
International Energy Agency
Bioenergy Agreement
Task 19
Biomass Combustion

Working Group Meeting, Biomass Combustion

Arranged by:
Sjaak van Loo and Jaap Koppejan
TNO-MEP, The Netherlands

Content:

Minutes of the Meeting,
Working Group Meeting-Biomass Combustion

August 31, 1999, Sandia Laboratories,
Livermore, USA

**IEA Working Group Meeting Task 19
Biomass Combustion
31/8/99, Livermore, USA**

Contents

Programme

Attendance list IEA-meeting, August 31, USA

Summary of the meeting

Status of activities

Ash related problems during combustion (USA)

Characterisation and Utilization of Biomass Ashes (Austria)

Modelling (the Netherlands)

Combined heat and power production (Switzerland)

Biomass Combustion - State of the Art review (Netherlands)

IEA/EU Standardisation project

Co-firing

Announcement of next meeting

Current Activities of Task 19

Addresses of current Task members

Programme

Time	Topic	Speaker
8:30 9:00	<i>Coffee</i>	
9:00 9:05	Opening	S. van Loo
9:05 9:15	Report of last meeting / Information from IEA	S. van Loo
9:15 9:30	Country presentation	Y. Schenkel (B)
9:00 10:15	Progress of task activities: Ash-related problems during biomass combustion Characterization and utilization of biomass ashes Modelling Combined heat and power production State-of-the-art report	L. Baxter (USA) I. Obernberger (A) S. van Loo (NL) H. Oravainen (SF) S. van Loo (NL)
10:15 10:45	Coffee break	
10:45 11:15	IEA/EU standardization project	I. Obernberger (A)
11:15 12:15	Cofiring (new Task Activity)	L. Baxter (USA)
12:15 12:30	Announcement of next meeting	S. van Loo
12:30 13:30	<i>Lunch</i>	
13:30 17:00	<i>Field trip to Sandia Laboratories together with delegates of Biomass conference of the America's</i>	
18:30 22:00	<i>Dinner</i>	

Attendance list IEA-meeting, August 31, 1999, USA

Representatives

Austria	Ingwald Obernberger, Institute of Chemical Engineering Fundamentals and Plant Engineering, Technical University of Graz
Belgium	Yves Schenkel, Département de Génie Rural, Centre de Reserche Agronomiques
Canada	Richard Logie, Renewable Energy Technology group, Energy Technology Branch, Department of Natural Resources
Denmark	Henrik Houmann Jakobsen, dk-TEKNIK
Denmark	Helle Junker, Elsamprojekt
Finland	Heikki Oravainen, VTT Energy, Fuels and Combustion
Netherlands	Sjaak van Loo, TNO-MEP
Norway	Øyvind Skreiberg, The Norwegian University of Science and Technology, Institute of Thermal Energy and Hydropower
Sweden	Claes Tullin, Swedish National Testing and Research Institute
USA	Larry Baxter, Sandia National Laboratories
USA	Don Hardesty, Sandia National Laboratories

Summary of the meeting

Opening / Report of last meeting / Information from IEA

The meeting was held in conjunction with the "Biomass Conference of the America's".

The fourth Task meeting was opened by Sjaak van Loo, welcoming all participants and presenting the agenda. Ten of fifteen member countries attended the meeting. The draft minutes of the third IEA-meeting in Amsterdam were accepted by the members.

Sjaak van Loo mentioned that from a meeting between ExCo members and Task leaders it became clear that Task participants should have funds for their contribution to Task activities from National Programmes. A scheme is given in annex 1. If there are any questions about support from National Programmes the participants are urged to contact their representative in the ExCo.

Country presentation

Yves Schenkel presented an overview of activities in Belgium. A copy of the sheets used are given in annex 2.

- At present in Belgium 1% of the energy-used is bio-energy. There is a potential of about 4%;
- Software is developed to evaluate the economy of project initiatives (BIOPRE). In several other countries similar software is used, developed or there is an interest in. Further information can be obtained through Yves Schenkel

Progress of Task activities

Ash related problems during biomass combustion

A presentation is given by Larry Baxter. The paper in annex 3 is summarising the presentation.

- Modelling of the condensed phase is conducted (quasi chemical and stoichiometric);
- Data evaluation by reviewing several databases;
- Data needed are temperature dependent thermodynamic quantities (enthalpy, entropy, and/or heat capacity) for inorganic (or organic) chemical species found in biomass or generated during its combustion. This will mainly be potassium salts and silicates, but could include sodium salts and alkali alumino silicates. Participants are invited to transfer available data to Larry Baxter

Characterisation and utilisation of biomass ashes

TU Graz has been working on the establishment of a database with composition of biomass fuels and ashes. The database includes ash composition and physical characteristics according to ash fraction, biomass fuel and combustion technology. Such a database could be instrumental in predicting ranges of composition of fuels and ashes.

Ingwald Obernberger presented the format of the database which was distributed to the participants (by Fritz Biederman) prior to the meeting.

- Differences are present in standards used. Standards have an effect on the results;
- Leaching is not included in the database. Elements are completely dissolved. Dissolving methods are important (Si);
- Participants are invited to try the database and submit data and comments.

Sjaak van Loo distributed a report on options for utilisation of biomass combustion ashes. In this report also legislation issues (in The Netherlands) are included.

- Participants are invited to submit information to the several activities. In the case the information is in a non-english language IEA can take care of translation (costs).

It was concluded that a draft report on Characterisation and utilisation of biomass ashes will be presented.

Modelling

The report on the questionnaire is distributed and presented by Sjaak van Loo (see annex 4).

In the questionnaire, nearly all experts have indicated their interest in co-operation and information exchange.

- It is decided to organise a workshop to bring together the various modelling experts. It will be organised in conjunction with the next Task meeting. The subject will be "modelling of biomass combustion to predict emissions".

Combined Heat and Power production

Heikki Oravainen presented an overview of Finnish small scale (5 - 10 MWe) CHP projects (see annex 5).

- A new CHP is under construction by Sermet Oy in which a Spilling steam engine will be used. The engine is modernized and has no oil leakage.
- Austria reports an ORC plant of 400 kWe using silica oil.

Biomass Combustion - State of the Art review (Netherlands)

A draft report was distributed to the participant with the request of adding information. The comments received were presented by Sjaak van Loo (see annex 6).

- Few comments were received. Some comments were "appropriate critical". Decided was that the present draft has not enough depth to serve as a "Handbook of Biomass Combustion".
- The proposal to adjust the quality with financial support from IEA to the authors/editors was accepted. All participants were invited to state to the Task leader their possible input to the Handbook and the costs involved.

IEA/EU standardisation project

There is a growing interest from both CEN, EU (DGXII and DGXVII) and IEA Task 28 on the standardisation of biomass fuel and ash analysis and the collection of precision data to be used for biomass standardisation. Characterisation is necessary to classifying and standardising biomass fuels. Therefore, a separate EU project proposal named "*Identification and reduction of sampling and testing errors in the field of solid biofuels*" has been submitted as a fifth framework project proposal by several partners.

Ingwald Obernberger presented the project structure (see annex 7).

- It was decided to wait with further action concerning the projected Round Robin until it is clear whether or not the IEA/EU proposal is committed.

Co-firing

Larry Baxter presented an overview of items of interest in co-firing biomass with coal (see also annex 8):

1. Fuel Characteristics and Resource assessment;
2. Fuel Preparation and Handling;
3. Pollutant Emissions;
4. Ash Deposition;
5. Carbon Conversion;
6. Chlorine-Based Corrosion;
7. Fly Ash Utilisation.

- From the discussion it became clear that IEA Clean Combustion Science (former Coal Combustion Science) is also planning activities in the field of co-firing.
- It was decided that the possibilities of co-operation between IEA Bioenergy (Task 19) and IEA CCS will be evaluated and, if possible, will be effectuated.

Announcement of next meeting

It was decided that the next meeting will be in conjunction with the "1st World Conference and Exhibition on Biomass for Energy and Industry" 5-9 June 2000 in Sevilla, Spain.

As Spain is not a participant in the Task, the Task leader will take care of organisation.

