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

Tuesday - Friday, June 6-9, 2000
Melia Lebreros hotel
Sevilla, Spain

IEA Working Group Meeting Task 19
Biomass Combustion
6-9 June, 2000, Sevilla, Spain

Content

Programme

Tuesday June 6: Co-firing workshop

Jointly organised with EU Thermie B project DIS/1743/98-NL, IEA Clean Combustion Sciences and IEA Bioenergy Task 19. Chairman: Gerard Smakman, NOVEM, NL, co-chairman: Phil Goldberg, IEA CCS

15:45 Opening, Chairman
15:55 Co- combustion in Scandinavia using fluid bed furnaces (Pia Salokoski, Fortum, Finland)
16:20 Co- combustion in coal power plants in Central Europe (F. van Dijen, EPON, Netherlands)
16:45 coffee break
17:15 Practical concepts for parallel firing, pre- gasification and gas cleaning (Claus Greil, Lurgi, Germany)
17:40 Overview of technical barriers related to co-firing (Christine Rösch, IER, Germany)
18:05 Overview of non-technical barriers related to co-firing (Harry Schreurs, NOVEM, Netherlands)
18:30 Overview of experiences with co-firing in the US (Larry Baxter, Sandia, USA)
19:00 Discussion

Thursday June 8: Task meeting part I

9:30 Coffee
10:00 Opening, Sjaak van Loo
10:15 Report of last meeting / Information from IEA / News flash, Sjaak van Loo
10:30 Comments on the handbook on biomass combustion, Chapter co-ordinators
12:00 Lunch
19:30 Task dinner

Friday June 9, 2000: Morning session: Modelling workshop

9:00 Opening, *Sjaak van Loo, leader IEA Bioenergy Task 19*
9:15 Background of Task 19 and results of questionnaires, *Jaap Koppejan (NL)*
9:30 Presentations of individual models

- Modelling of biomass and waste combustion at TNO, A.R.J. Arendsen, TNO, Netherlands
- Biomass Modelling Tools at Åbo Akademi, Edgardo G. Coda Zabetta, Åbo Akademi, Finland
- Modelling of batch combustion processes, Øyvind Skreiberg, Norwegian University of Science and Technology, Norway
- Optimisation of Low-NOx biomass grate furnaces with CFD modelling, Robert Scharler, TU Graz, Austria
- Mathematical models for design and development of fixed-bed gasification systems, Colomba Di Blasi, Università degli Studi di Napoli "Federico II", Italy
- A numerical model for fixed bed combustion, Jenny Larfeldt, TPS, Sweden

10:20 Coffee
10:40 Presentations of various models (ctd)

- CFD modelling of biomass combustion, Xue-Song Ba, Lund Institute of Technology, Sweden
- Modelling of Solid Fuel Conversion and Transport with TOSCA, Bernhard Peters, FZK, Germany

- Modelling wood combustion in grate furnaces by calculation of the solid fuel transport and conversion on the grate followed by CFD calculations in the gas phase, Thomas Nussbaumer, Verenum, Switzerland
- Straw Bed Conversion, Robert van der Lans, CHEC, Inst. for Kemiteknik, DTU, Denmark
- Application of the 3D Combustion Code AIOLOS to Small Scale and Industrial Combustion Systems, Sven Unterberger, IVD, Stuttgart, Germany

11:30 Discussion on options for mutual co-operation and Task 19 involvement
12:30 Joint lunch with participants in modelling workshop and Task 19 members

Afternoon session: Task meeting, part II
13:30 Country presentation from Australia and introduction
14:00 Initiation of an internet site on Task 19
14:30 Cofiring Task activity: results of questionnaires, work programme and MOU with IEA CCS, *Sjaak van Loo (NL), Larry Baxter (USA)*
15:45 Break
16:15 Collaboration with Task 28 and status of EU - TBX proposal on characterisation of solid biofuels, *Jaap Koppejan (NL), Ingwald Obernberger (A)*
17:00 Other topics
17:15 Announcement of next meeting

Attendance list IEA-meeting, 6-9 June 2000, Sevilla

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Summary of the meeting

Tuesday June 6: Co-firing workshop

The final seminar of the EU Thermie B project “Addressing the constraints for successful replication of demonstrated technologies for co-combustion of biomass/waste” was held at the 1st World Conference and Exhibition on Biomass for Energy and Industry and was supported by the IEA Coal Combustion Science Group and the IEA Bioenergy Task 19: Biomass Combustion. It was organized by TNO-MEP. Over 130 participants attended the seminar which incorporated both the results of the two workshops held earlier in the EU-project as well as co-firing experiences and research activities in the USA. A summary of the meeting is given below, the full report is available from TNO-MEP.

The final seminar was chaired by Gerard Smakman (coordinator of the EU project and Operating Agent for Task 19) together with Philip Goldberg (DOE, USA and active in IEA CCS). Presentations were given by Pia Salokoski (Fortum, Finland) and Frans van Dijen (EPON, Netherlands) on the situation for co-combustion in Scandinavia and central Europe. Claus Greil (Lurgi, Germany) focused on the practical concepts for parallel firing, pre-gasification and gas cleaning with particular emphasis on CFB gasification. The technical barriers related to co-firing which were identified during the first project workshop were listed by Christine Rösch (IER, Germany), while the non-technical barriers identified at the second project workshop were listed by Harry Schreurs (NOVEM, Netherlands). The meeting was closed with experiences with cofiring in the USA in a presentation from Larry Baxter. Regretfully, there was no-one from the EU present to elaborate on future EU policies and support to cofiring initiatives under the 5th Framework Programme.

Co-combustion is practised with different types and amounts of biomass wastes in different combustion and gasification technologies, configurations and plant sizes. Currently, direct cofiring is the most commonly applied configuration. The typical configuration applied in Finland is a fluidised bed combustion installation within the range of about 20 to 310 MW where different biomass wastes from forest industries are directly cofired, eventually with REF, RDF, coal or oil. Here, installations need to be fuel flexible, one reason for this is that the sparsely populated countries make specialized mass burning installations uneconomical. In Sweden, there are a large number of grate fired boilers in the range 1-30 MW which are operated for district heating (mostly firing "biomass" only, but it often means co-combustion of different types of residues). In paper and pulp industries, there are both fluidised and grate furnaces that burn mixtures of bark, sludges, wood residues, oil and some coal. A couple of PF boilers in Sweden are converted to fire pulverised biomass and/or a mixture of biomass/coal, biomass/peat or biomass/oil (80-300 MW th). A major factor is the taxation system, which makes heat generation more attractive by using biomass and electricity production more attractive by using fossil fuels. For this reason, it is attractive for operators of a cogeneration facility to cofire a share of biomass in the fuel mix according to the heat demand.

In Austria, co-combustion is accomplished mainly in the pulp and paper industries, using their own residues and wastes (e.g. black liquor) in small industrial boilers and in two large scale demonstration units of Verbund AG. In the Netherlands and Germany, biomass wastes (i.e. sewage sludge, demolition wood) are co-combusted at relatively small percentages in coal-fired power stations. In the USA, many test programs have been carried out with co-

combustion of biomass and waste with coal. In the USA, the generation capacity for cofiring biomass and wastes in existing coal-fired plants could theoretically reach 2 GW by 2005 and 5 GW by the year 2010. Current government support measures (tax incentives etc) however need to be modified to realize such growth rates. The current experience in the USA is almost limited to non-commercial tests.

Indirect cofiring by pre-gasification is applied in a number of demonstration plants in Austria (Zeltweg), Finland (Lahti) and the Netherlands (Geertruidenberg). One of the major advantages is that ashes of the main fuel and the co-combusted fuel are kept separate. In parallel firing installations such as applied at a combination of a MSWI and gas fired combined cycle power plant in Moerdijk (Netherlands), a fully separate combustion installation is used for the biomass/waste and the steam produced is fed to the main installation where it is upgraded to higher conditions. Though the investment in indirect cofiring and parallel firing installations is significantly higher than in direct co-combustion installations, advantages such as the possibility to use relatively difficult fuels with high alkali and chlorine contents and the separation of the ashes are reasons why this can be justifiable.

Technical barriers related to the receiving, handling, storage, pre-processing, conveying and feeding of biomass waste in a co-combustion installation are mainly related to the type and consistence of the biomass waste used as co-combustion fuel. For example, the receiving, handling and storage of fresh wood chips or other wet fuels may cause odour or spore emissions. The technical constraints affecting the combustion system, the emission control and the usability depend on the plant process and technology as well as on the properties of the biofuels used for co-combustion.

Most of the problems occurred have been solved partially or completely. The major technical constraints remaining are erosion and chlorine-induced corrosion. Other technical constraints, which have not always been overcome satisfactory, are the functionality of the boiler cleaning systems and the resistance of the heat exchanger materials and the reduction of NO_x emissions. SCR catalyst manufacturers often do not provide guarantees for operation with biomass fuels because of the negative influence of alkalis in the fuel on the catalyst. The higher content of unburned ashes in the bottom and fly ashes can also be a problem, depending on the burn-out efficiency of the plant and the use of the ashes. As stated before, indirect co-combustion is one way to avoid operational problems in the main boiler.

The amount of flue gases per unit of energy resulting from biomass combustion is much larger than that of coal. When co-firing biomass, this implies that flow patterns of combustion gases through the boiler can be dramatically modified. This limits the percentage of biomass that can be co-fired.

Several non-technical barriers are identified with co-combustion. Future government support, such as tax incentives, is uncertain for the lifetime of a co-combustion plant. In a liberalising European energy market where cost cutting is crucial for survival, the country policies on emissions, subsidies, taxes etc. still vary significantly. Since local authorities can impose even more stringent emissions limits in the permits, geographical differences in flue gas cleaning and water cleaning requirements may occur for the companies throughout the country. The presence of a European level playing field with uniform policies is therefore essential. Further, the draft emission legislation for co-combustion installations is (at least for non-clean biomass) more stringent than for stand-alone installations. Related to this is the uncertainty in more stringent emission standards for co-combustion installations, directly affecting the feasibility through additional gas cleaning equipment required.

Especially for larger installations, there is only limited experience with fuel handling, logistics, sampling, and trading. Since future availability and prices of fuel are uncertain in a growing bioenergy market, long term fuel supply contracts are made with a higher than usual fuel price. The different company culture of traditional biomass traders and the power companies may result in differences in opinion and conflicts. The NIMBY effect needs to be avoided by creating awareness with local municipalities, communicating plans and improvement of the local image.

A major barrier is the marketability of fly-ash in installations where biomass is co-combusted with coal. Although the quality of fly-ash from such processes as ingredient in cement or concrete should not necessarily be worse than that of pure coal firing, current building material standards restrict the use of fly ash to that of coal only.

Thursday June 8: Task meeting part I

Opening

The official Task meeting took place on June 8-9 in the Melia Lebreros hotel in Sevilla and was chaired by Sjaak van Loo (Task leader). After welcoming everyone, the report of meeting 4 in Oakland was approved by the task members without further comments.

Information from IEA

Late May, Sjaak van Loo has presented a proposal by to the ExCo on continuation of Task 19 in the triennium 2001-2003 with the new name 'Biomass Cofiring and Combustion'. It is enclosed in the annexes. As the shift in name indicates, more emphasis will be on co-combustion of **biomass** in **existing coal**-fired power plants. As a reaction it was commented by Claes Tullin that cofiring biomass with various wastes is already performed in several fluidised bed installations in Sweden. One way in which Task 19 could be instrumental is by recommending certain co-firing technologies for certain fuels and conditions.

During the next Task meeting, proposals for new Task activities will be discussed. Task members are invited to submit proposals to the Task leader that could be performed under the flag of the new Task with measurable milestones, a time table, a total budget and efforts of Task members (based on national programs). Part of the budget of the Task leader will be allocated for such activities.

An evaluation will be held on the performance of the current task under its task members. Everyone is invited to submit strengths and weaknesses felt under the current task and suggestions for improvement.

