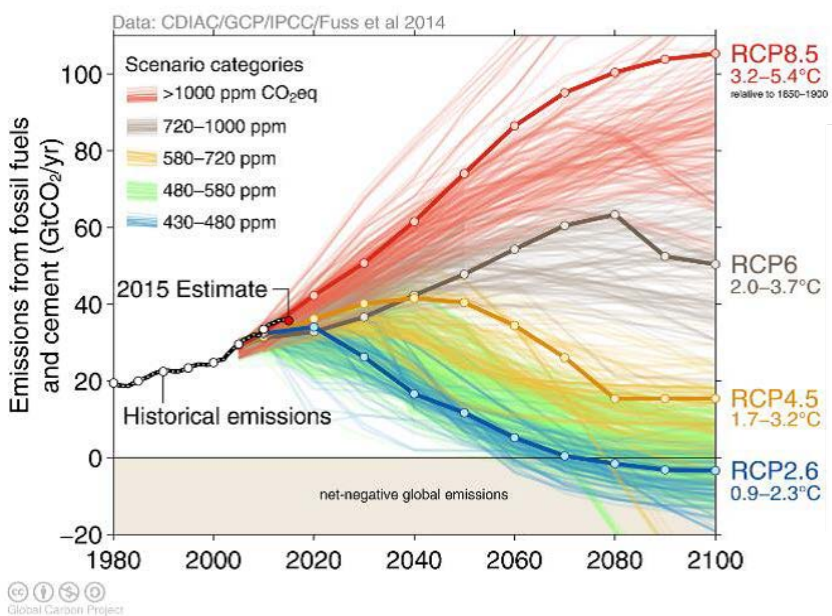
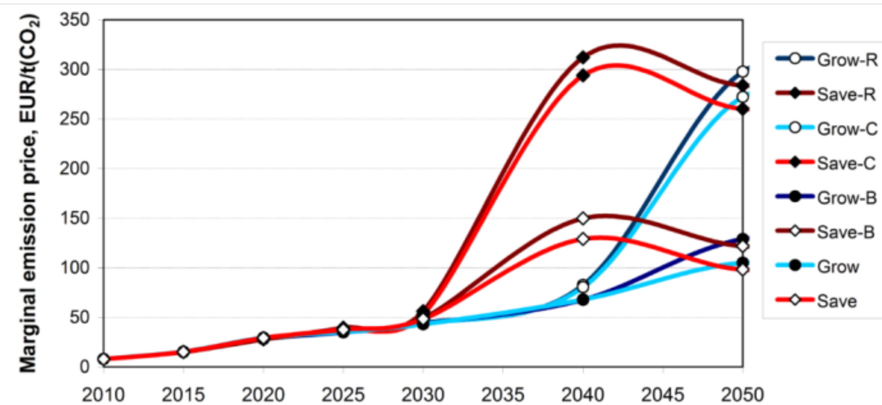
BIOCCS needs to be implemented a.s.a.p.





- 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!

Contact Details

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