Current Activities of Task 19

Title	Subject	Co-ordinator	Contributors
Ash related problems during combustion	<ul style="list-style-type: none"> • agglomeration • deposit formation • aerosol formation • corrosion 	USA	NZ, S, DK, CH, A, SF
Characterization and utilization of biomass ashes	<ul style="list-style-type: none"> • characterisation • data base • legislation • ashes from co-firing • ash treatment 	A	DK, NL, USA, S, CH
Classification of biofuels	<ul style="list-style-type: none"> • inventory of activities • inventory of standards 	NL	NL
Modelling	<ul style="list-style-type: none"> • inventory of activities 	NL	All
CHP	<ul style="list-style-type: none"> • dissemination 	CH	CH
State-of-the-art report	<ul style="list-style-type: none"> • wood stoves • small scale • medium scale • large scale • co-firing • CHP 	NL	NL, S, CH, SF, CH
Cofiring	not yet known	USA	not yet known

Addresses of current Task members

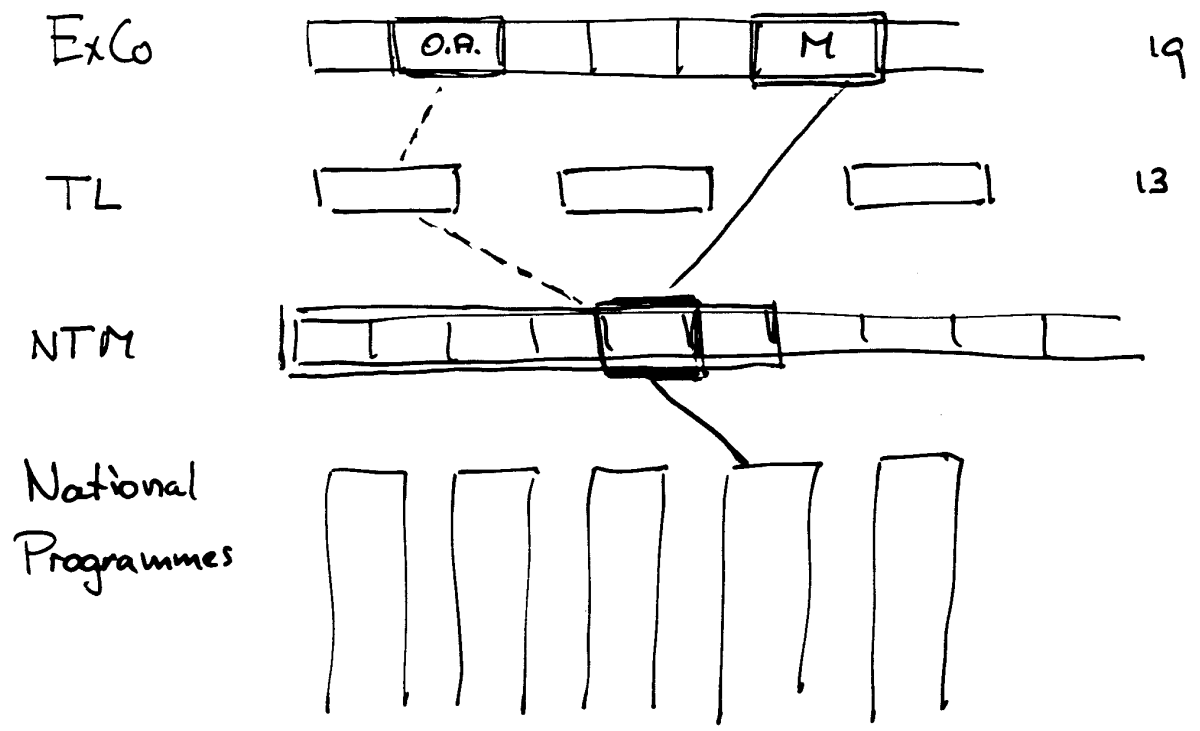
CEC	Mrs. Garbine Guiu	European Commission DG Research Rue de la Loi, 200 B- 1049 Brussels tel. +32 2 299 0538 fax + 32 2 299 3694 e-mail Garbine.Guiu@cec.eu.int
Austria	Ingwald Obernberger	Technical University of Graz Institute of Chemical Engineering Infeldgasse 25 A-8010 GRAZ tel +43 316 481300 fax +43 316 4813004 email obernberger@glvt.tu-graz.ac.at
Australia	Peter Coombes	Debra Electricity Level 12, Darling Park 201 Sussex Street Sydney 2000, Australia tel +612 92852789 fax +61 2 92852780 email peter.coombs@de.com.au
Belgium	Yves Schenkel	Département de Génie Rural Centre de Reserche Agronomiques Chaussée de Namur, 146 B-5030 GEMBLoux tel +32 81 612501 fax +32 81 615847 email schenkel@cragx.fgov.be
Brazil	Fransisco Domingues Alves de Souza	Institute for Technological Research - IPT Mechanical Engineer Cidade Universitária CEP: 05508-901 São Paulo -SP tel +55 (11) 37674520 fax +55 (11) 37674784 email fdesouza@ipt.br
Canada	Peter Hall	Department of Natural Resources Canadian Forest Service 580 Booth Street, 7th floor K1A OE4 OTTAWA, Ontario tel +1 613 9478987 fax +1 613 9479090 email phall@nrca.gc.ca

Denmark	Henrik Houmann Jakobsen	DK-Teknik Gladsaxe Mollevej 15 DK-2860 SOBORG tel +45 39 555999 fax +45 39 696002 email hhoumann@dk-teknik.dk
Finland	Heikki Oravainen	Technical Research Centre of Finland VTT-Energy P.O. Box 1603 FIN-40101 JYVÄSKYLÄ tel +358 14 672532 fax +358 14 672596 email Heikki.Oravainen@vtt.fi
France	Severinne Bouvot- Maudit	ADEME 2, Square La Fayette F49004 ANGERS CEDEX 01 tel +33 2 41204235 fax +33 2 41 20 4200 email severine.bouvot@ademe.fr
Netherlands	Sjaak van Loo (task leader)	TNO-MEP P.O. Box 342 7300 AH APELDOORN tel +31 55 5493745 fax +31 55 5493740 email s.vanloo@mep.tno.nl
Netherlands	Gerard Smakman (operating agent)	NOVEM P.O. Box 8242 3503 RE UTRECHT tel +31 30 2393454 fax +31 30 2316491 email g.smakman@novem.nl
Norway	Øyvind Skreiberg, Ph.D.	The Norwegian University of Science and Technology Institute of Thermal Energy and Hydropower 7034 Trondheim tel +47 73 597200 fax +47 73 598390 email oesite@tev.ntnu.no
New Zealand	John Gifford	Forest Research Institute Private Bag 3020 ROTORUA tel +64 7 3475877 fax +64 7 3479380 email giffordj@rimu.fri.cri.nz

Sweden	Claes Tullin	Swedish National Testing and Research Institute Box 857 S-501 15 BORAS tel +46 33 16 5555 fax: +46 33 131979 email: claes.tullin@sp.se
Switzerland	Thomas Nussbaumer	Verenum Langmauerstrasse 109 CH-8006 ZÜRICH tel +41 1 3641412 fax +41 1 3641421 email verenum@access.ch
United Kingdom	William R. Livingston, PhD.	Mitsui Babcock Energy Limited Technology Centre High Street Renfrew PA4 8UW Scotland tel +44 141 8862201 fax +44 141 8853370 email wlivingsto@mitsuibabcock.co.uk
USA	Larry Baxter	Sandia National Laboratories Combustion Research Department CA 94551-0969 LIVERMORE tel +1 510 2942321 fax +1 510 2941004 email lbaxter@sandia.gov

Annex 1

Scheme of relations between National Team Members, Task Leader and ExCo



Annex 2

**Country Presentation
Yves Schenkel, Belgium**

BIOMASS COMBUSTION ACTIVITIES

1. Modelling

- Biogames : fluidised bed gasification
- Slow pyrolysis : statistical modelisation

2. Market development

- Refined biofuels
- BIOPRE : <100 kW
>100 kW < 5 MW
- CHP

BIOMASS COMBUSTION ACTIVITIES

1. Modelling

- Biogames : fluidised bed gasification
- Slow pyrolysis : statistical modelisation

2. Market development

- Refined biofuels
- BIOPRE : <100 kW
>100 kW < 5 MW
- CHP

Annex 3

Investigation of Superheater Fouling in Biomass Boilers with Furnace Exit Gas Temperature Control

INVESTIGATION OF SUPERHEATER FOULING IN BIOMASS BOILERS WITH FURNACE EXIT GAS TEMPERATURE CONTROL

R.B.Williams,^a M.Jenkins,^b R.R.Bakker~ L.L.Baxter'

^aDepartment of Biological and Agricultural Engineering, University of California, Davis, California, 95616 USA

^bCombustion Research Facility, Sandia National Laboratories, Livermore, California, USA

Fouling, slagging, and agglomeration in biomass furnaces and boilers contribute to higher operating costs and decreased flexibility in fuel selection. Few strategies, other than fuel selection, exist for reducing fouling that are not capital intensive. One possible means by which to mitigate fouling without major retrofit is through control of furnace exit gas temperature (FEGT). Laboratory scale and full-scale boiler experiments were conducted to test the technical benefits from changes in furnace temperature. Full scale deposition experiments were conducted at a 50 MW, biomass facility using deposition probes inserted near the superheaters. Two furnace operating conditions were tested: one at high FEGT and one at low FEGT. Deposit rate, strength, and tenacity decreased with lower FEGT. Compositional and structural differences in the deposits were observed. These experiments demonstrate that some control of fouling is possible through furnace and combustion temperature management, Economic feasibility is discussed in a companion paper.