Handbook on biomass combustion

The content of the revised handbook was discussed through chapter-by-chapter presentations of the chapter authors. It was generally agreed that the quality of the handbook has already significantly improved as compared to the previous version.

It was mentioned that the final product should be a reference handbook on biomass combustion with a clear, logical structure and well balanced division of topics to provide a good introduction to the subject of biomass combustion. Quality is more important than quantity. Enough references should be included to help the interested reader to find more information. Instead of illustrations, principles should be shown. For example, the chapter on domestic biomass combustion now contains too many graphs with only little differences. Similarly, figure 2.1 shows the combustion of methane and should therefore be taken out. An index should be included and the nomenclature used described.

Currently there are two types of information in the handbook:
1. Constant, remaining information e.g. combustion principles
2. Constantly changing data such as emission guidelines.

It was decided to split up the previous chapters 4 and 5 and add a chapter on R&D needs. The revised Table of Contents is given below:

1. Introduction	Austria
2. Basic principles of combustion	Norway
3. Domestic biomass heating applications	Finland
4. Biomass Fuel Supply and Pre-Treatment	Austria
5. Industrial applications	Austria
6. Power generation and cogeneration	Switzerland
7. Co-combustion	UK
8. Environmental aspects of combustion of biomass	Denmark
9. Research and development - needs and ongoing activities	Austria

Specific additional inputs requested are:

Chapter 1 (Introduction, Austria):
Input from every member country to chapter 1.1 is needed (political side constraints to increase the use of biomass for energy) - those countries which are already implemented in chapter 1.1 should critically review the text regarding their country and if necessary send corrections or changes to Inwald Obernberger; those countries which are not considered so far should provide a brief description about their country regarding the above mentioned topic.

The introduction should include a clear definition of biomass and why it is considered renewable and environmentally friendly.

Chapter 2 (Basic principles of combustion, Norway):
Data on ultimate and proximate analysis of biomass fuels will be included in table 2.2. It is suggested to host a small program for the calculation of the adiabatic combustion temperature of biomass fuels on the Internet site of Task 19, once established.

Chapter 3 (Domestic biomass heating applications, Finland):
The structure of the chapter will be changed to the type of fuel:
1. log combustion
2. pellet combustion
3. chip combustion

All data on emissions should go to chapter 8 (environmental aspects) The word ‘Wood’ in the title of this chapter will be replaced by ‘Biomass’.

Chapter 4 and Chapter 5 (Austria)
The previous Chapter 4 (industrial biomass combustion) will now be split in two separate chapters : chapter 4 on Biomass Fuel Supply and Pre-Treatment and chapter 5 on Industrial applications.

Chapter 6 (Power generation and cogeneration, Switzerland):
Previously the first part of chapter 5. The part on co-combustion will move to chapter 7.

Chapter 7 (Co-combustion, UK)
Is was generally agreed that an additional chapter on co-combustion will be included. William Livingston offered to coordinate this work.

Chapter 8 (Environmental aspects, DK)
It was mentioned that more information on ash utilisation should be included in this chapter. Please forward country specific information on ash utilisation to Henrik Houmann Jakobsen

Chapter 9 (R&D, Austria):
All countries should critically review R&D needs and ongoing activities in the field of biomass combustion addressed in this chapter and make additions or comments regarding further needs and activities if necessary (with reference to relevant publications / projects).

Follow-up actions
We suggest to have a next draft available before the next task meeting. In order to meet this target, all members are requested to submit their detailed contributions and comments to the chapter coordinators. Chapter coordinators are requested to distribute specific information needs. Upon revision of the chapters, all chapter coordinators are requested to mail us their revised version so we can put them together and start editing the whole book. This process will take quite some time.

Regarding the distribution of the document, Sjaak van Loo will explore ways for publication of the report (e.g. through a university press). The Task will create and publish its own handbook without direct involvement of IEA Caddet. The handbook will be an IEA publication and published as a joint product of the members of Task 19. Authors will not be mentioned by chapter but jointly on one of the first pages.

Suggested time schedule:
31 August: deadline for additional inputs to chapter coordinators
15 October: deadline for submission of chapters to task leader
30 November: distribution of second draft version of handbook to all
7/8 December: discussion of second draft version at next task meeting

Friday June 9, morning: Modelling workshop

On Friday morning, the Task 19 workshop on modelling the combustion of biomass took place. The report of the modelling workshop has already been distributed to all participants and task members.

Of the 13 organisations that were invited on the basis of a questionnaire send out earlier, 11 participated. The workshop provided a floor for developers of various biomass combustion models from different organisations and countries to exchange experiences and difficulties in an open setting, which was much appreciated.

While many application models are based on a CFD calculation code, the level of physical and chemical knowledge built into the CFD code may vary from one model to another, depending on the application of the model. Most models are developed together with an equipment manufacturer to provide insight in the effects of boiler modification on combustion quality. Although the accuracy of the models is typically insufficient to calculate emissions from a given combustion installation, modelling may be very instrumental in evaluating the effects of boiler modification on combustion quality (e.g. by placing additional nozzles or a baffle). One reason for the inaccuracy of CFD codes is the fact that most of these codes have in the past been developed for coal combustion.

However, there is still a great need for knowledge on the consequences for selecting a set of physical and chemical mechanisms on the accuracy of the model, depending on the type of application. While the chemical mechanisms are usually quite well understood and described, the physical mechanisms (turbulence, convections, etc) are much less understood. A steering guide that tells which model to use for what kind of situation would be welcome.

Many models are based on empirical results, and the accuracy of certain assumptions or equations chosen is unknown. Closely related to this is the problem that it may be difficult to solve some complex or implicit thermodynamic equations. It was therefore suggested to communicate proven approaches in this field.

In order to cross-check the validity of the various models applied, it was suggested to perform a validation test. Modelling a whole furnace makes it unclear where errors occur, therefore a validation test should be simple and describe only a submodel of an installation. It was agreed that the devolatalization of biomass on a fuel bed is least understood (e.g. the great influence of alkalis on the char yield) and therefore difficult to describe and calculate. However, since the data requirements of the various models for the fuel bed vary quite a bit, lots of data would be needed and it is questionable whether such a data set would be available at all. Other difficulties generally felt are related to the bed dynamics and the radiation mechanisms.

All participants are asked to list and prioritise the difficulties felt with the development of combustion models, in order to identify eventual follow-up activities. It is anticipated that some of the problems identified during the discussions may be surmounted through bilateral or multilateral future cooperation.

After the morning workshop, a joint lunch was arranged with Task 19 members and the participants in the modelling workshop.

Friday June 9, afternoon: Task meeting, part II

Country presentations

Being a new Task member, Peter Coombes presented an overview of the activities in **Australia** in the area of biomass combustion. Copies of the overhead sheets are attached in annex 2.

Australia participates in Task 19 through the Biomass Taskforce, an association of 28 organisations from industries, government and R&D. Peter Coombes of Delta Electricity represents this Biomass Taskforce.

A large driving force for bioenergy is the mandatory purchase of renewable energy by retailers of electricity (9500 GWh in 2010) using renewable energy certificates. Similar to other countries, Australia recognizes co-firing biomass with coal as one of the most cost-effective options for CO_2-mitigation. The focus of co-firing research is on fuel storage, processing and handling issues, combustion and char burnout, and ash related issues such as deposition. Another interesting option in Australia is the replacement of exisiting low pressure steam boilers and turbines in sugar mills by equipment with larger steam pressure and electricity generation conversion efficiency.

After the presentation of Peter Coombes, all other task members shared recent developments in their respective countries. A summary is given below:

Belgium will implement a system on green certificates for electricity produced from sustainable sources. A 5 percent target for green electricity in 2005 must mainly be realised with offshore windparks and biomass. As the availability of biomass may become a restricting factor, there will be more emphasis in the near future on forest extension, energy crops, import and biomass characterisation.

The current biomass use in **Austria** is 100 PJ, it is foreseen that this will double in the coming decades. One way is by subsidised introduction of wood pellet combustion. The share of renewable electricity in the electricity supply mix should grow by an additional until 2005. For electricity from biomass, a buyback rate of about 0,10 Euro/kWhe is expected. It is foreseen that more biomass CHP installations will become operational, also using ORC cycles and Stirling engines. Two co-combustion installations are now operational: a CFB pregasifier before a coal furnace and a PC burner, refurbished with a biomass grate. Combustion trials are done on miscanthus and waste wood. One driving force for increased attention for waste wood is a ban on dumping combustible wastes after 2005.

In **Denmark**, a follow-up programme for small scale solid biomass CHP plants has been started by the Danish Energy Agency to evaluate the experiences from 20 existing CHP plants (See annex 3.). A wide variety of plants are investigated, including gasification, stirling engines, steam turbine plants and a pyrolysis plant. After the evaluation, more existing heat-only plants may convert to CHP.

In **Finland**, biomass co-combustion has been practised for a long time, in the near future it is foreseen that the share of biomass and peat to be co-fired will increase to 25%. As a consequence of a bias in tax conditions, it becomes more attractive to substitute peat by wood residues. More focus has therefore been on the efficient harvesting and combustion of forest residues. Also, existing peat power plants are retrofitted to burn wood, using fluid bed technologies. In order to reduce processing costs for municipal solid waste in sparsely populated country as Finland, co-combustion of MSW with other fuels is practised in several projects.

Finland is interested in initiating a research project on NO_X reduction together with other Task members. See annex 4. The aim is to evaluate the results from several R&D projects and actual plants, comparing the effectiveness of various measures. Heikki Oravainen will distribute additional information to everyone.

In **Sweden**, pellet production has already reached 1 million tons, while the current domestic market for pellets is only 600 ktons. High availability of low-cost residues is a driving factor. A small scale biomass programme of the Swedish National Energy Administration (STEM) is operational (budget of 2,5 Meuro/year) with an increased emphasis on emission reduction. Also, combustion of waste wood and sludge becomes more important in Sweden. Analogous to Austria and other countries, dumping of combustible wastes will be prohibited after 2002. Sweden has applied for an EU project on the combustion of waste wood.

In the **Netherlands**, a new emission guideline for biomass combustion has been announced by the ministry of environment. This guideline is considered rather stringent by many (dust= 10 $mg/m3_{11\%\ O2}$ and NO_x = 70-133 $mg/m3_{11\%\ O2}$, depending on efficiency). Because it is relatively more expensive to obey these norms at a small scale, it is anticipated that especially the feasibility of small scale biomass combustion will be affected.

More emphasis is laid on biomass co-combustion in coal-fired plants. One reason is the relatively low fixed and variable costs. Another reason is the environmental requirement recently issued that coal power plants should lower their CO_2 emission per kWh produced to a level which is equal to that of natural gas fired installations. This implies that the existing coal power plants should cofire around 40% biomass on an energy basis.

Though **New Zealand** avails of large resources of hydro for electricity generation, there is a large market for heat generation until 10 MW_{th}. Main barriers for increased application of biomass boilers are their limited fuel flexibility in a situation with limited fuel contractability and the relatively high investment. There is a need for modellers to design more fuel-flexible combustion technologies with acceptable costs.

Core activities of the **USA** biomass programme are energy crop cultivation, co-firing and gasification (the Vermont project). In the field of legislation and tax incentives, efforts are made to promote bioenergy. The market for ‘Green Energy’ still needs to be developed significantly, a major reason is the fact that biomass still has a negative image with the public and many environmental groups. Cofiring biomass in existing coal plants is a cost-effective option to reduce CO_2-emission, but problems are with ash utilisation and the deactivation of the catalysts through alkali’s present in the biomass. For safety reasons, several factilities are trying to substitute SNCR using ammonia by SCR installations.

Co-combustion

During the current triennium, few activities has been done in the area of co-firing. The latest event in which Task 19 was involved, was a workshop during the Sevilla biomass conference on the barriers of cofiring biomass. In the next triennium, the Task will put more emphasis on the problems identified with co-combustion, as descripted in Annex 1. It is foreseen that more interaction will take place with IEA Clean Combustion Sciences, a Memorandum of Understanding has already been signed (see annex 5).

