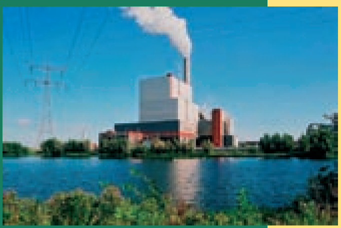
IEA Bioenergy

Task 38

Greenhouse Gas Balances of Biomass and Bioenergy Systems

Greenhouse Gas Balances of Biomass Import Chains for "Green" Electricity Production in The Netherlands

Summary



Amer power plant in the Netherlands, Courtesy of Essent

Discharge dock and silos on the Amer river, Courtesy of Essent

Various utility companies are considering or already initiated the import of biomass for co-firing purposes in its coal plants, mainly with the intention to reduce CO_2 emissions. In this study, a Life Cycle Inventory has been performed of 2 existing biomass import chains to evaluate the overall environmental impact of biomass import and its application as fuel to generate electricity by co-firing. This paper is focussing on the results concerning the Greenhouse Gas Balances. We considered production, transport and co-firing of wood pellets from Canada and palm kernel shells from Malaysia in a 600 MW_{el} coal fired power plant in the Netherlands and compared those chains with various reference systems. Primary energy losses as a consequence of transport to the Netherlands and co-firing in a state-of-the-art pulverised coal power plant vary between 0 and 30 % of the biomass energy content. Net greenhouse gas emissions of co-firing are in the range of -3 500 to 250 g / kWh versus 650 to 1050 g / kWh for the fossil fuel reference systems. In the most optimistic scenario, pellet co-firing avoids methane emissions that would have occurred if the pellets were decomposed at landfills when not applied for co-firing purposes. In the most pessimistic scenario, palm kernel shells co-firing competes with the application as resource for fodder production, requiring production and transport of soybeans as alternative resource. In general, the considered chains are effective GHG mitigation schemes, but the reference systems of the import and export countries are important factors that should be considered case by case.

Scope

Kay Damen and André Faaij

Utrecht University

In order to reduce national greenhouse gas emissions (GHG) emissions, the Dutch government set a target in the so-called 3rd energy paper, which states that 10 % of the domestic total energy supply in 2020 should consist of renewable sources. The main emphasis was put on renewable electricity, for which a target was set of 17 % contribution to the domestic electricity demand. In order to stimulate the production of renewable ("green") electricity, various financial regulations have been taken, among which greening the fiscal system and the introduction of feed-in tariffs.

Amer power plant in the Netherlands, Courtesy of Essent

Biomass is considered to play a key role in the realisation of this target; about 40 % of the renewable energy should be produced from biomass. Since the availability of indigenous biomass resources of good quality is limited and prices tend to be high, various Dutch utility companies are importing biomass from other countries to produce renewable electricity. Co-firing biomass with coal is the most important conversion route, being relatively cheap (modest investments are required to adapt coal-fired power plants), efficient and resulting in direct replacement of coal.

Since green electricity has a high market value as a sustainable product, strict requirements are set on its environmental and socio-economic impacts. In order to be sold as green electricity, the sustainability of biomass production and import should be guaranteed. This is a complex issue in the case of biomass import, since the production, harvesting and transport of the biomass takes place in another country, which makes it very hard to introduce and control standards. Especially large-scale, intensive biomass cultivation may have environmental and socio-economic impacts, which might not be in line with sustainability criteria.

The objective of this study is to provide a GHG-balance (and required energy balance) of two existing biomass import chains. The chains considered consist of production, transport and co-firing wood pellets from Canada and palm kernel shells (PKS) from Malaysia in a coal fired power plant in the Netherlands.