1. INTRODUCTION

Fireside tube fouling is a problem inherent in all high temperature steam generating systems, decreasing heat transfer and sometimes flow area owing to bridging of deposits and degrading the performance and efficiency of the steam generating plant. The degree of the problem depends on several factors including boiler design, operating parameters and fuel type. Fuel choice constitutes the main fouling control after plant installation. Maintenance shutdowns are costly both in terms of expense and lost generation revenue. Steam plant operators choose the best fuels available within their budgetary constraints. Although lower quality fuels are not always available at lower cost, constraining fuel quality to maintain low fouling rates within normal operating conditions limits the number of fuels available to the operators.

Operators know empirically that fouling is generally reduced by lowering the exit gas temperature. For fouling compounds and particles diffusing to or impacting the surface, rapid cooling and solidification while crossing the thermal boundary layer reduces the number of particles adhering to the surface. If the exit temperature is low enough, the particles will

solidify in the bulk gas. Reduced temperatures also result in reduced chemical reaction rates. The strength of the deposit formed is reduced, which makes it easier to remove by soot blowing. Disadvantages of the method are associated with the costs of building larger furnaces to accommodate the reduced heat transfer coefficients, loss of efficiency if high superheat temperatures cannot be attained, and possible derating of capacity and loss of revenue for existing units. Deposit-related corrosion may also be increased at lower temperatures. As a short-term remedial method for existing units, the technique may be effective, employed either continuously or intermittently. Intermittent operation at lower temperature may weaken deposits through thermal cycling, also making soot blowing more effective (Jenkins, et al., 1994).

In order to test the hypothesis that fouling can be reduced by control of furnace gas exit temperature, experiments were conducted in two stages: 1) the fouling characteristics of a commercial biomass fuel were evaluated in a laboratory scale combustor under differing combustion gas temperatures and air-fuel ratios, and 2) a full-scale commercially operating biomass power plant was used to evaluate fouling and slagging by modulating furnace gas exit temperature.

2. LABORATORY-SCALE EXPERIMENTS

2.1. Methods

Combustion experiments utilizing a wood/almond shell fuel blend were conducted in the Multi-Fuel Combustor (MFC) at Sandia National Laboratories, Livermore, California. The MFC is an entrained flow combustor in which milled fuel (16 mesh) is pneumatically injected into and burned in the air stream of an electrically heated down-flow tube furnace, 15 cm internal diameter by 4.3 m length. The wall temperature of the furnace can be controlled, as can the temperature of a vitiated air stream (obtained by burning natural gas in the air to increase the temperature) entering the top of the furnace. The furnace exhausts into an open test section, through which deposition probes of various types can be inserted. In these tests, air cooled mild steel tubes (19 mm OD) were used as deposit collection probes simulating superheater tubes in commercial power plants.

Controlled variables were furnace wall temperature, exhaust gas temperature, and exhaust O₂ concentration. Test conditions are listed in Table 1, arranged by order of test. Three probes, one instrumented with a thermocouple, were used in each test. They were held stationary and in a plane perpendicular to the furnace flow. After each test, the probes were photographed, the deposit end of one probe from each test was cast in epoxy resin to preserve the deposit for later electron microprobe analysis, and deposits from the other two probes were removed and weighed.

A total of 47 kg of fuel blend (two slightly different types) was burned during the tests. Type 1 fuel was a wood and 20% blend (by weight) of pre-screened almond shell sieved to remove fines passing 16 mesh. Type 2 fuel used the same wood fuel with a 20% blend of almond shell as received from the supplier. The wood portion of the fuel was obtained from Wheelabrator Shasta Energy Inc., a commercial biomass power plant in Anderson, California. Fuel compositions are given in Table 2.

Table 1

Test conditions for wood/almond shell blend fired in the MFC

Test	Exit gas Temp. (°C)	Exit O ₂ (mol %)	Furnace wall Temp. (°C)	Probe Temp. (°C)	Fuel Type	Natural gas pre-heat (on/off)
1	760	6.6	1100	500		on
2	980	3.6	1370	500		on
3	980	6.6	1370	500		on
4	980	6.6	1370	500	2	on
5	980		1370	500		off
6	780		1100	500		off
7	780		1100	400		off

Table 2

MFC fuel blend compositions

	Elemental Analysis			Ash Elemental			
	(% dry matter)			Fuel 1		Fuel 2	
	Fuel 1	Fuel 2		(% ash)	(% dm)**	(% ash)	(% dm)**
C	49.12	49.11	SiO ₂	31.07	1.27	32.69	1.40
H	5.75	5.76	Al ₂ O ₃	11.53	0.47	11.77	0.50
N	0.84	0.87	TiO ₂	0.52	0.02	0.53	0.02
S	0.03	0.03	Fe ₂ O ₃	6.59	0.27	6.52	0.28
Ca	0.03	0.03	CaO	15.15	0.62	15.16	0.65
Ash	4.09	4.27	MgO	3.85	0.16	3.83	0.16
O*	40.15	39.93	Na ₂ O	1.36	0.06	1.36	0.06
			K ₂ O	14.50	0.59	13.56	0.58
			P ₂ O ₅	2.57	0.11	2.64	0.11
			SO ₃	1.01	0.04	0.99	0.04
			Cl	0.03	0.001	0.03	0.001
			CO ₂	10.11	0.41	9.39	0.04
			und. tt	1.71	0.07	1.53	0.07

t Wood and almond shell components analyzed separately.

tt undetermined

by difference

** % dry matter derived from % ash.

2.2. Results and discussion

Though a typical test lasted 3-6 hours, deposit masses were small, varying from 0.03 to 0.25g. Each deposit formed a characteristic white dust-like layer on the metal probe surface, thicker on the side which faced the flow, lighter and sometimes absent on the downstream side. This initial deposit layer is typically formed by the condensation of an alkali salt. For biomass the composition is most often a potassium chloride or sulfate. On top of the white

layer a gritty tan or light brown deposit crown formed on the surface facing the upstream flow. Crown deposits were removed by light brushing, indicating the development of limited strength and tenacity in the deposit. Deposits obtained with natural gas co-firing are fine textured, indicating substantial burnout of the fuel particles, while those obtained without natural gas co-firing are more coarse textured, with a larger fraction of charred fuel particles, and larger particles originating most likely from the soil. Table 3 lists the deposit masses in decreasing order of deposit/fuel mass ratio and tests grouped by natural gas or no gas preheat. With these data, a conclusive relationship of deposit mass and structure to furnace gas temperature in the MFC was not observed. With natural gas preheat, the deposition fraction for both lower temperature conditions is substantially lower than at the higher temperature. However, without gas preheat, the lower temperature test produces the highest deposition fraction, perhaps as a result of the limited burnout of fuel particles in the furnace.

Table 3
Deposit weights by decreasing deposit fraction (deposit/fuel mass)

Test	Exh. Temp/	Deposit Total		Deposit Fraction		Rel. Dep. Frac**		
		Mass	Fuel	Ash (g)	Fuel(%)	Ash (%)	Fuel (-)	Ash(-)
5	980/6	0.2563 (g)	7.8 (kg)	319.2	0.0033	0.0803	1	1
7	78016-T400*	0.1854	8.3	337.8	0.0022	0.0549	0.68	0.68
6	78016 (no nat. gas)	0.1078	8.4	342.8	0.0013	0.0314	0.39	0.39
1	760/6	0.0698	3.6	148.5	0.0019	0.0470	1	1
4	980/6-2t	0.0469	3.1	131.0	0.0015	0.0358	0.79	0.79
2	98016	0.0657	7.6	322.0	0.00087	0.0204	0.45	0.45
3	980/3	0.0331	4.0	165.3	0.00082	0.0200	0.42	0.42

Relative deposition fraction: relative to highest value.

T400 indicates 400 °C preheat. Otherwise, Temperatures were 500 °C. 1- Type 2 Fuel.