Analogous to Task 19, CCS is task shared, which implies that collaboration in task activities is done on and voluntary basis using national budgets. Members of CCS are Germany, Italy, Canada, USA, Japan, Denmark, Finland, Netherlands and Australia. The coordinator of CCS will forward addresses of CCS task members and a list of meetings of the CCS task to members of Task 19.

A major barrier identified is ash utilisation, since many CEN, ISO, DIN and ASTM standards forbid the use of fly-ash derived from other fuels than coal in cement. Though research has shown that concrete strength is generally not affected when cofiring biomass, it **may** be affected when cofiring herbaceous fuels such as straw. One way to avoid mixing fly-ash this is by pre-gasification. However, this is significantly more expensive than direct cofiring.

ASTM is currently working on revised technical standards for fly-ash utilisation. Fortum (Finland) and Sandia (USA) have projects on ash utilisation from cofiring installations. It was therefore suggested that Larry Baxter (USA) and Heikki Oravainnen (Finland) will provide high quality information on ash data to CEN to get try get European legislation changed. Once CEN and ASTM standards are modified, ISO standards may as well be changed.

Another interesting issue is SCR deactivitation (see country presentation of USA).

Initiation of an Internet site on Task 19

It was agreed by the task members that Task 19 will have its own internet site. This site will consist of a publicly accessible part that provides information on task activities, addresses and photographs of task members, task products (such as the handbook, software for biomass combustion, database on ash characterisation etc.) and a private domain where task members can download undisclosed information such as task reports, agendas of meetings, draft chapters of the handbook currently prepared etc.

In the coming months, TNO will explore options for hosting the site and start designing the home page. All task members are requested to submit photographs and suggestions for the site to the Task leader.

Characterization and utilization of biomass ashes

For the activity on *Characterization and utilization of biomass ashes*, Austria has distributed an updated version of the database. Task members are requested to contribute additional data. Task members are also requested to supply information on the current legislation with regard to ash disposal and treatment.

In the previous year, there has been intensive correspondence with the leader of Task 28 (biomass characterisation), mr. Andy Limbrick of Green Land, UK. Green Land was also major player in a large EU - TBX proposal on characterisation of solid biofuels, in which the earlier formulated Round Robin of Task 19 would be taken up. Regretfully however, this proposal has been rejected. We will have to reconsider if and how we can still proceed with the round robin, eventually together with Task 28. In Sevilla, Sjaak van Loo and Larry Baxter participated in the task meeting of Task 28.

The work program of task 28 has a broad focus and does not include test methods and the use of fly ash from biomass combustion in cement production because of a lack of time (Task 28 already finishes by the end of March 2001). However, it was agreed that they were important topics and should be included in the proposal to extend Task 28 for another three years. After some discussion about the use of ash derived from biofuels, it was agreed that Task 19 should generally take the lead on such work. However, the particular case highlighted by Mr Baxter deserved further consideration and should be kept under review.

Major activities where Task 19 could be involved in related to characterisation and standardisation are biomass analysis, a round robin test, evaluation of results and coordination. Proposals for activities for the next triennium are welcomed.

In a meeting in Stockholm, it was decided that only clean biomass fuels will be included in the standardisation process of CEN/TC/335, which is implemented under the mandate of the EC. This decision, which is in line with the EU directive on waste combustion, only includes five categories:

- Energy crops
- Residues from agriculture and forestry
- Solid residues from agroindustries
- Cork residues
- Residues from wood industries, excluding halogenated wood and demolition wood.

A priority list will be drafted on standards for sampling, quality assurance, physical and chemical characteristics and nomenclature.

Other topics

Claes Tullin (Sweden) wants a more clear definition of biomass and foresees a task for IEA Task 19 in this. According to Sjaak van Loo, work on defining biomass and waste has already been done by other task such as the IEA task on Municipal Solid Waste Incineration. Sjaak van Loo will collect and disseminate this information.

Announcement of next meeting

It was decided that the next task meeting will be held in Brisbane, Australia on December 7-8. The meeting will coincide with "Bioenergy 2000 Conference" to be held 4 to 5 December on the Gold Coast with site visits on the 6th December. Peter Coombes will make necessary arrangements for this.

Task members indicated that it would be better to schedule next meetings further in advance because of the need to obtain appropriate travel budgets from national funds.

Future activities

Appointments

- The 6th IEA-meeting of Task 19 will be in Brisbane, Australia on December 7-8, 2000 following the "Bioenergy 2000" conference of December 4-6.
- The next draft of the biomass combustion handbook should be available before the next task meeting. In order to meet this target, all members are requested to submit their detailed contributions and comments to the below chapter coordinators. Upon revision of the chapters, all chapter coordinators are requested to mail us their revised version so we can put them together and start editing the whole book. The task leader will explore ways to publish the handbook against low costs.
- Regarding the co-combustion activity, all are requested to submit information on current national status of co-combustion (legislation in particular with regard to re-use of ashes, initiatives, planning, policies). Based on your information we can e.g. prepare a position paper on ash utilisation.
- Good proposals are welcomed for the next triennium with measurable milestones, a time table, a total budget and efforts of Task members (based on national programs).
- Opinions of task members are welcomed on the performance of Task 19 in the past triennium. The results will be presented at the next meeting in Brisbane. Some issues may be
  1. results achieved in the various activities
  2. arrangements made for task meetings
  3. cooperation amongst task members and role of task leader
  4. .... (any other)
- An internetsite will be established. All are requested to submit photographs for the address section.
- Task members are invited to submit data on ash composition and utilization to Austria.

Annex 1. Task Proposal Biomass Combustion and Co-firing

IEA BIOENERGY AGREEMENT

Task 19:
Biomass Combustion and Co-firing

Task Proposal 2001 - 2003

Prepared by: Sjaak van Loo
TNO-Institute of Environmental Sciences, Energy Research and Process Innovation
The Netherlands

Date: March 2000

Task Proposal Summary Sheet

Task Title: Biomass Combustion and Co-firing

Proposer

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Endorsement by ExCo Member of participating country

- Country: The Netherlands
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- Signature:

Summary of proposal items: Objective, work scope, work programme, deliverables, management qualifications

The objective of the Task in the period 2001 - 2003 is to stimulate the expansion of the production of bio-energy by the exchange of information on technical and non-technical experience with co-firing of biomass in existing power plants and with biomass combustion in stand alone medium scale CHP plants.

A significant factor in the Task will be industrial participation and the interactions between IEA activities. Interaction between IEA Bioenergy and IEA Clean Combustion Sciences will be further intensified by continuing to perform joined activities.

Technical issues to be addressed are:

- small and medium scale CHP:
  development of modular systems, environmental acceptability, alternative and difficult-to-burn feedstock, innovative combustion technology
- co-firing:
  ash deposition, ash utilisation, NO_x, corrosion, char combustion, pre-processing of biomass, resource assessment

Non-technical issues to be addressed are keys to successful projects, logistics and contracting, environmental constraints and legislation, acceptance by the public and financial incentives.

The activities will be executed based on specific project descriptions to be endorsed by the ExCo. Project proposals will at least consist of measurable milestones, a time table, a total budget and efforts of Task members (based on national programs).

The proposed Task Leader is Sjaak van Loo, who has been Task Leader of Task 19 in the previous period. His present position is Head of the Department of Thermal Conversion Technology at TNO Institute of Environmental Sciences, Energy Research and Process Innovation (TNO-MEP), Board member of the Netherlands Bio-Energy Association, Board member of the Institute for Plant Fibre Research and Board member of the Sustainable Energy Research Association.

Annual budget: US$ 140.000 (based on US$ 10.000 per participant, 14 Task participants)

Content

1 Objective

Task 19: Biomass Combustion and Co-firing is a continuation and extension of the previous Task 19: Biomass Combustion.

Biomass Combustion is well-established commercially and provides over 90% of the bioenergy used at present. Co-firing biomass with coal in traditional coal-fired boilers (subsequently referred to as co-firing) represents one combination of renewable and fossil energy utilisation that derives the greatest benefit from both fuel types. The scope of work in this area will be emphasised on further expand the use of biomass combustion for heat and power generation. Special emphasis will be on small and medium scale CHP plants and co-firing biomass with coal in traditional coal-fired boilers.

The objective of the activity in the period 2001 - 2003 is to stimulate the expansion of the use of Biomass Combustion and Co-firing for the production of heat and power to a wider scale. The objective will be reached by generating and disseminating information on technical and on non-technical barriers and anticipated solutions.

2 Scope of work

2.1 Working areas

At present combustion technology plays a major role in energy production from biomass. The main benefits of combustion compared to other technologies (i.e. gasification, pyrolysis, liquefaction) is that combustion technology is commercially available and can be integrated with existing infrastructure. For further implementation of biomass combustion, combustion technology should nevertheless be optimised to keep it competitive as gasification and pyrolysis develop.

The emphasis of the activities in the Task period 2001 - 2003 will be on the following two working areas:

- small and medium scale CHP;
- co-firing coal with biomass and related wastes.

a) Small and medium scale CHP

In most member states the potential market for small scale biomass fueled co-generation systems is large because of the local availability of biomass and a substantial application potential in buildings, small industries and horticulture. The advantages of small scale systems over large scale systems are the lower costs for transport and the potential better overall efficiencies because of the local use of the heat generated. The investment costs however of these small scale power systems are high in comparison to larger scale power systems, which is considered to be the main obstacle for further market introduction. Investment costs could be lowered by development of modular systems.

Besides the development of modular systems attention will be paid to:

- environmental acceptability;
- alternative and difficult-to-burn feedstock;
- innovative combustion technology.

b) Co-firing coal with biomass and related wastes

Co-firing biomass with coal represents one combination of renewable and fossil energy utilisation that derives the greatest benefit from both fuel types. Co-firing capitalises on the large investment and infrastructure associated with the existing fossil-fuel-based power systems while requiring only a relatively modest investment to include a fraction of biomass in the fuel. When proper choices of biomass, coal, boiler design, and boiler operation are made, traditional pollutants (SO_x, NO_x, etc.) and net greenhouse gas (CO_2, CH_4, etc.) emissions decrease. Ancillary benefits include increased use of local resources for power, decreased demand for disposal of residues, and more effective use of resources. These advantages can be realised in the very near future with very low technical risk. However, improper choices of fuels, boiler design, or operating conditions could minimise or even negate many of the advantages of burning biomass with coal and may, in some cases, lead to significant damage to equipment. From an inventory within Task 19 the following items were selected to be of importance in research, development and demonstration in this field:

- Fuel Characteristics and Resource assessment;
- Fuel Preparation and Handling;
- Pollutant Emissions;
- Ash Deposition;
- Carbon Conversion;
- Chlorine-Based Corrosion;
- Fly Ash Utilisation.

The activities will be restricted as follows:

- co-combustion of biomass in existing coal fired boilers;
- in case of co-combustion of producer gas from biomass gasification, pyrolysis oil or charcoal only attention will be paid to the aspects of co-firing these materials and not to the gasification, pyrolysis or carbonisation itself

For further market introduction the emphasis will be on information exchange on non-technical issues like emissions, emission guidelines, economics, financial incentives, logistics and public acceptance.
Stimulation of large-scale implementation of biomass combustion and co-firing can only be efficient if relevant knowledge is available. The focus of the activities will therefore be on gathering and dissemination of information on relevant expertise.

2.2 Co-operation

A significant factor in the Task will be industrial participation and interactions between IEA activities and between IEA and the European Union.

From experiences from previous activities it can be concluded that industry finds information exchange the most important benefit from co-operation with IEA. The present interaction with industry through participation of industry in seminars, workshops etc. should be continued. A further enhancement of the industrial participation could be realised by formulating joint projects between participating members and industry. Targeted programs could be the EU 5th framework programme and Altener. One of the actions in the field of market introduction will be dissemination of information on biomass combustion and co-firing related industry.