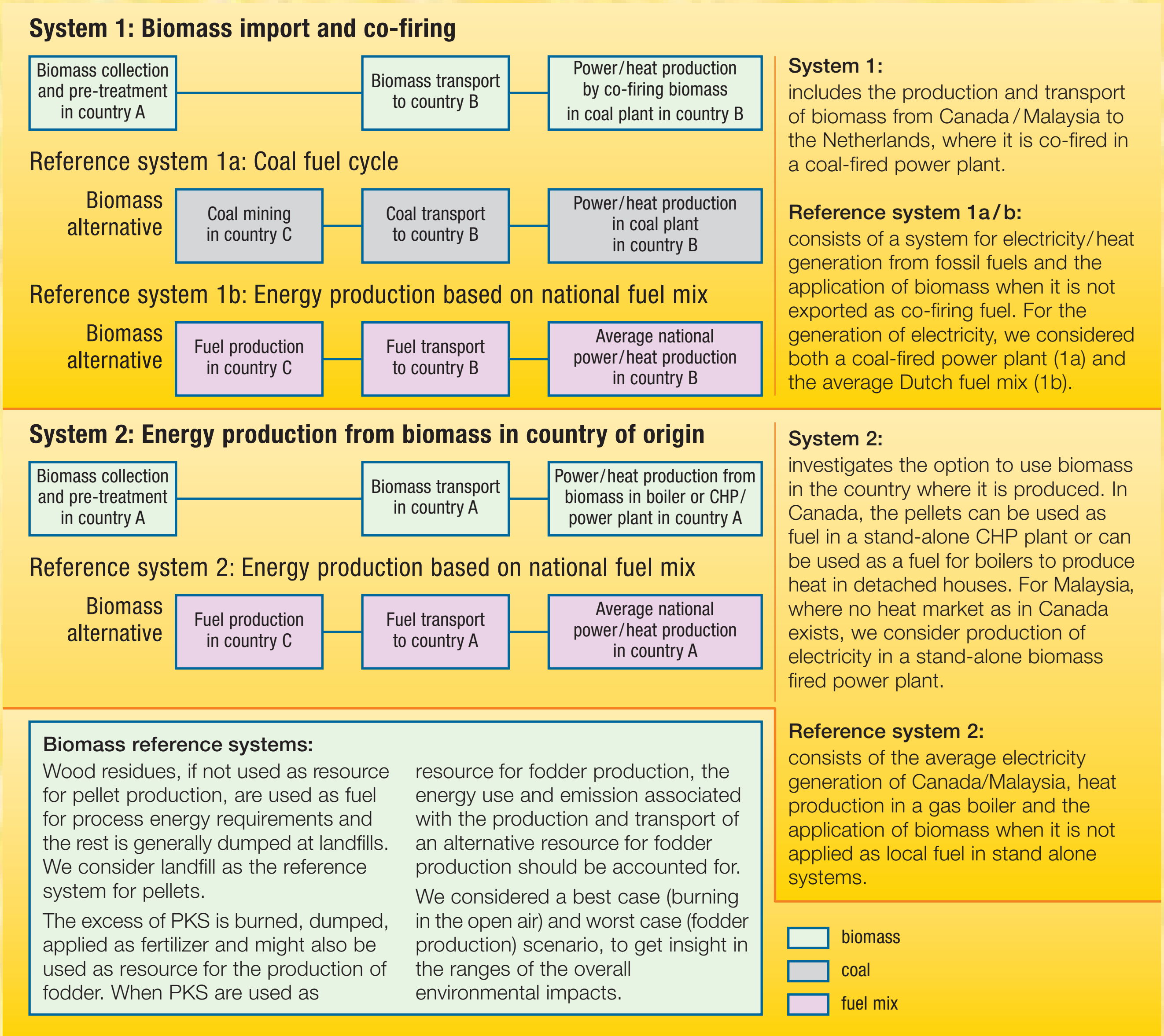


Figure 1. Biomass chains versus reference systems

Methodology

Different utilization routes and reference systems considered in this study are depicted in figure 1.

When co-firing biomass, the electricity and heat output can decrease with respect to the 100 % coal reference system due to: increased internal energy use (feed-line), posssible decrease of carbon burnout and derating because of the lower heating value of biomass compared to coal. Consequenetly, relatively more air is required to burn the fuel mix in comparison to coal only, which causes a higher throughput of flue gas through the boiler. This may result in a lower heat transfer. This effect depends strongly on the boiler type/design. When the boiler is designed for a maximum gas volume, the fuel input must be reduced, which results in a lower steam production.

For emission calculations, the functional unit is 1 kWh produced by biomass conversion. CO_2 emissions caused by burning or decomposition of biomass are assumed to be zero, since the released CO_2 makes part of the short-rotation cycle. Emissions of CH_4 and N_2O when co-firing are assumed to be equal to emissions of 100 % coal-firing.

System Components

Case specific data provided by companies involved in biomass import and co-firing were used for biomass composition and production, transport and co-firing. For energy use and process emissions such as transport and national power generation, scientific publications and reports, IEA statistics and LCA databases (GEMIS and SIMAPRO 5.0) were used [1].

Pellet production and transport (figure 2)

In several regions in Canada, large amounts of wood residues become available at chip mills and sawmills, among which bark, sawdust and shavings. These residues can be used to produce pellets, a high quality fuel with a high energy density. The pelletisation process requires electricity (134 kWh/tdm pellets) and heat, which is generated in a boiler fueled with sawdust.

Palm kernel shell production and transport (figure 2)

Malaysia is the major producer of palm oil in the world. During the production of palm oil from fresh fruit bunches (FFB), several residues become available, among which fibre and palm kernel shells. Circa 60 % of the PKS are used as fuel in the local palm oil industry.

Biomass co-firing

Essent Energie is co-firing different types of biomass in a modern pulverised coal-fired power plant equipped with low NO_x burners. It has a net electric and thermal capacity of respectively 600 MW_{el} and 350 MW_{th} of low-calorific heat. In this study, base case calculations are performed assuming no heat is produced resulting in a net electric efficiency of 42.5 %.