3. FULL SCALE EXPERIMENTS

3.1. Methods

An almond-wood fuel mixture of the same type used in the pilot scale experiments was fired in boiler #1 at the Wheelabrator Shasta Energy Co. power plant in Anderson, California, under two operating regimes. The power plant is of conventional supercritical Rankine-cycle design with a net generating capacity of 50 MWe. Steam is generated in three identical, stoker-fired traveling grate boilers connected to a common steam header supplying three turbogenerators. The boilers consist of a waterwall furnace followed by primary and secondary superheaters, economizer, and air-heater in the convection pass. Secondary superheaters are radiant units located above the grate at the furnace exit. Normal superheater outlet steam temperature is 485°C (905°F), and steam pressure is 6.2 MPa (900 psi). A

variety of chipped wood is used as primary fuel and the plant is permitted to fire up to 25% (heating value) natural gas (although no natural gas was during the experiments).

Three air-cooled deposition probes, constructed of 5 1 mm OD type SA213-T22 tubing and mounted on carriers, were positioned at modified furnace viewports near the secondary superheater pendants (approximately 13.5 m above the grate). When inserted, the probes extended 1.2 m inside the furnace. The probes were instrumented with thermocouples connected to a controller which adjusted the coolant air flow rate. Each probe could be operated independently of the others.

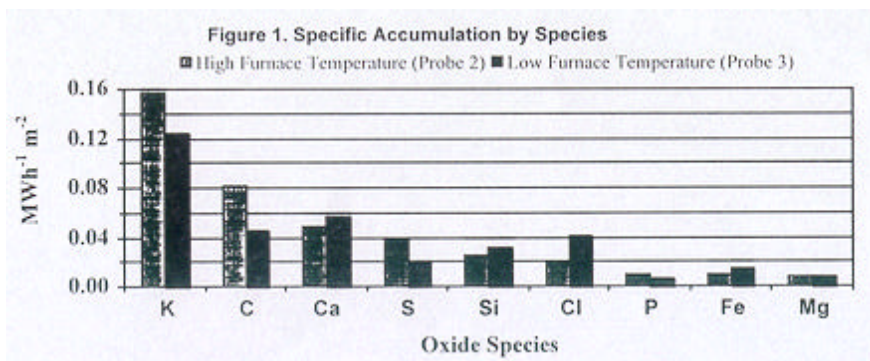
The two furnace operating conditions utilized during the experiment were (1) full load plant operation (50 MWe plant net, or 16.7 MWe per boiler) with a high FEGT and (2) low load operation (during off-peak periods; nighttime and weekends) when the plant was operated at 60% capacity (10 MWe per boiler); at a lower FEGT. A 20% blend (by weight) of almond shells in wood fuel (composition similar to that in Table 2) was fired to boiler no. 1, while the other two boilers received the normal wood fuel. The goal was to fire equal amounts of fuel blend to the boiler during each operating regime. One probe (probe 1) was inserted in the boiler during all times the test fuel blend was being fired. Probe 2 was inserted only during the full load operating regime, and probe 3 was inserted during the low load regime. After the tests, the probe deposits were removed, weighed and analyzed. Table 4 summarizes parameters of the experiment and some of the results.

Table 4
Boiler and probe parameters and deposit weights

Parameter	Units	Ave. Full Load	Ave. Low Load	Probe 1
		Value (Probe 2)	Value (Probe 3)	Fullnow
Furnace Gas Temp. at Probes	°C	900-950	750-800	
Wood Feed Rate, db* Almond	kg/h	12,813 (81%)	7556(79%)	
Shell Feed Rate, db Stearn Flow	kg/h	3087(19%)	1984(21%)	
Super Heater Steam Temp.	°C	77,111	47,174	
Probe Temperature Duration of	h	484	479	
Test Total Fuel Fired Total	Mg	500	500	500
Deposit Deposit Rate Specific	g/hg		61.25	104.25
Dep. Rate <u>Dep. wt. 1 Total Fuel</u>	MWh- ¹ g	683.7	584.3	1268
<u>wt.</u>	mg-	51.9	38.9	93.5
		1.21	0.64	0.90
		0.425	0.373	nd
		<u>0.076</u>	0.067	<u>nd</u>

3.2. Results and discussion

The appearance of each probe was similar with a gritty dark tan/light brown covering along the upstream half of the probe, heaviest along the stagnation line and towards the ends of the probes, tapering off near the boiler wall. The granular particles adhering to the upstream half of probes 1 and 2 were larger (~2.4 mm dia.) and more numerous than those on probe 3, which were about 1.5 mm in diameter. The deposit from the high temperature test (probe 2) was very tenacious and required vigorous scraping (with rigid nylon plastic) after wetting and brushing. The deposit from the low temperature test was much more friable, needing only mild brushing and rinsing to remove. Although the amount of fuel fired in the low temperature test was 85% of that fired in high temperature test, the low temperature deposit weight was only 75% of that from the high temperature case. Table 4 lists the specific deposit rate ($\text{g/MWh}^{-1} \text{M}^{-2}$) as well as the deposit:fuel ratio (g Mg^{-1}). Both indicate that deposit mass differences are not simply due to a difference in the amounts of fuel fired. Figure 1 shows the specific accumulation for the more prominent species in the deposits from each furnace condition. Potassium, carbonate, and sulfate deposition rates were less for the lower FEGT. The specific chlorine deposition rate was elevated by a factor of 2 for the lower temperature probe, which is of some concern for possible corrosion effects.



4. CONCLUSIONS

Deposit mass and tenacity were reduced with lower furnace gas temperature in both full scale and pilot experiments, although not conclusively in the latter. Deposition rate and structure are influenced by adjusting the furnace exit gas temperature. In the full-scale experiments, during the low temperature conditions, the deposition rate was reduced by 12% and the deposit tenacity was reduced as well, implying the deposits produced at low temperature would be more easily removed through conventional soot blowing techniques. An increase in G by a factor of 2 in the low temperature deposit of the full scale tests raises a concern over corrosion that must be addressed if FEGT control is to be employed as a means to reduce fouling. Longer term experiments should be implemented to assess the potential

compromises between deposit composition, formation rate, and deposit tenacity. The economic consequences of this method depend on the relationships among these factors. An economic study including sensitivity to boiler operating performance is addressed in a companion paper (Yomogida et al., 1999).

5. ACKNOWLEDGMENTS

The work reported was funded under a research contract from the California Energy Commission. The authors appreciate the assistance of G. Scippa, B. Carlson, J. Duffy, J. Rovenstine, B. Englin, and the operations and maintenance crew at Wheelabrator Shasta Energy Co. Inc. is also gratefully acknowledged.

REFERENCES

- Jenkins, B.M., L.L. Baxter, T.R. Miles, T.R. Miles, Jr., L.L. Oden, R.W. Bryers, and E. Winther (1994). Composition of ash deposits in biomass fueled boilers: results of fullscale experiments and laboratory simulations, ASAE Paper No. 946007, ASAE, St. Joseph, Michigan.
- Yomogida, D.E., B.M. Jenkins, B.R. Flattsough, and V.M. Tiangco (1999). Model performance of a biomass fueled power station with variable furnace exit gas temperature for fouling control, Proceedings of the 0 Biomass Conference of the Americas.

Annex 4

Presented sheets on Modelling

IEA Bioenergy

Task 19: Biomass Combustion

Modelling

Sjaak van Loo



Status

- Report on results of questionnaire finished;
- Distribution to 38 institutions and Task members;
- Proposal on follow-up.

Proposed follow-up:

- Workshop on modelling of biomass combustion to predict emissions;
- Group of respondents working on modelling emissions from biomass combustion
 - 11 respondents;
 - 9 institutes;
 - 7 countries (Austria, Switzerland, Italy, Denmark, Norway, Sweden, Finland);
 - wanting to co-operate;
 - small spread in model types.