Within the IEA attention is paid to co-firing coal with biomass and related wastes in two different Implementing Agreements:

- Implementing Agreement for a programme of research, development and demonstration on Clean Combustion Sciences;
- Implementing Agreement for a programme of research, development and demonstration on Bioenergy; Task 19: Biomass Combustion and Co-firing.

Both groups have signed a Memorandum of Understanding (see Appendix 1) in which co-operation is acknowledged. The co-operation will consist of sharing knowledge and executing mutual projects in this field. Progress will be discussed in annual mutual meetings.
The co-operation is believed to be exceptionally successful because leading knowledge on coal combustion is combined with leading knowledge on biomass.

Within IEA Bioenergy the task is (closely) related to other tasks, especially to activities in the field of biomass gasification, pyrolysis and techno-economic analysis. Tuning of the activities and mutual information exchange will be stimulated by arranging exchange of minutes of meeting, reports and mutual meetings.

3 Work program

The work program will be set in discussions with the Task members. The emphasis of the activities in the Task period 2001 - 2003 will be on the following two working areas:

- small and medium scale CHP;
- co-firing coal with biomass and related wastes.

Possible project proposals for these area's are formulated below.
The proposed activities, further suggestions included, will be evaluated and prioritised by the members. One of the criteria will be sufficient (financial) back-up from national programmes and or national industry. Agreements will be made on the contribution of members to activities of interest. Also agreements will be made on targeted results at the end of the working period.

3.1 Small and medium scale CHP

Attention will specifically be paid to the development of modular systems. Besides this attention will be paid to:

- environmental acceptability;
- alternative and difficult-to-burn feedstock;
- innovative combustion technology.

3.1.1 Development of modular systems

The objective is to prepare a design contest for small scale modular CHP-systems and thus to reach lower investment costs and shorter implementation periods for these systems. In the USA a similar project is ongoing under the title of “small, modular bio-power project”. A proposal is also submitted in the Altener programme to support the activities. The activity could include the following phases:

- Preliminary definition;
- Cost reduction estimates;
- Check with industry and potential users;
- Indication of interest;
- Evaluation and elaboration of the contest.

a) <u>Preliminary definition</u>
Selection of the primary boundary conditions of the type of projects to be provoked. The size of the projects is thought to be in the range of 50 kW_e to 3 MW_e. The set of criteria for the project will be selected. This first phase should lead to a first general conceptual design and definition of the type of project that the design contest is aiming at.

b) <u>Cost reduction estimates</u>
For several potential technologies the cost reduction potential when introducing modular systems will be estimated. In this phase contact and co-operation with "techno-economic analysis" will be important.
Some relevant industries will be consulted for carrying out the assessment. Since there is no data available on this topic in public domain, the activity will largely be carried out based on the expertise of the participants and industry.

c) <u>Check with industry and potential users</u>
Task members, some representatives of Central and Eastern European countries and a limited number of industries that are expected to be willing to solicit for a contest shall be questioned about:

- the definition of the projects;
- the expected cost reduction;
- the expected market potential for specific market segments;
- non-technical aspects that have to be taken into account.

Moreover an evaluation of relevant existing information on market potential in different countries and C+E European countries will be given.

d) <u>Indication of interest</u>

An indication of the interest of industry and member countries to play an important role in the contest will be determined. The partners shall use their national and international contacts to gather information on this subject and, more specifically, to evaluate the experiences with the US-DOE "small modular bio-power project", which has similar objectives as the contest that is prepared in this activity.

e) Evaluation and elaboration of the contest
The findings of the previous work shall be discussed amongst the members. This shall lead to a conclusion on the feasibility of a contest on the basis of an evaluation of the findings and a proposal for an organisational, legal and financial structure. This shall be done partly on the basis of an evaluation of the US "small modular biopower project" and the experiences with the other partners on previous contests. For the financial structure a representative from the European Commission shall be invited.

3.1.2 Environmental acceptability

Potential thresholds on biomass combustion are the emissions and the handling of combustion residues. Emission limits on NOx and particles are becoming stricter.
In this Task period activities on these issues will be formulated in discussion with the Task members. As an example information on NOx-formation and reduction, aerosol formation and dust emission abatement could be gathered and distributed.

Although ash from biomass combustion in some countries is used as fertiliser, in other countries ash is seen as waste and is land filled. To overcome this potential threshold knowledge should be made available on ash composition (based on feedstock and technology) and national guidelines on the use and/or disposal of ash from biomass combustion.
Activities on ash characterisation and utilisation will be continued.

3.1.3 Alternative and difficult-to-burn feedstock;

Difficult-to-burn feedstock like straw, agricultural waste, waste wood etc. will have effect on reactor design. The implications on ash agglomeration, corrosion, emissions etc. will be evaluated, from theoretical knowledge on biomass combustion and from practical experience by industry. The availability of knowledge on predicting these effects will be evaluated. If possible, strategies will be formulated to predict these effects and to introduce technical and environmental sound combustion of difficult-to-burn feedstock.
Continuing the present activities on biomass characterisation the emphasis will be on difficult-to-burn feedstock such as straw, agricultural waste, wood waste etc. Apart from collecting data, attention will be paid to standardisation of analysis methods.

3.1.4 Innovative combustion technology.

Innovative combustion processes can contribute to further implementation of biomass combustion. Innovative combustion processes like pressurised combustion and FICFB-technology will be evaluated with respect to status of technology, research needs, current innovations, (electrical) efficiency, availability, reliability, costs, etc. Also attention will be paid to the impact of new materials on the efficiency of biomass combustion (better steam quality).

3.2 Co-firing biomass with coal

3.2.1 Fuel Characteristics and Resource assessment

The biomass fuels considered range from woody (ligneous) to grassy and straw-derived (herbaceous) materials and include both residues and energy crops. Woody residues are generally the fuels of choice for coal-fired boilers while energy crops and herbaceous residues represent future fuel resources and opportunity fuels, respectively. Biomass fuel properties differ significantly from than those of coal and also show significantly greater variation as a class of fuels than does 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 near 0 to 2.5 %), relatively low heating value (typically about half that of hv bituminous coal), and low bulk density (as low as one tenth that of coal per unit heating value). These properties each affect design, operation, and performance of co-firing systems.
The availability of biomass suitable for co-firing at various represented countries will be listed and evaluated.

3.2.2 Fuel Preparation and Handling

Biomass is generally not as friable as coal and comminution of biomass is best performed with different equipment and at higher energy cost compared to coal. The most commonly used biomass comminution technologies include fuel hogs, tub grinders, and cutters of various types. It is possible to reduce biomass to arbitrarily small sizes by recycling material in a flow loop, but the cost of reducing biomass to sizes less than about ¼ inch increases substantially as the particle size decreases.
Because biomass fuels are hygroscopic, have low densities, and have irregular shapes, fuel handling is more difficult than for an equivalent coal system and is best done in a separate stream. Some exceptions to this general rule includes biomass that has already been processed to an appropriate small size (sander dust and some types of sawdust) and very dense and relatively brittle biomass (some nut shells). Additionally, trivial amounts of biomass used for co-firing can often be directly mixed with coal (and generally produce a trivial impact on greenhouse gas emissions). When the biofuels are mixed with the coal, care must be taken to prevent skidding, bridging and plugging in pulverisers, hoppers and pipe bends.
Best practices for reducing the size of biomass particles in preparation for co-firing will be listed and evaluated.

3.2.3 Pollutant Emissions

Co-firing biomass with coal can have a substantial impact on the emissions of sulfur and nitrous oxides (SO_x and NO_x). SO_x emissions almost uniformly decrease when firing biomass with coal, often in proportion to the biomass thermal load, because most biomass fuels contain far less sulfur than coal. An additional incremental reduction (beyond the amount anticipated on the basis of fuel sulfur content alone) is sometimes observed due to sulfur retention by alkali and alkaline earth compounds in the biomass fuels.
The effects of co-firing biomass with coal on NO_x emissions are more difficult to anticipate. Experimental characterisation of NO_x emissions during combustion of coal, biomass, and various blends of the two fuels have demonstrated NO_x emissions from biomass-coal blends both greater and less than those from coal alone. However, combustion of most residual-

wood-derived biomass results in lower NO_x emissions. These fuels are also among the best candidates for co-firing from many other standpoints.
The fuel and combustion environments that may lead to a reductions in NOx will be determined.

3.2.4 Ash Deposition

Ash deposition rates and deposit management problems from biomass fuels can greatly exceed or be considerably less than those from firing coal alone. Absolute deposition rates from some herbaceous fuels exceed those of coals by about an order of magnitude, whereas deposition rates for high-quality woods are nearly an order of magnitude less than those from coal. These trends are in part attributable to the total ash contents of the fuels. When normalised for ash content, ash deposition efficiencies of some herbaceous materials still exceed those of coal by large margins whereas deposition efficiencies for wood are much 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 indicated by a direct interpolation between the two rates. Experimental evidence supports the hypothesis that this reduction in ash deposition occurs primarily because of interactions between alkali (mainly potassium) from the biomass and sulphur from the coal.
The following general trends are observed: (1) ash deposition rates should decline when co-firing wood or similar low-ash, low-alkali, low-chlorine fuels; (2) ash deposition rates should increase when co-firing 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 co-fired fuels.

Information on the rates, mechanisms, and properties of ash deposits formed from co-firing coal and biomass will be gathered and evaluated.

3.2.5 Carbon Conversion

Experiments on the conversion of carbon in biomass fuels show that larger particles (sizes greater than 3 mm (1/8 inch)) will likely undergo incomplete combustion, with significant residual carbon expected at sizes greater than 6 mm (1/4 inch) and moisture contents greater than 40%. High-density biomass fuels (nut shells, high-density wood, etc.) also decrease burnout.

The carbon from incomplete combustion of biomass particles does not always figure prominently in fly ash analyses. Typically, 90-95% of the dry, ash-free biomass fuel devolatilises in a relatively rapid reaction, leaving only 5-10% to oxidise in a comparatively slow reaction. Furthermore, few commercial co-firing operations use more than 10 % biomass on an energy basis. Therefore, the potential increase in fly ash carbon content is a few percent residual carbon in a few percent of the fuel. Finally, very large particles are more likely to collect in the bottom ash than in the fly ash.

The size, shape, and moisture content allowable for biomass fuels that will result in efficient fuel
conversion (particle burnout) will be determined.

3.2.6 Chlorine-Based Corrosion

Corrosion may be greatly exacerbated by high-chlorine or high-alkali fuels. High-temperature corrosion of superheaters is among the greatest concerns and may be induced by chlorine-containing species on the tube surface. Some forms of biomass include significant chlorine concentrations. Inorganic transformations during combustion often result in selective deposition of chlorine-containing species (generally alkali chlorides) on heat transfer surfaces, greatly increasing the surface chlorine concentration relative to that of the bulk gas. Many biomass fuels, in particular either herbaceous or intensely cultivated fuels, contain high chlorine and alkali concentrations, creating particularly worrisome conditions.
Co-firing somewhat ameliorates the corrosion potential through interactions of sulphur (primarily derived from the coal) with alkali chlorides (primarily derived from the biomass) to form alkali sulphates. Sulphation converts condensed-phase, highly corrosive alkali chlorides on heat transfer surfaces to gas-phase species (generally hydrochloric acid) that are less corrosive and that leave the surface relatively easily. The HCl may condense on lower-temperature surfaces such as air heaters. However, this problem is generally less serious and more manageable than superheater corrosion.

Experimental investigations with a wide range of fuels at pilot-scale indicates that there are fuel-based parameters that indicate when chlorine concentrations exceed the capacity of sulphation mechanisms control surface chlorine (and thereby corrosion). These data are consistent with the limited commercial-scale data available. Generally, the molar ratio of sulphur to available alkali and chlorine should exceed 5, with greater values providing decreased corrosion potential. Available alkali is the fraction of total alkali that is either water soluble or ion exchangeable. This is generally close to the total alkali for biomass fuels that do not contain soil or other extraneous sources of alkali.