Annex 5

Presented sheets on CHP

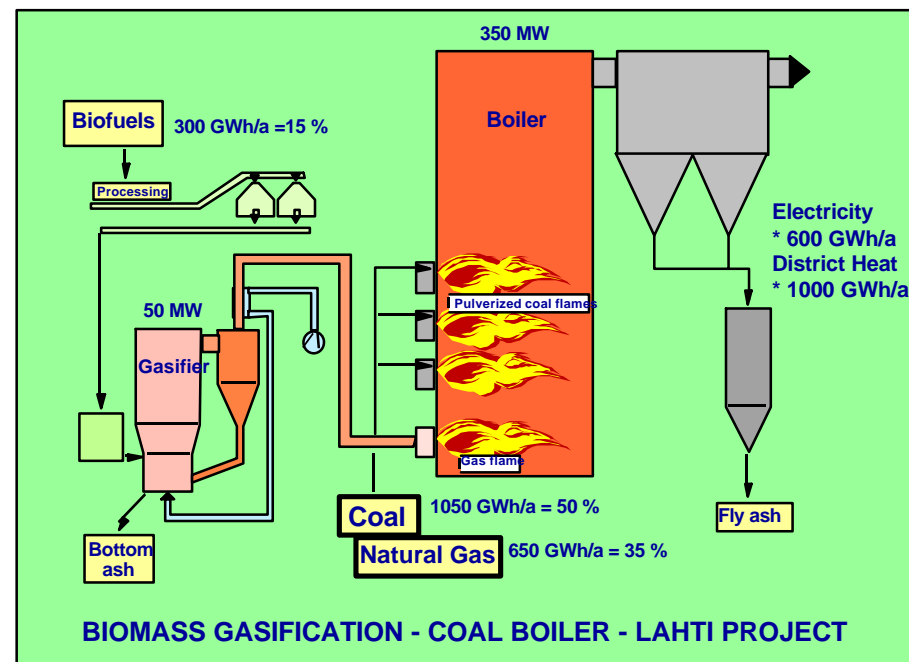
COFIRING CONCEPTS IN FINLAND

- New fluidized bed boiler
- Fluidised bed retrofit to grate or pulverized fuel fired boiler
- Atmospheric gasification connectec to an existing boiler

Atmospheric-pressure CFB gasification technology, earlier commercialised for lime-kiln applications, is now applied to co-utilisation of locally available residues and wastes in existing boilers

Activities in PROGAS:

- Gasification of biofuels which have problematic ash behaviour
- Gasification of different waste-derived fuels
- Gas cleaning for removal of alkali/heavy metals and chlorine



COMBINED HEAT AND POWER IN FINLAND

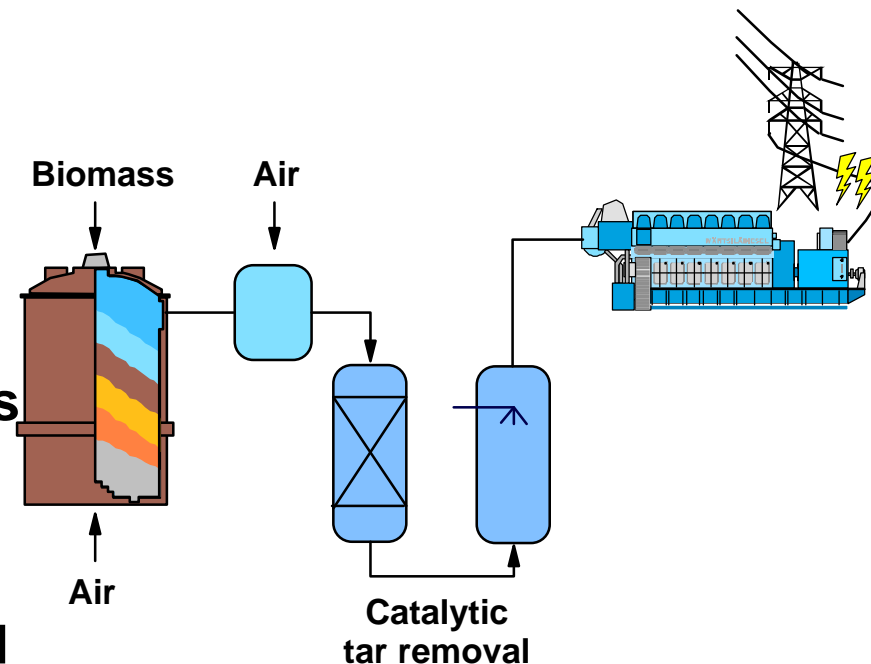
- 1/3 of electricity comes from CHP
- 56 % of CHP electricity comes from industrial plants and 44% from municipal district heating plant
- 80 % of district heat produced in CHP plants

FUELS USED IN DISTRICT HEATING AND CHP PLANTS IN FINLAND

- Natural gas 34% increasing
- Coal 29% decreasing
- Peat 20% stable
- Oil 7% decreasing
- Wood 7% increasing
- others 3% ?

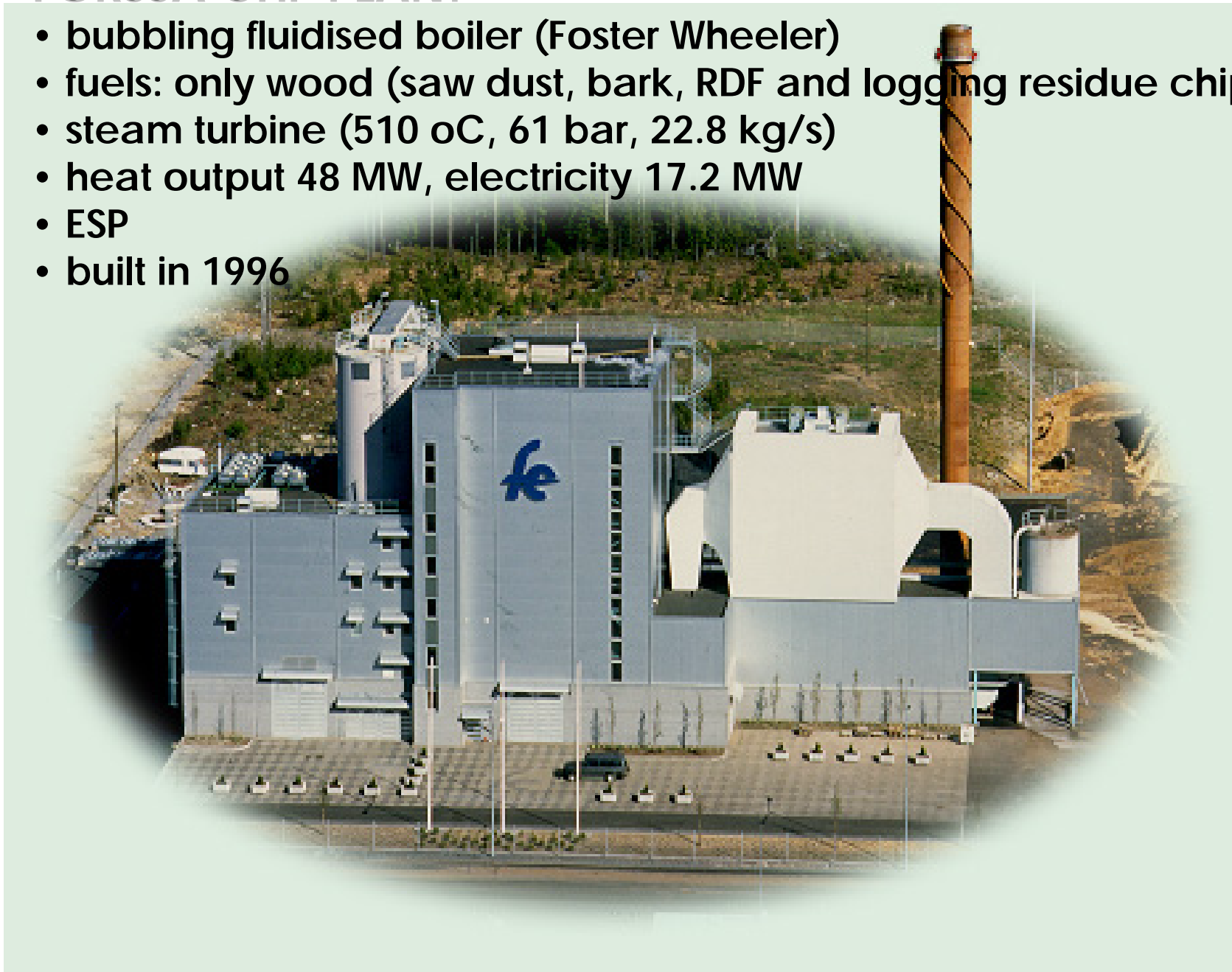
SMALL-SCALE POWER PLANT BASED ON FIXED-BED GASIFIER AND ENGINE

- Size class 100 - 3000 kW_e
- Bioneer gasifiers in commercial operation with peat and wood since 1982 in Finland
- Competitiveness is based on large number of "standard" plants
- Complete tar decomposition required - R&D in Progas
- Development of a novel fixed-bed gasifier



FORSSA CHP PLANT

- bubbling fluidised boiler (Foster Wheeler)
- fuels: only wood (saw dust, bark, RDF and logging residue chips)
- steam turbine (510 oC, 61 bar, 22.8 kg/s)
- heat output 48 MW, electricity 17.2 MW
- ESP
- built in 1996



SMALL SCALE CHP PLANTS IN FINLAND

Plant name	Starting	Electricity MW_e	Heat MW_{th}	Boiler type	Main fuel
Pieksämäki	1992	9	25	BFB	Peat and wood
Kankaanpää	1992	6	16	BFB	Peat and wood
Kuhmo	1992	5	13	CFB	Wood
Ylivieska	1993	5	15	BFB	Peat
Kuusamo	1993	6	17	BFB	Peat
Lieksa	1994	8	22	CFB	Peat and wood
Forssa	1996	7	48	BFB	Wood, RDF

New project proposal:

IN PRACTICE REALIZED MEANS OF REDUCING NO_x-EMISSIONS FROM WOOD COMBUSTION

The aim is to gather information from different IEA countries what have been results in trying to lower NO_x - emissions in wood combustion using different means

- results from R&D projects
- results from actual plants
- comparison of different means
- summary report in year 2000
- coordination Finland

Annex 6

Presented sheets on the Handbook of Biomass Combustion

IEA Bioenergy
Task 19: Biomass Combustion

State-of-the-art biomass combustion

Sjaak van Loo



Status

- Draft report send out;
- Few comments received (Norway, Finland, Sweden, EC)
- Some comments were appropriate critical:

Not enough depth to serve as a "Handbook of Biomass Combustion"

Proposed follow-up:

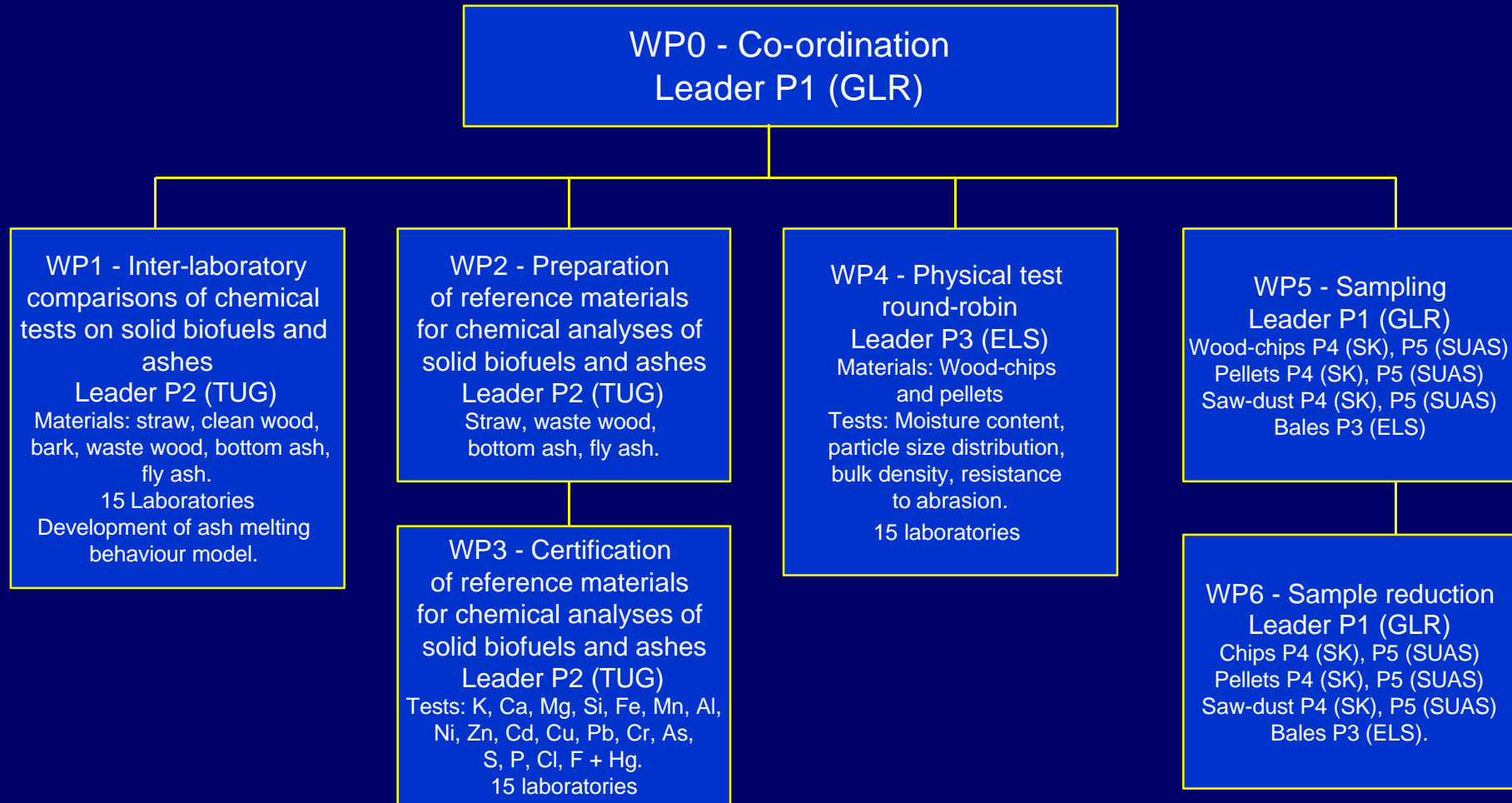
- Adjust the quality;
- IEA budget for authors/editors;
- All authors are mentioned;
- Printing in book form in a relative large edition.



Annex 7

**Presented sheet on the
IEA/EU standardisation project**

TBX project structure



Annex 8

Cofiring biomass with Coal

COFIRING BIOMASS WITH COAL

Larry Baxter and Allen Robinson¹

Sandia National Laboratories, Combustion Research Facility, Livermore, California

Cofiring biomass with coal in coal-fired boilers represents a near-term, low-risk, low-cost option for reducing greenhouse gas emissions, increasing renewable energy generation, and increasing sustainability of energy supplies from power production. Economically, cofiring competes favorably with other renewable options. This document focuses on four of the critical fireside issues associated with cofiring: ash deposition, NO_x production, corrosion, and carbon burnout.

Biomass ash deposition rates and NO_x emissions can either exceed or be less than those of coal, depending on the type of biomass used. SO_x emissions are nearly always reduced when biomass is cofired with coal. The potential for chlorine-based, high-temperature corrosion is lower for a biomass-coal blend than for pure biomass fuels in most cases, but it may not always be negligible. Biomass particles much larger than coal particles can be consumed in a pc boiler, but at sizes of 1/8 inch or larger there is increased chance of incomplete combustion. Substantial carbon-in-flyash problems are not anticipated until initial particle sizes exceed 1/4 inch. Specific guidelines are suggested in each area in terms of expected behavior and best-practice operation.

Prudent choices of fuels, boiler design, and boiler operation should lead to little or no fireside problems during cofiring. Less prudent choices can lead to significant boiler damage and operational costs.

1. INTRODUCTION

Concerns regarding the potential environmental impact of using fossil fuel are increasing in the US and abroad. These concerns arise from the related but not identical issues of sustainable power generation, renewable energy production, and global warming. One means of addressing these concerns is increasing the fraction of renewable and sustainable fuel in the national energy budget. Traditionally, renewable energy sources such as biomass struggle to compete in open markets with fossil energy, particularly when fired in dedicated power plants. Furthermore, many renewable energy technologies suffer from low efficiencies or high technical risk. This investigation describes a combination of renewable and fossil energy

¹ Currently at Carnegie Mellon University, Pittsburgh, Pennsylvania

utilization that derives the greatest benefit from both fuels: cofiring biomass with coal in pulverized-coal-fired boilers. Cofiring in this manner combines the efficiencies of **scale, design, and temperature** of coal-fired power plants with the renewable energy benefits of **qualified biomass**. **Qualified biomass includes** any source of biomass that is renewably and sustainably produced. This includes nearly all residual wood and agricultural products in the US.

Cofiring of biomass with coal in traditionally coal-fired boilers increases the potential market for renewable energies significantly beyond the realistic market for dedicated biomass systems while capitalizing on the large investment and infrastructure associated with the existing fossil-fuel-based power systems. When proper choices of biomass, coal, boiler design, and boiler operation are made, traditional pollutants (SO_x and NO_x) and net greenhouse gas (CO₂) emissions will decrease. In addition, the efficiency of power generation from biomass will increase relative to existing and many future stand-alone biomass power systems. Ancillary benefits include increased use of local resources for power, decreased demand for disposal of residues, and continued use of the large, reliable, and proven coal-based capacity that is the current backbone of the US power system. These advantages can be realized in the very near future with very low technical risk (1994; Tillman et al., 1994; Swanekamp, 1995; Boylan, 1996; Aerts and Ragland, 1997; Belle-Oudry and Dayton, 1997; Hunt et al., 1997; Junker et al., 1997; Robinson et al., 1998). However, improper choices of fuel, boiler design, or operating conditions could minimize or even negate many of these advantages while putting the boiler at risk.