The sulphur to alkali/chloride ratios should generally be based on fuel compositions through individual burners, not total fuel composition. Most boilers do a relatively poor job of mixing flue gases. In cases where biomass is introduced non-uniformly among the burners (most cases), local flue gas compositions in the convection pass are determined by individual burner composition, not total fuel composition. In the rare cases of rapid and thorough mixing in the furnace, burner-to-burner variations in sulphur, chlorine, and alkali content are less important. The corrosion potential of biomass-coal blends and means of ameliorating corrosion problems will be determined.

3.2.7 Fly Ash Utilisation

Well over 1/3 of the fly ash generated in US power stations, and essentially 100 % of the fly ash in many other countries, is used in a secondary market. One of the large, high-value markets is as a concrete additive. Current standards for the use of fly ash as a concrete additive preclude using fly ash from any source other than coal. This may pose a significant financial barrier to co-firing for many plants. This issue has both technical and regulatory aspects.
The technical case for precluding fly ash from co-firing wood with coal as a concrete additive appears to be unjustified. Laboratory tests of concrete made from cement containing commercially produced fly ash and laboratory fly ash indicate that there are no short- or long-term deleterious effects on the properties of the concrete when using wood-based co-fired ash. There are less comprehensive data available for herbaceous biomass fuels, but the existing data and theoretical considerations suggest that alkali, chorine, and other properties may compromise several important concrete properties. Investigation of this issue is ongoing.

The regulatory issues are associated with the specific wording of national and international standards that, while not actual regulations, are the basis for regulations and policy for many institutions. Strict interpretation of all national and international standards that address this issue of which we are aware would preclude all fly ash from use in concrete if it contains any amount of non-coal-derived material. This would include co-fired fly ash as well as fly ashes from dedicated coal systems that involve other cleanup processes (scrubbers, sulphur-injected precipitators, etc.). These standards are under active revision in the US and abroad, but such revisions often take many years to complete. There are also many markets/customers that do not explicitly require adherence to these standards.

A change to ISO and country standards that currently preclude biomass (only accept coal) ash from use in the cement industry could be initiated.

3.3 General activities

General activities will cover the following items:
- organisation of Task meetings (twice a year);
- minuting of meetings;
- keeping the Task 19 internet site (presently under construction) up to date;
- organisation of seminars for industry and potential users (combined with Task meetings);
- organisation of excursions (combined with Task meetings);
- publication of Task-reports;
- information exchange between relevant IEA-Tasks;
- information exchange between Task 19 and IEA-CCS;
- reporting to the ExCo;
- facilitating of Task projects.

4 Deliverables

The objective of the activities is strongly related to knowledge transfer to industry and to potential users of biomass combustion technology. Therefore the main deliverables will be disseminating the results of the projects and working areas by:
- publication of project results as IEA-reports and as contribution to seminars and workshops (the quantity will be depending on the number of activities);
- meetings of members (at least twice a year);
- organisation of seminars for industry and potential users (at least twice a year);
- mutual IEA/industry project proposals.

Furthermore the links between different related IEA activities will be improved.

5 Schedule and milestones

The activities are scheduled below.

Deliverables	2001				2002				2003			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

Deliverables	2001				2002				2003			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Working program	x				x				x			
Task meeting/seminar/excursion	x		x		x		x		x		x	
Minutes of meeting		x		x		x		x		x		x
IEA/Industry project proposals					x		x		x		x	
Reports on Task projects				x				x				x
Annual report to ExCo				x				x				
End-of-task report to ExCo												x

6 Annual budget

The annual budget for the Task will be US$ 140.000. This budget is based on a contribution of US$ 10.000 per participant and an anticipated participation of 14 member countries. The budget can be divided in:

- Labour and benefits: US$ 105.000
- Travel: US$ 10.000
- Materials and Supplies: US$ 5.000
- Consultants [1)]: US$ 5.000
- Other Costs[2)]: US$ 15.000 +
- Total: US$ 140.000 exclusive V.A.T.

1): costs for minuting meetings;
2): costs for translations, meeting rooms, invited experts, publications, etc.

7 Task management qualifications

7.1 Task leader activities

The Task Leader will be responsible for:

- submitting an annual program of work to the ExCo;
- co-ordination of the program of work;
- supplying minutes of all meetings;
- editing an annual and an end-of-task report to the ExCo;
- explanation on progress on the working program to the ExCo once a year.

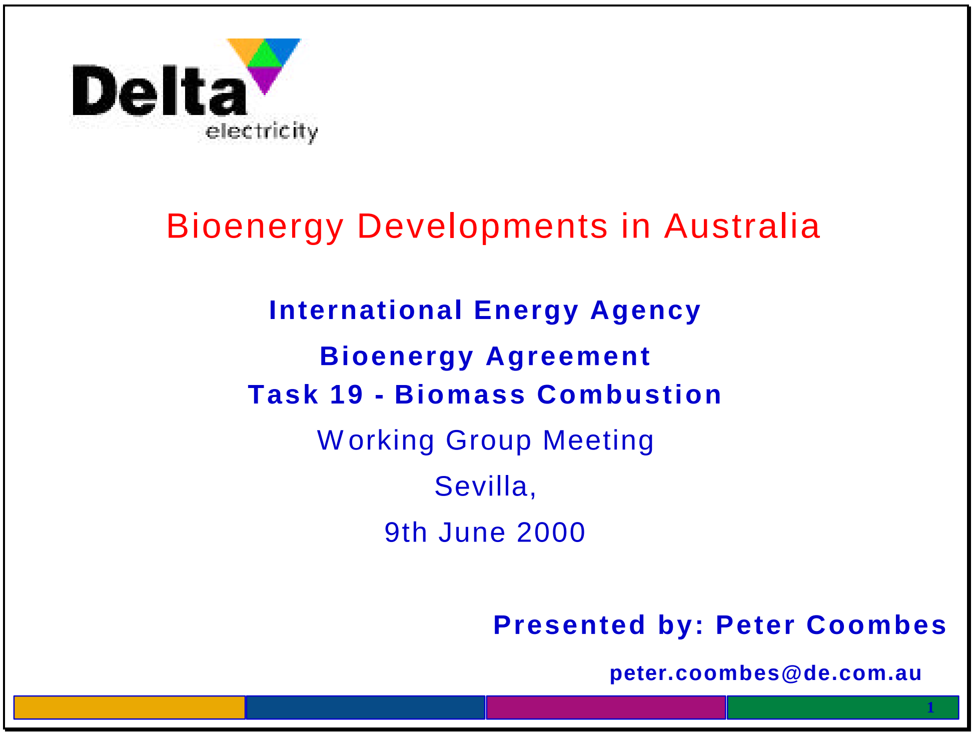
7.2 Qualifications of TNO-MEP

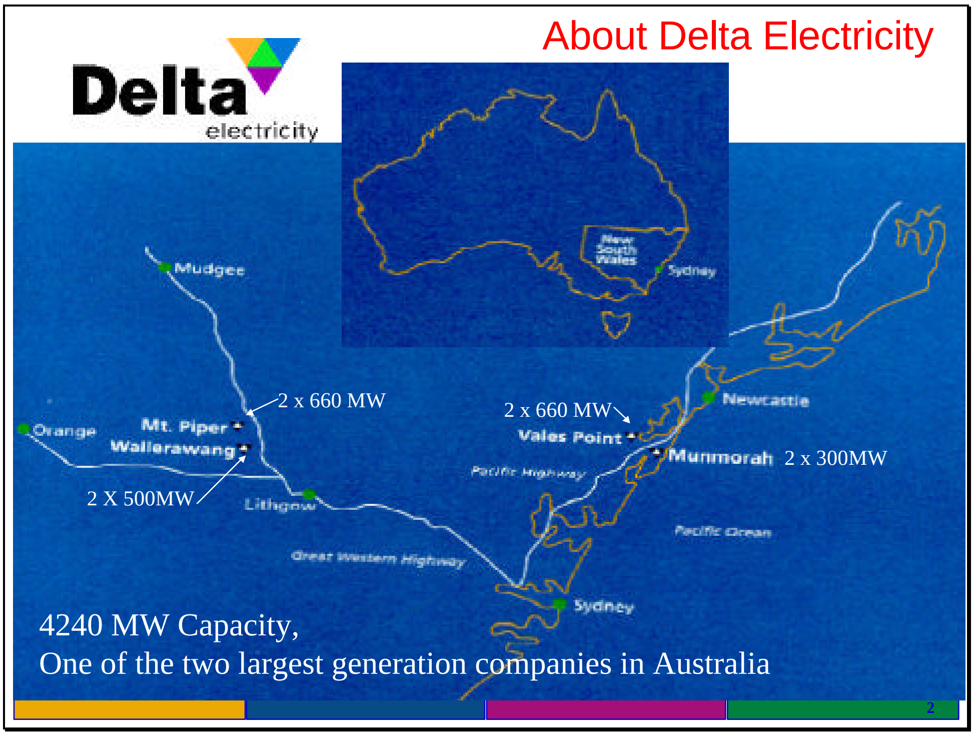
As a part of the TNO Institute of Environmental Sciences, Energy Research and Process Innovation (TNO-MEP) the Department of Thermal Conversion Technology has been involved in energy from biomass since the 70's and has a great deal of experience in both fundamental and practical issues on energy from biomass and waste. The Department performs technological research, and closely co-operates with industry and universities in the Netherlands and abroad. The knowledge obtained is used to develop and implement thermal processing technologies into actual practice. In addition to combustion research, the department also performs research into gasification, pyrolysis, liquefaction, catalytic combustion, (high temperature) gas cleaning, etc. The activities are conducted both for industry and the government. Policy groundwork and feasibility studies are often conducted for public authorities.

7.3 Proposed Task Leader

Proposed Task Leader is Sjaak van Loo, who has been Task leader of Task 19 in the previous period. Sjaak van Loo has his background in chemical engineering and has been working at TNO since 1985. Up to 1991 he has been working as project leader in the field of emission abatement. In 1991 he has been working as co-ordinator at the Ministry of Physical Planning and the Environment in the field of thermal processing of waste (MSW, car wrecks, etc.). Since 1992 his field of work is energy from biomass. At present Sjaak van Loo is Head of the Department of Thermal Conversion Technology at TNO Institute of Environmental Sciences, Energy Research and Process Innovation (TNO-MEP), Board member of the Netherlands Bio-Energy Association, Board member of the Institute for Plant Fibre Research and Board member of the Sustainable Energy Research Association.