The motivation and economics of reducing greenhouse gas emissions in this manner can be appreciated in part by comparison with other approaches to the same problem. While all methods of reducing carbon emissions will be required to reduce current emissions, cofiring provides more effect with less effort, cost, and risk than any other approach, with the possible exception of conservation. Figure 1 illustrates the efficiency increase required to produce the same amount of CO₂ reduction as a given level of cofiring. For example, cofiring 30 percent with a CO₂-neutral biomass fuel will achieve the same reduction in CO₂ emissions as increasing efficiency by a factor of 1.43. Cofiring 30 percent biomass is achievable in some power plants, though difficult for most. Increasing efficiencies by a factor 1.43 is not possible by any proven technology. A few benchmarks are indicated in the diagram for context, with efficiencies indicated in absolute numbers on the right ordinate, assuming a modern coal plant with 38% efficiency as a base case. The inset illustrates the region of the diagram of most practical interest. The rational upper limit to cofiring averaged across the nation lies somewhere between 5 and 15 percent by most estimates.

Any meaningful change in CO₂ concentrations in the atmosphere is going to require all of the advanced technologies, fuel substitution, conservation, sequestration, and other technology that can be mustered. However, fuel substitution is relatively easily accomplished with low capital investment (\$50-2001 kW on biomass in most cases) and reasonable fuel costs and virtually no technical risks. There are, however, fireside consequences to cofiring that may pose operational, equipment, or emissions risks. This document focuses on these issues and proposes practical guidelines in each area.

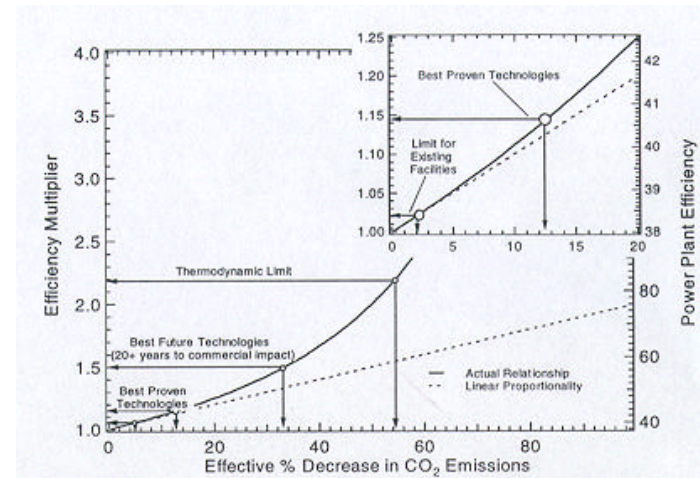


Figure 1. Comparison of increases in efficiency required to achieve the same reduction in CO₂ emissions as can be achieved by a given level of fuel substitution.

2. FUEL CHARACTERISTICS

The fuels investigated in the experimental portions of the work range from woody (lignaceous) to grassy and straw (herbaceous) materials. The former are generally the most easily adopted to pc-firing conditions while the latter represent opportunity fuels from relatively large agricultural residue sources and future fuels from energy crops. Biomass fuel properties vary more widely than do those of coal. As examples, ash contents vary from less than 1% to over 20% and fuel nitrogen varies from around 0.1% to over 1%. Other notable properties of biomass relative to coal are a generally high moisture content (usually greater than 25% and sometimes greater than 50% as-fired, although there are exceptions), potentially high chlorine content (ranging from essentially 0 to 2.5%), relatively low heating value (typically half that of hv bituminous coal), and low bulk density (as little as one tenth that of coal per unit heating value). These and other properties must be carefully considered for successful implementation of cofiring.

3. Results and Discussion

3.1. Pollutant production

Pollutant production investigated here includes emissions of both SO₂ and NO_x. SO₂ emissions almost uniformly decrease when firing commercially significant types of biomass, often in proportion to the biomass thermal load. An additional incremental reduction beyond the amount anticipated on the basis of fuel sulfur content is sometimes observed and is based on sulfur retention by alkali and alkaline earth metals in the fuels. Some forms of biomass contain high levels of these materials. The SO₂ emissions are relatively straightforward and are not illustrated in detail here.

NO_x emissions are more difficult to anticipate. Experimental characterization of NO_x emissions during combustion of neat coal, neat biomass, and various blends of the fuels combustion in a pilot-scale facility illustrate that NO_x emissions from biomass can either exceed or be less than those of coal (Robinson et al., 1998). Low-nitrogen wood fuels typically produce much lower NO_x, most commonly uniformly less than that of coal as a function of oxygen content. When analyzed on a lb NO_x per unit energy production basis instead of a ppm basis, NO_x emissions from biomass fuels increase disproportionately compared to coal. Still, wood fuels generally produce lower NO_x emissions than coal, and herbaceous fuels may be higher or lower, depending on overall oxygen concentration and fuel nitrogen content.

The large difference in fuel oxygen contents between biomass and coal suggest that blends (yt-- coal and biomass could produce quite different results than would be expected based on the behavior of the individual fuels. However, our data suggest there is no significant chemical interaction between the off-gases.

Figure 2 illustrates a comparison of measured NO_x emissions for a variety of coal-biomass blends with those predicted from the behavior of the pure fuels. Points that fall along the diagonal indicate no significant interaction. Importantly, all of these experiments were conducted without low-NO_x burners, fuel staging, reburning, etc. Generally, NO_x emissions from blends of coal and biomass interpolate quite accurately between the measured behaviors of the neat coal and biomass fuels if no low-NO_x burner, fuel staging, or boiler technology is used. Since biomass produces a significantly larger volatile yield than coal, there is potential for biomass to create large fuel-rich regions useful for NO_x control. The biomass fuels best suited for use in pc boilers are woods, most of which reduce total NO_x emissions significantly below that from coal.

The guidelines derivable from this work relative to NO_x emissions include the following: (1) there is insignificant chemical interaction between the off-gases from biomass and coal that would alter NO_x emissions; (2) NO_x emissions from the most well-suited biomass fuels for cofiring (wood residues) generally are lower than those from coal, leading to some overall NO_x reduction relative to coal during cofiring; and (3) the large volatile yield from biomass can be used to advantage to lower NO_x emissions during cofiring through well-established, stoichiometric-driven means.

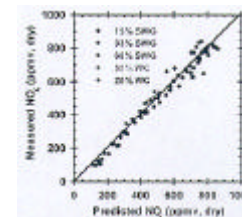


Figure 2. Comparison of measured NO_x concentrations to concentrations interpolated (predicted) from the measured behavior of the pure fuels. Data along the diagonal line indicate no interaction between the fuels.

3.2. Ash deposition

Ash deposition rates from biomass fuels can greatly exceed or be considerably less than those of coal. Figure 3 illustrates rates of deposit accumulation during standardized experiments on simulated superheater tubes. Absolute deposition rates from some herbaceous fuels exceed that of coal under identical conditions by about an order of magnitude whereas deposition rates for high-quality woods are nearly an order of magnitude less than that of coal. These trends are in part attributable to the ash contents of the fuels. When normalized for ash content differences, ash deposition efficiencies of herbaceous materials still exceed those of coal, whereas those of wood are lower. These trends can be described in terms of ash particle sizes and chemistry. Deposition rates from blends of coal and biomass lie between the observed rates for the neat fuels but are generally lower than one would expect if interpolating between the behavior of the neat fuels.

Experimental evidence supports the hypothesis that this reduction in ash deposition occurs primarily because of interactions between alkali (mainly potassium) from the biomass and sulfur from the coal. Some of these data are presented in the discussion of corrosion.

The guidelines relative to ash deposition include the following: (1) deposition rates should decline when cofiring wood or similar low-ash, low-alkali, low-chlorine fuels; (2) deposition rates should increase when cofiring high-chlorine, high-alkali, high-ash fuels, such as many herbaceous materials; and (3) deposition rates depend strongly on both individual fuel properties and interactions between the cofired fuels.

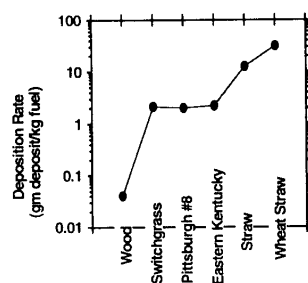


Figure 3. Rates of deposit accumulation during standardized investigations on simulated superheater tubes in the Multifuel Combustor.

3.3. Carbon conversion

It is impractical to reduce most biomass fuels to the size of pulverized coal. A small fraction of such fuels, such as sander dust, are available in small sizes because of upstream processing. The great majority of fuels will require size reduction. Size reduction of biomass is nearly always more energy intensive than for coal. A concern regarding overall burnout of the biomass fuel arises as the sizes of pulverized coal particles are compared with those of practically achievable sizes for biomass fuels. Biomass and coal are consumed by both thermal decomposition (devolatilization) reactions and by char oxidation. A larger fraction of biomass is released as volatile gases during combustion (85-95% of initial particle mass) than is released from coal (50-65%). This large volatile yield occurs over a relatively short time and greatly decreases the time required for complete combustion compared to a coal particle of similar size. The largest fraction of biomass' and coal's combustion history involves char oxidation. Experimental data indicate that biomass chars burn under strongly diffusion controlled conditions, as is consistent with theory. However, the rates of combustion differ from those of coal owing to its generally nonspherical shape and lower char density, both of which effects can be reasonably well modeled. Furthermore, the slip velocity between char particles and local gas is higher for biomass than coal, increasing the effective residence time of a char particle for combustion. Moisture content also greatly affects biomass burnout time. Devolatilization, while slower for biomass than coal, is generally much shorter than either drying or char combustion. The increased time for biomass devolatilization relative to coal is hypothesized to be associated with intra-particle temperature gradients in the relatively large biomass particles.

The guidelines relative to carbon conversion derivable from this work include the following: (1) particles prepared with top sizes greater than 3 mm (1/8 inch) will experience increasing difficulty completing combustion, with significant residual carbon expected at

sizes greater than 6 mm (1/4 inch) as measured by the smallest dimension in the typically non-equant particles; (2) fuels with moisture contents exceeding 40% will need to be reduced further in size to achieve complete combustion; and (3) biomass char burning rates are controlled by geometry and size, not kinetics, making burning rates essentially fuel independent if size, shape, density, and moisture contents are the same.

3.4. Corrosion

The high chlorine and alkali contents of some biomass fuels raise concerns regarding corrosion (Baxter and Nielsen, 1997; Nielsen et al., 1998). The greatest concern focuses on high-temperature corrosion of superheater tubes induced by chlorine on the surface. The corrosion aspects of this investigation characterized chlorine concentration in the deposit and its dependence on operating conditions. Chlorine selectively deposited on heat transfer surfaces, and the data are consistent with a mechanism of alkali chloride condensation. More significantly, the amount of chlorine in the deposit decreased sharply with increasing sulfur content, consistent with thermodynamics and the proposed mechanism. The stoichiometry of the overall chemical reaction between alkali chloride and sulfur defines a parameter describing the potential chlorine concentration in a deposit as a function of fuel properties (Robinson et al., 1998). The theoretical description is based on the stoichiometry and thermodynamics of reactions between chlorinated and sulfated alkali. At values greater than unity, this parameter indicates that very little chlorine should remain on the heat transfer surface at equilibrium. As values decrease from unity, significant chlorine is predicted to remain on the surface. As indicated in the figure, the data indicated that significant amounts of chlorine remain in the deposit well beyond the point that equilibrium considerations alone would predict none (values of the abscissa above unity). This illustrates that there are kinetic or transport effects that limit the conversion of alkali chlorides to alkali sulfates. Chlorine in the deposit was not avoided until four to eight times as much sulfur was present in the gas phase as is required by equilibrium to react with all of the alkali.

The guidelines relative to avoiding chlorine-based corrosion in the boiler are as follows: (1) fuel chlorine should be minimized in all cases; (2) the ratio of sulfur to available alkali or chlorine should be maintained at values above about 8; and (3) tube surface temperatures should be kept as low as possible.

4. CONCLUSIONS

This work demonstrates that the potential advantages of biomass-coal cofiring, as outlined above, can be achieved without risk to the boiler if judicious choices regarding fuel selection, boiler operation, and boiler design are made. Conversely, non-judicious choices can lead to potential risk for the boiler and troublesome operation. The most benign fuels are high-quality woods, with increasingly careful attention to boiler operation and fuel selection required as fuel properties move more toward those typical of some high-alkali, high-chlorine, high-ash, and high-nitrogen forms of biomass.

5. ACKNOWLEDGEMENTS

This work is supported by DOE's Offices of Fossil Energy (FE) and Energy Efficiency and Renewable Energy (EE). FE support is from the Federal Energy Technology Center, with Phil Goldberg is project manager. EE support comes through the Biomass Power Program; Raymond Costello is the project manager.

REFERENCES

- (1994). Wood Fuel Cofiring at TVA Power Plants Volume 1: Retrofitting Existing Boilers to Cofire Wood Fuel, Electric Power Research Institute.
- Aerts, D. and K. Ragland (1997). Co-firing Switchgrass and Coal in a 50 MW Pulverized Coal Utility Boiler, University of Wisconsin-Madison.
- Baxter, L.L. and H.P. Nielsen (1997). The effects of fuel-bound chlorine and alkali on corrosion initiation, Abstracts of Papers of the American Chemical Society 214 (pt.1), Fuel, Vol. 44.
- Belle-Oudry, D.A. and D.C. Dayton (1997). Analysis of combustion products from the cofiring of coal with biomass fuels, 214th American Chemical Society National Meeting, Las Vegas, Nevada.
- Boylan, D.M. (1996). Southern Company tests of wood/coal cofiring in pulverized coal units, Biomass and Bioenergy, 10, pp. 139-147.
- Hunt, E.F., D.E. Prinzing et al. (1997). The Shawville coal/biomass cofiring test: A coal/power industry cooperative test of direct fossil-fuel CO₂ mitigation, Energy Conversion and Management, 38(Suppl.), pp. S551-S556.
- Junker, H., L.L. Baxter, et al. (1997). Cofiring Biomass and Coal: Plant Comparisons and Experimental Investigation of Deposit Formation. Engineering Foundation Conference on the Impact of Mineral Impurities on Solid Fuel Combustion, Kona, Hawaii.
- Nielsen, H.P., L.L. Baxter, et al. (1998). Deposition of potassium salt on heat transfer surfaces in straw-fired boiler: a pilot-scale study, submitted to Fuel.
- Robinson, A.L., H. Junker, et al. (1998). Interactions between coal and biomass when cofiring, Twenty-Seventh Symposium (International) on Combustion, Boulder, Colorado, Combustion Institute.
- Swanekamp, R. (1995). Biomass co-firing technology debuts in recent test burn, Power, 139, pp. 51-53.
- Tillman, D.A., E. Hughes, et al. (1994). Cofiring of biofuels in coal fired boilers: Results of case study analysis. 1st Biomass Conference of the Americas, Burlington, Vermont.

GAS COFIRING FOR PERFORMANCE IMPROVEMENT AND EMISSIONS REDUCTION IN BIOMASS-FIRED BOILERS

H.B. Mason,' L.R. Waterland,' S.A. Drenman,b I.S. Chan,~ V. Tiangco,' C. Knight,~ R.J.Auzenne'

'Arcadis Geraghty & Miller, 555 Clyde Avenue, Mountain View, California 94039 ' Coen Company, Inc., Burlingame, California

'Gas Research Institute, Chicago, Illinois 'California Energy Commission, Sacramento, California 'Burney Mountain Power, Sumej, California 'Fairhaven Power Co., Eureka, California

Although biomass is an economical and renewable boiler fuel, its variability in fuel composition and moisture can severely limit boiler performance. The solid-bed method of biomass firing, aggravated by high moisture levels, can cause boiler derates, poor load following during peaking power demands, and high levels of particulate or CO emissions. Gas cofiring is a technology whereby a small amount of gas is fired through dual side-wall burners to correct problems with biomass combustion and thereby improve performance and reduce emissions. In this project, a 105,000 lb/hr boiler at Burney Mountain Power powering an 11 MW generator, and a 180,000 lb/hr boiler at Fairhaven Power powering an 18 MW generator, are being retrofit for gas cofiring. To meet permit requirements and reduce total emissions impacts, a special low-NO_x gas cofire burner is being developed by Coen Company. The burner uses a high pressure drop to maximize flame penetration into the boiler and offer high turndown. The mixing of the gas and air is patterned to give internal staging and flame cooling to reduce NO_x. At Burney, the cofire retrofit will allow the plant to attain full contractual load during the peak periods, and enable reducing load to a hot standby during off-peak periods. Cofiring at Fairhaven will allow compliance with NO_x and CO emissions while maintaining full load with wet wood.