Annex 2. Country presentation, Peter Coombes, Australia





Australian Participation

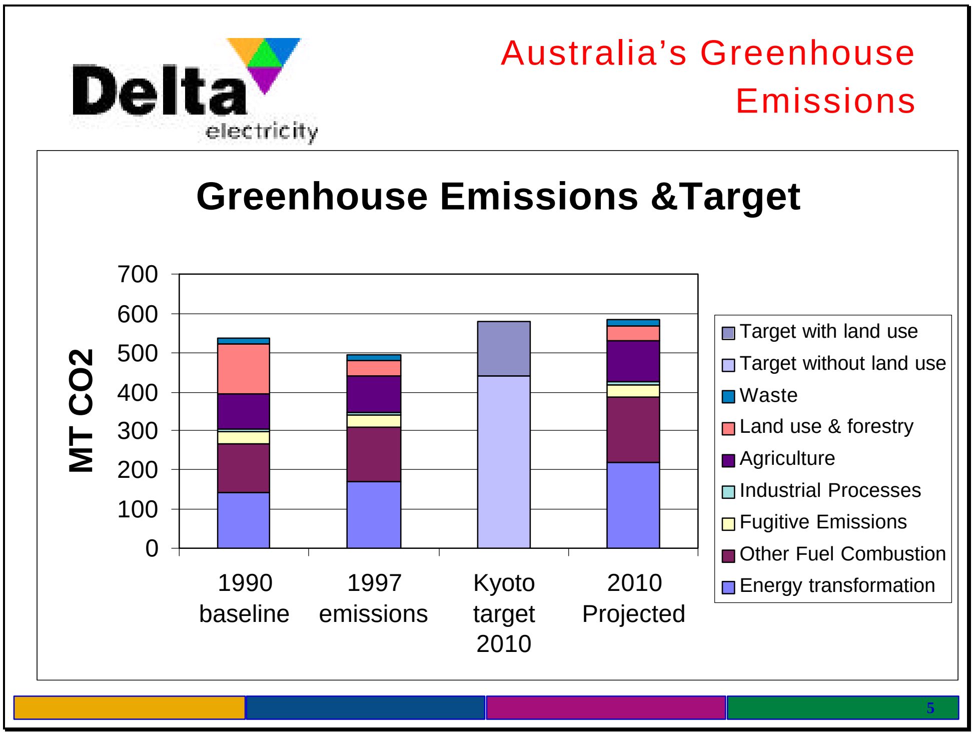
- **Biomass Taskforce**
  - Association of 28 industry, government and research organisations
- **Key Participants in Task 19**
  - Delta Electricity
  - Stanwell Corporation
  - Tarong Energy
  - CS Energy
  - Pacific Power International
  - Western Sydney Waste Board
  - CSIRO Energy Technology
  - CSIRO Forest Products

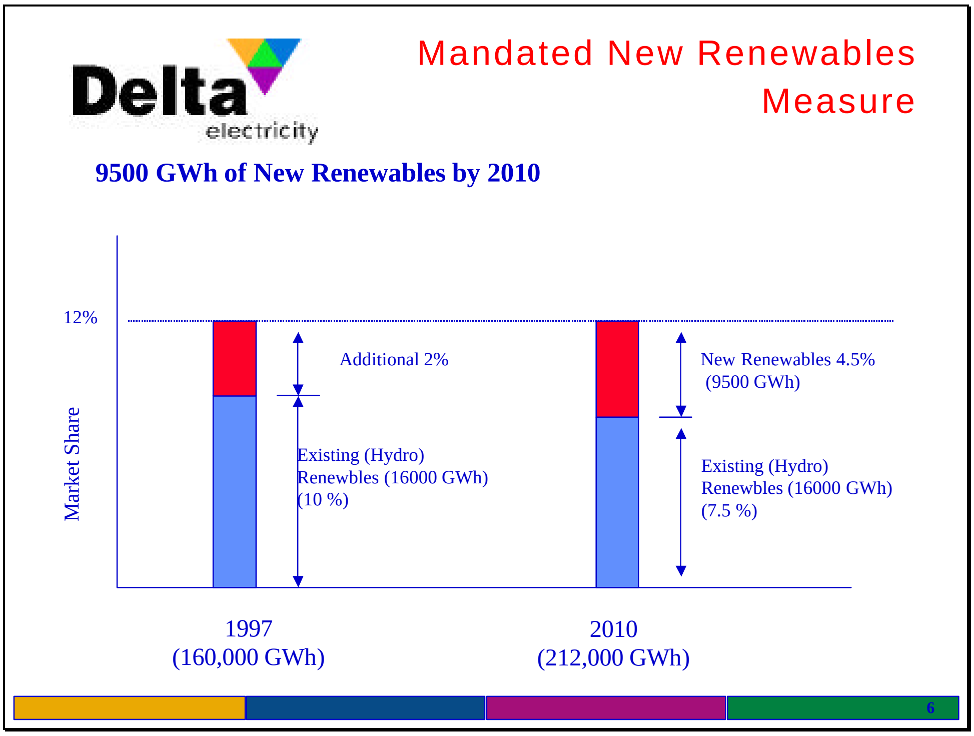
3

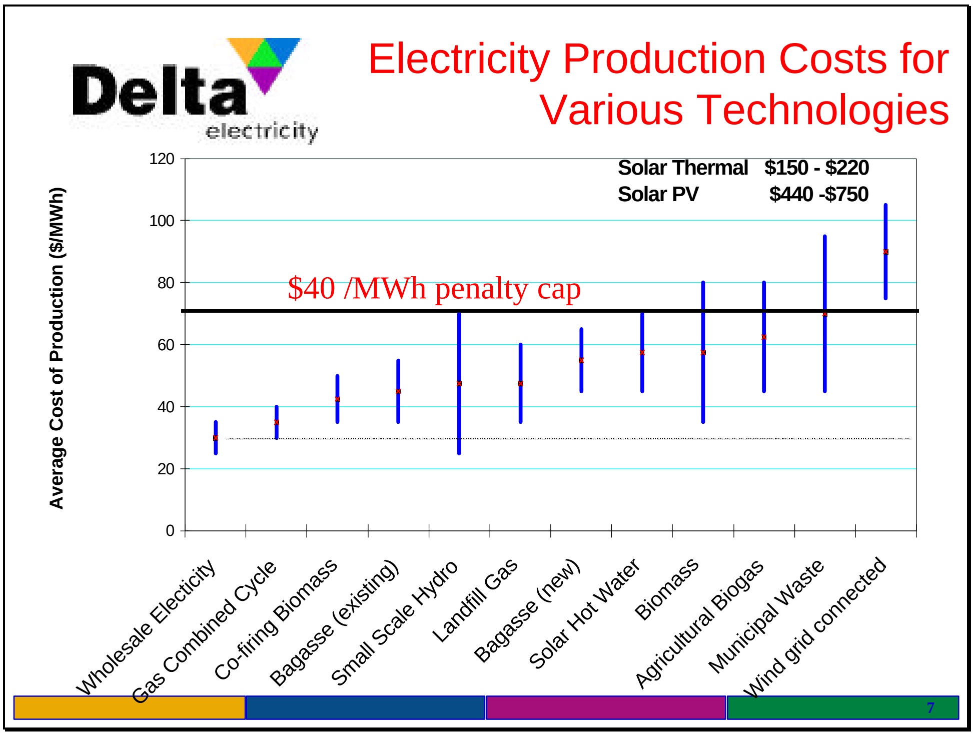
Drivers for Bioenergy Development

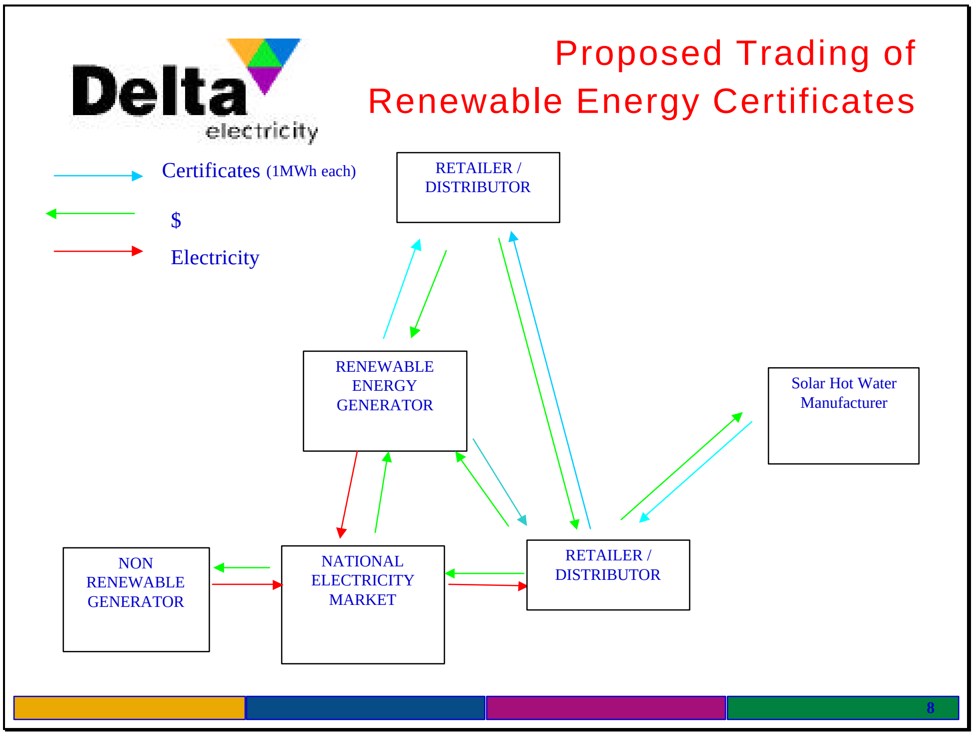
- **Australia's Greenhouse Response**
- **Key Measures affecting bioenergy:**
  - **Mandatory 9500GWh of additional Renewable Electricity by 2010**
    - **Requires electricity retailers to purchase a mandatory quantity of renewable energy**
    - **Recognises bioenergy as an eligible source**
  - **Efficiency Improvement Standards for Power Stations**
    - **Recognises co-firing with biomas as an efficiency improvement opportunity**

4


Delta electricity
Australia's Greenhouse Emissions
Greenhouse Emissions &Target
MT CO2
700
600
500
400
300
200
100
0
1990 baseline
1997 emissions
Kyoto target 2010
2010 Projected
Target with land use
Target without land use
Waste
Land use & forestry
Agriculture
Industrial Processes
Fugitive Emissions
Other Fuel Combustion
Energy transformation
5

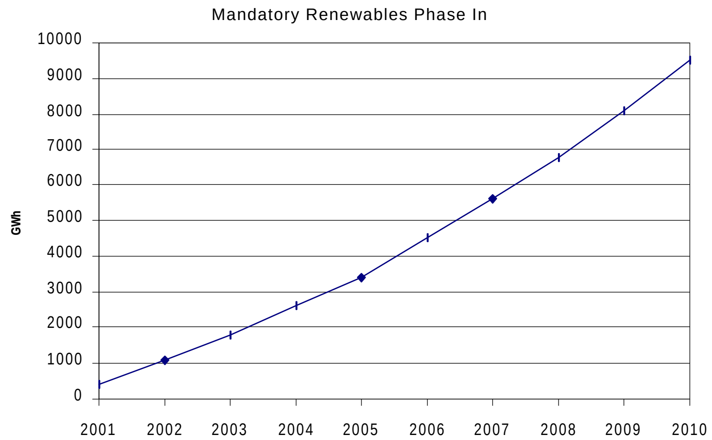

Delta electricity
Mandated New Renewables Measure
9500 GWh of New Renewables by 2010
Market Share
12%
Additional 2%
Existing (Hydro) Renewbles (16000 GWh) (10 %)
New Renewables 4.5% (9500 GWh)
Existing (Hydro) Renewbles (16000 GWh) (7.5 %)
1997 (160,000 GWh)
2010 (212,000 GWh)
6


Delta electricity
Electricity Production Costs for Various Technologies
Solar Thermal $150 - $220
Solar PV $440 -$750
$40 /MWh penalty cap
Average Cost of Production ($/MWh)
0
20
40
60
80
100
120
Wholesale Electicity
Gas Combined Cycle
Co-firing Biomass
Bagasse (existing)
Small Scale Hydro
Landfill Gas
Bagasse (new)
Solar Hot Water
Biomass
Agricultural Biogas
Municipal Waste
Wind grid connected
7


Delta electricity
Proposed Trading of Renewable Energy Certificates
Certificates (1MWh each)
$
Electricity
RETAILER / DISTRIBUTOR
RENEWABLE ENERGY GENERATOR
Solar Hot Water Manufacturer
NON RENEWABLE GENERATOR
NATIONAL ELECTRICITY MARKET
RETAILER / DISTRIBUTOR
8

Delta electricity

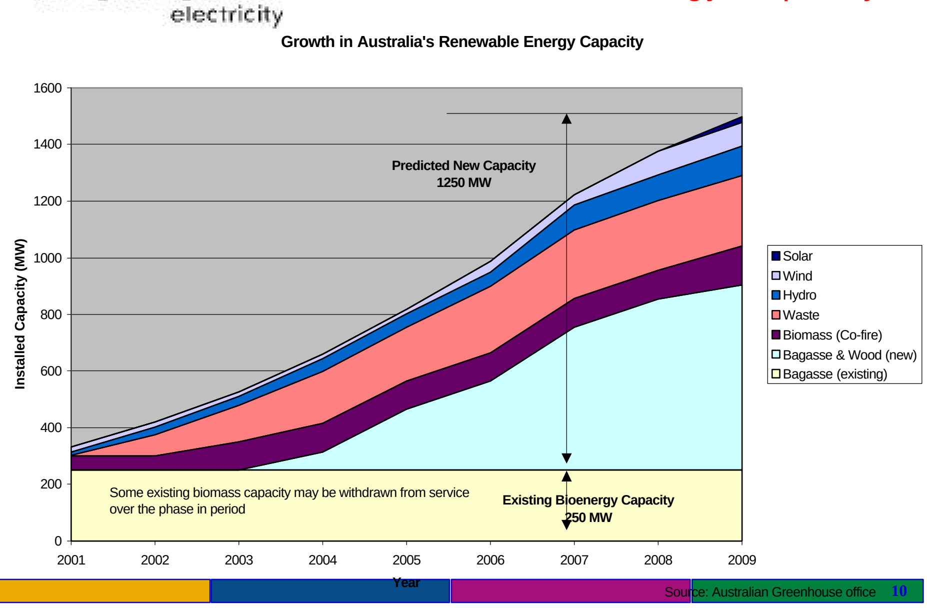
New Renewable Demand Based on Mandatory Target



9

Delta electricity

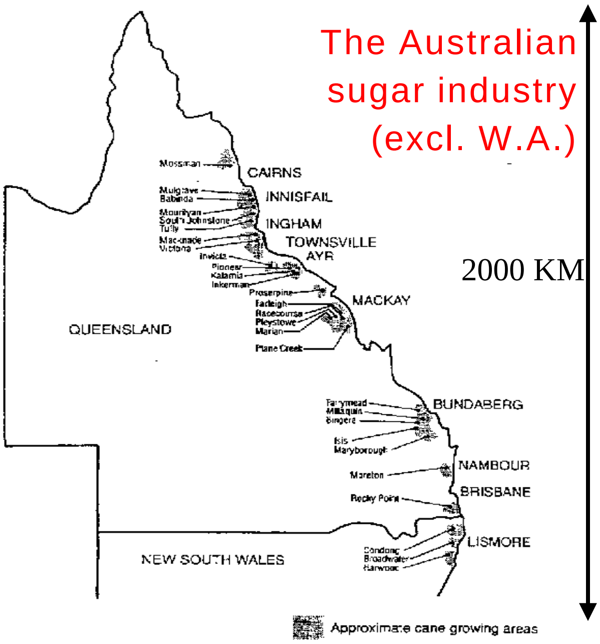
Growth in Australia's Renewable Energy Capacity



Source: Australian Greenhouse office 10

Delta electricity

The Australian sugar industry (excl. W.A.)



Estimated Fuel Potential

- Bagasse 12 MT/year
- Cane Trash 10 MT/year

Energy Content 200 PJ

11

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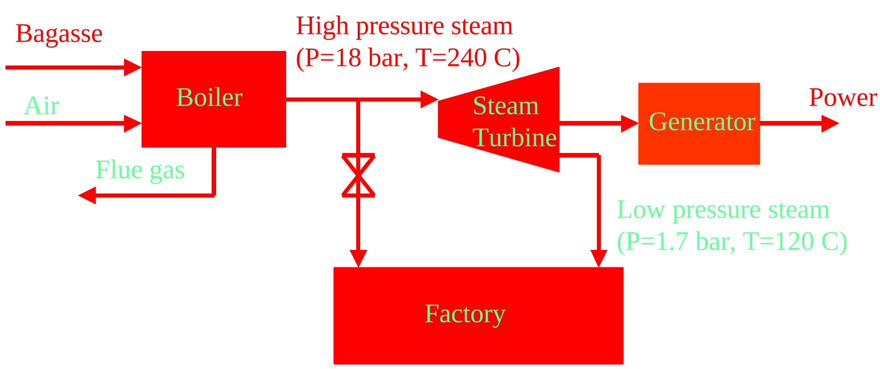
Typical Sugar Mill Cogeneration Configuration



Source: Sugar Research Institute
T Dixon

12

Opportunities for Efficiencies in the Sugar Industry

- Low steam pressures and temperatures (18 bar, 240ºC) - low power generation efficiencies
- All process steam is extracted from the turbine at relatively high steam pressure - low power generation efficiencies
- Opportunity to improve sugar mill low pressure process steam demand - currently averaging 52 tonnes of steam to process 100 tonnes of cane
- Large high pressure steam demand from inefficient turbine driven shredder, mills and boiler fans

Source: Sugar Research Institute
T Dixon

13

Sugar Industry Improvement Potential

(based on 600 t/h cane mill)

Cycle	Crushing season export (MWe)	Maintenance season export (MWe)	Annual GWhrs	Improvement
Conventional (current) low pressure steam	29	0	29	
Conventional high pressure steam	52	0	52	80%
Conventional high pressure steam (all year)	52	91	143	400%

*Source: Sugar Research Institute
T Dixon

14

Bagasse/Biomass Storage and Handling Investigations

Delta electricity

- Harvesting Trash with Cane
- Extended harvesting season
- Effects of Weather exposure (water, dust, runoff)
- Bagasse dewatering / In-situ drying
- Storage Options

15

Sugar Mill Cogeneration

Delta electricity

- Joint Project with Delta Electricity and NSW Sugar Milling Co-operative
- Redevelopment of

– Condong Sugar Mill	30 MW	Mid 2002
– Broadwater Sugar Mill	38 MW	Mid 2002
– Harwood Sugar Mill	30 MW	2004

- Plants will utilise predominantly cane based fuels
  - bagasse and cane trash
- Supplementary fuel
  - Saw mill residue, Camphor Laurel & Council green waste
- Production 600 - 700 GWh per year
- Greenhouse gas savings 540,000 tonnes CO_2 per year

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Delta electricity

Broadwater Sugar Mill Boiler

17

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Co-firing Coal And Biomass

- Being investigated by a number of coal fired power stations in Australia
- Use existing coal fired plant - feed biomass via coal mills
- 5 % Blend of biomass with coal
- Co-firing in PF plant higher efficiency
  - 33 - 35 % vs 18 -22 % for small stand alone plant
- Delta's power stations are close to a sustainable plantation forestry resource
- Expect up to 300 GWh/year requiring 300,000 tonnes biomass fuel per year
- Saving up to 270,000 tonnes of CO_2 per year

18

Delta

Walleraang Power Station

2 x 500 MW Pulverised Coal Units

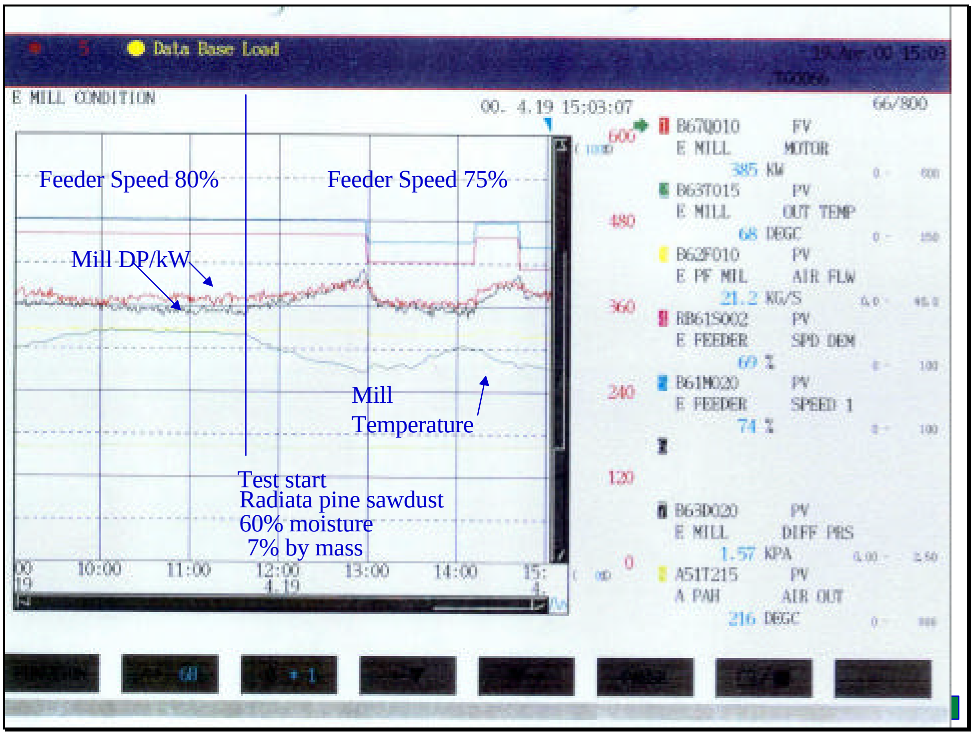
19

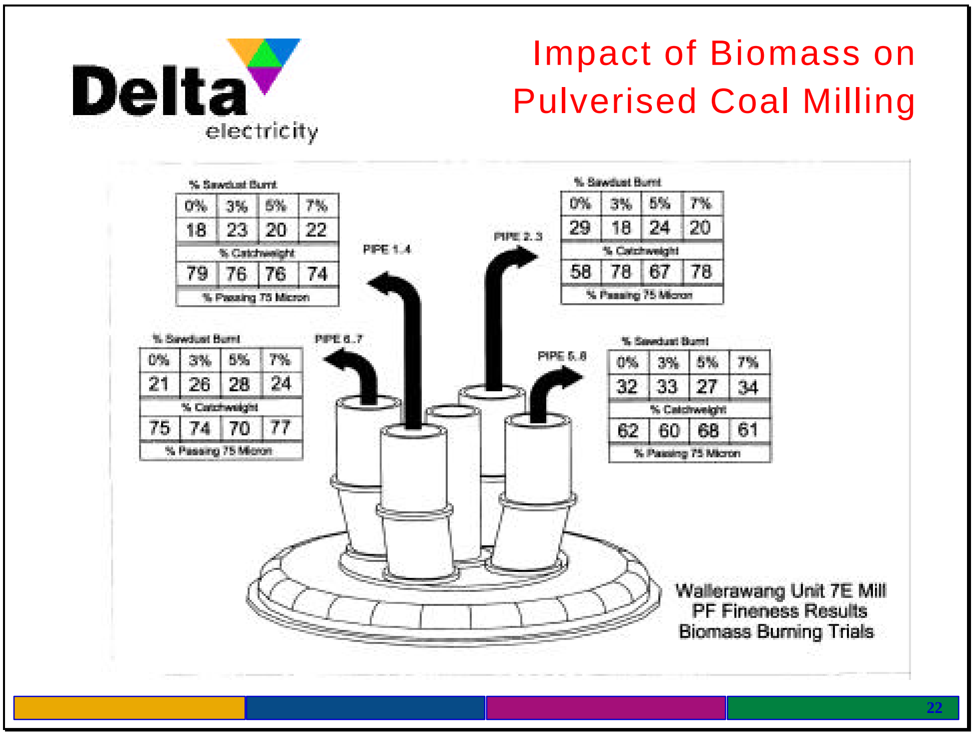
Delta

electricity

Wood Chip & Coal Fuel Feed

20


Data Base Load
E MILL CONDITION
Feeder Speed 80%
Feeder Speed 75%
Mill DP/kW
Mill
Temperature
Test start
Radiata pine sawdust
60% moisture
7% by mass
10:00
11:00
12:00
13:00
14:00


Delta electricity
Impact of Biomass on
Pulverised Coal Milling
PIPE 1.4
PIPE 2.3
PIPE 6.7
PIPE 5.8
% Sawdust Burnt
0% 3% 5% 7%
18 23 20 22
% Catchweight
79 76 76 74
% Passing 75 Micron
% Sawdust Burnt
0% 3% 5% 7%
29 18 24 20
% Catchweight
58 78 67 78
% Passing 75 Micron
% Sawdust Burnt
0% 3% 5% 7%
21 26 28 24
% Catchweight
75 74 70 77
% Passing 75 Micron
% Sawdust Burnt
0% 3% 5% 7%
32 33 27 34
% Catchweight
62 60 68 61
% Passing 75 Micron
Wallerawang Unit 7E Mill
PF Fineness Results
Biomass Burning Trials
22

Delta electricity

Overview of Coal/Biomass Combustion Research at Co-operative Research Centre for Black Coal Utilisation

The UNIVERSITY of NEWCASTLE AUSTRALIA

Black Coal Utilisation CRC

Dr B. Moghtaderi, and Professor T.F. Wall
Department of Chemical Engineering
Cooperative Research Center for Black Coal Utilisation
University of Newcastle, Australia

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The UNIVERSITY of NEWCASTLE AUSTRALIA

Black Coal Utilisation CRC

- **The focus of co-firing research is on:**
  - ***.Processing and handling issues;***
  - ***.Combustion related issues;***
  - ***.Ash related issues.***

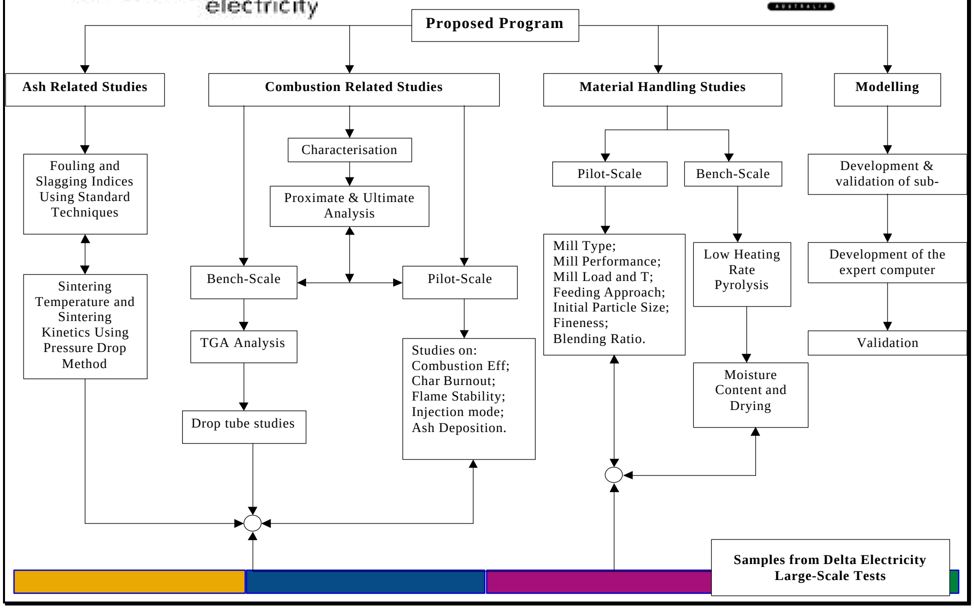
- **Current activities involve:**
  - ***Char burnout using blends processes by large-scale pulverisers.***
  - ***Ash deposition ;***
  - ***Storage related issues (in particular drying);***
  - ***Handling and fuel processing issues (collaboration with center for Bulk Solid Handling);***
  - ***Development of test programs for Industry partners (Delta Elc.);***
  - ***Safety related issues (low heating rate pyrolysis in pulveriser units).***

24

Delta electricity

CRC Biomass Co-Firing Research Program

Black Coal Utilisation CRC



Delta electricity

Drop Tube Furnace Used for Char Burnout Tests

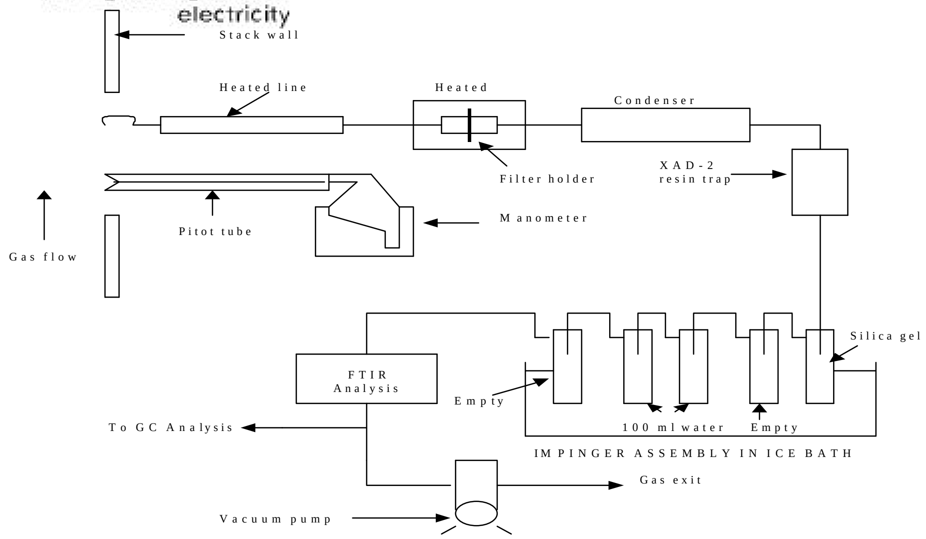
26

Emissions Prediction

- Sampling Flue Gas from laboratory combustion of fuel samples
    - Timber treated with preserving chemicals
    - Engineered timber products containing adhesives
    - Low heating rate combustion gives worst case outcome
- Aims
    - Design of a portable extraction system based on USEPA recommendations
    - Online measurement of NOx, SOx and acid gases using FTIR
    - Trapping and GC analysis of VOCs and extraction and analysis of PAHs using GC/MS
    - Sampling, extraction and analysis of PCBs and dioxins and furans using state of the art analysis techniques

27

Emissions Analysis Apparatus



Extraction line for sampling and analysis of emissions from co-combustion

28

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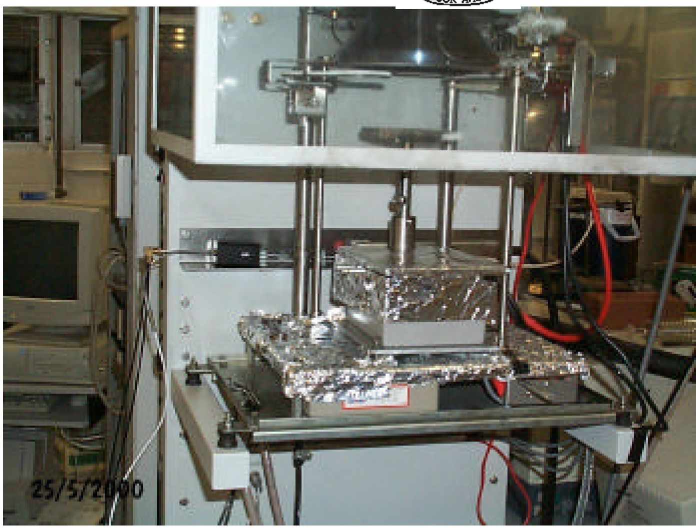
Cone Calorimeter



Delta electricity

Flue Gas Sample Extraction Equipment

Contact Details:

A/Prof B Z Dlugogorski

Dr E M Kennedy

Dr A Bhargava

Department of Chemical Engineering
The University of Newcastle
Callaghan, NSW 2308, Australia
Phone +61 2 4921 6180
Fax +61 2 4921 6920
email: cgbzd@alinga.newcastle.edu.au

Annex 3. Danish Folow-up Programme for Small Scale Solid Biomass CHP plants

Annex 4. Proposal from Finland on NOX reduction

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 NOx - 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

VTT ENERGY

MEMORANDUM OF UNDERSTANDING

FOR CO-OPERATION IN THE FIELD OF CO-FIRING COAL WITH BIOMASS

1. Introduction

Concerns regarding the potential global environmental impacts of fossil fuels used for power generation and other energy supplies are increasing. One means of mitigating these environmental impacts is increasing the fraction of renewable and sustainable energy in the national energy supply. Traditionally, renewable energy sources struggle to compete in open markets with fossil energy due to low efficiencies, high cost, and high technical risk.

Co-firing biomass with coal in traditional coal-fired boilers (subsequently referred to as co-firing) represents one combination of renewable and fossil energy utilisation that derives the greatest benefit from both fuel types. Co-firing capitalises on the large investment and infrastructure associated with the existing fossil-fuel-based power systems while requiring only a relatively modest investment to include a fraction of biomass in the fuel. When proper choices of biomass, coal, boiler design, and boiler operation are made, traditional pollutants (SO_x, NO_x, etc.) and net greenhouse gas (CO_2, CH_4, etc.) emissions decrease. Ancillary benefits include increased use of local resources for power, decreased demand for disposal of residues, and more effective use of resources. These advantages can be realised in the very near future with very low technical risk. However, improper choices of fuels, boiler design, or operating conditions could minimise or even negate many of the advantages of burning biomass with coal and may, in some cases, lead to significant damage to equipment.

Within the International Energy Agency (IEA) attention is paid to co-firing coal with biomass and related wastes in two different Implementing Agreements:

- Implementing Agreement for a programme of research, development and demonstration on Coal Combustion Sciences;
- Implementing Agreement for a programme of research, development and demonstration on Bioenergy; Task 19:. Biomass Combustion and Co-firing.

2. Scope of this Memorandum of Understanding (MoU)

This MoU is made between IEA Coal Combustion Sciences (CCS) and IEA Bioenergy: Biomass Combustion and Co-firing (BCC) to acknowledge the co-operation in the field of co-firing coal with biomass and related wastes. The scope of the co-operation is to encourage, support and promote research, development and implementation of co-firing coal with biomass through knowledge sharing and transfer. The co-operation is believed to be exceptionally successful because leading knowledge on coal combustion is combined with leading knowledge on biomass.

3. Proposed co-operation

In the period 2001 - 2003 CCS and BCC will co-operate in the field of co-firing coal with biomass and related wastes.

From a preliminary inventory by BCC the following items were selected to be of importance in research, development and demonstration in this field:

- Fuel Characteristics and Resource assessment;
- Fuel Preparation and Handling;
- Pollutant Emissions;
- Ash Deposition;
- Carbon Conversion;
- Chlorine-Based Corrosion;
- Fly Ash Utilisation.

The co-operation is proposed to consist of sharing knowledge and executing mutual projects in this field. One of the objectives could be to establish guidelines for fuel properties, injection design, and fuel preparation when firing biomass with coal. Progress will be discussed in an annual mutual CCS/BCC meeting.
The way of co-operation will be detailed before the end of 2000.

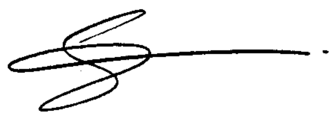
4. Acknowledgement

The above intention is acknowledged by both groups represented by their leaders.

IEA Coal Combustion Sciences

Les Dale
March 15, 2000

IEA Bioenergy: Biomass Combustion and Co-firing



Sjaak van Loo
March 15, 2000

Annex 6. Current Activities of Task 19

Title	Subject	Co-ordinator	Contributors
Ash related problems during combustion	• agglomeration • deposit formation • aerosol formation • corrosion	USA	NZ, S, DK, CH, A, SF
Characterization and utilization of biomass ashes	• characterisation • data base • legislation • ashes from co-firing • ash treatment	A	DK, NL, USA, S, CH
Classification of biofuels	• inventory of activities • inventory of standards	NL	NL
Modelling	• inventory of activities • workshop for modellers	NL	All
CHP	• dissemination	CH	CH
Handbook		NL	All
Cofiring	• workshop with IEA CCS and EU project • inventory of barriers	USA	not yet known