Biomass is mixed with coal and transported to the boiler house, where the mix is crushed by a mill and fed to the boiler. Co-firing shares of 7 and 20 wt % are considered. Simulation modelling to determine the impact of co-firing on the electrical efficiency indicated that the efficiency will hardly be affected when co-firing pellets and PKS at low co-firing shares (6–8 wt %). The estimated efficiency drop when co-firing 20 wt % pellets and PKS is 1.3 % points.

Local biomass use in stand-alone plants

The 25 MW_{el} state-of-the-art biomass-fired CHP in Cuijk, the Netherlands (electric efficiency of 26 %) is used as stand alone CHP in Canada. For the biomass fired power plant in Malaysia, the performance of the Cuijk plant operating without heat production is used. For heat production, an 11 kWth pellet boiler with an efficiency of 78 % is used.

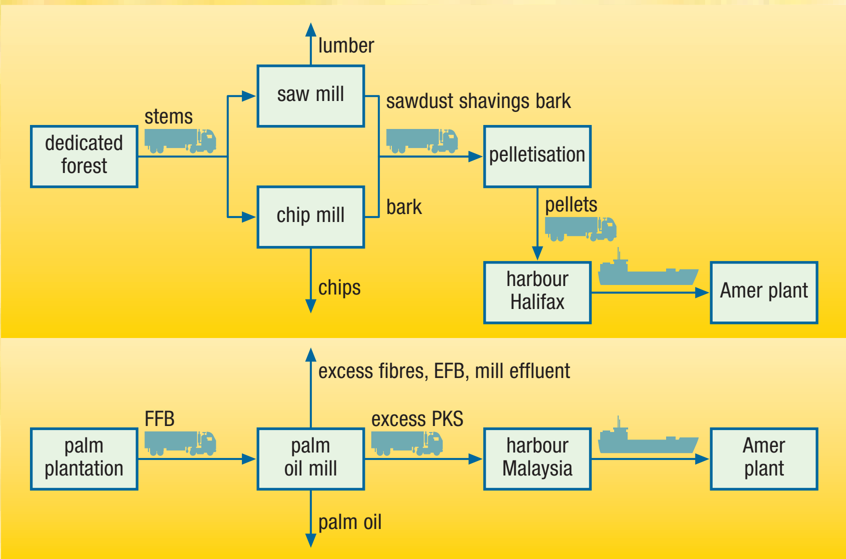


Figure 2. Pellet and PKS production and transport. Biomass is transported to Rotterdam by ocean vessel and transferred to barges for delivery to the power plant.

Reference electricity and heat production

The Amer plant fuelled with 100 % coal is used as reference system 1a. The primary energy required for mining and transport of the Dutch coal mix is 11 % of its LHV. The average efficiency of Dutch electricity production (reference 1b) is circa 41 %. Canada has a high overall electrical efficiency of circa 60 %. The overall efficiency of electricity production in Malaysia is 45 %. For heat production, an average efficiency of 90 % is assumed.

Biomass reference sytems

Pellet decomposition at landfills results in a gas composed of approximately 50 % CO_2 and 50 % CH_4 [2]. Only a part of the non-lignin compounds is degraded. Mann [2] assumed 50 % of cellulose and hemicelloluse is degraded, corresponding to 35 % of the carbon present in biomass. Recent experiments in which a 19 and 29 years old landfill in Australia have been excavated indicate that only 2.5 and 4.1 % of the amount of carbon present in wood products has been decomposed [3]. In this study, we consider a range of 3 to 35 % in the amount of carbon that is being decomposed at landfills. Landfill gas capture is generally not practiced at wood waste landfills in Canada.

PKS burning in the open air is a significant source of CH_4, NO_x and N_2O. The emissions of these compounds are calculated by means of an IPCC method to assess emissions of field burning of agricultural residues.

When PKS are used for fodder production, an equivalent amount of alternative resource must be produced and imported. We considered soybean production in Iowa, USA, rail/barge transort to New Orleans, from where it is transported to the Netherlands.

Results

For producing a GHG balance, first the energy balance of the various chains (and reference systems) is made. Some key findings are:

- The production and transport of pellets and PKS represents 10–12 % of the biomass heating value when co-firing, versus 3–8 % when used as fuel in the country of origin.
- The use of pellets as fuel for stand alone CHP plants/heat boiler in Canada is less efficient than export to the Netherlands for co-firing purpose with co-firing shares up to 7 wt %. This can be explained by the higher electric efficiency of the Amer plant in comparison to the considered conversion systems for Canada.
- The electrical efficiency of co-firing 20 instead of 7 wt % pellets is decreased to a level below local application as fuel for stand alone CHP plants/heat boiler. For PKS, even at co-firing shares of 20 wt %, it is still more efficient to export the shells than burning them in stand-alone power plants in Malaysia.

Figure 3 shows that net GHG emissions of pellet import and co-firing are negative, because avoided methane emissions during decomposition at landfills and coal mining are high in comparison to GHG emissions caused by pellet supply and co-firing. The variation in the emission is caused by the range in carbon decomposition. Table 1 shows the net avoided GHG emissions of pellet and PKS (co-)firing versus various reference electricity/heat systems.

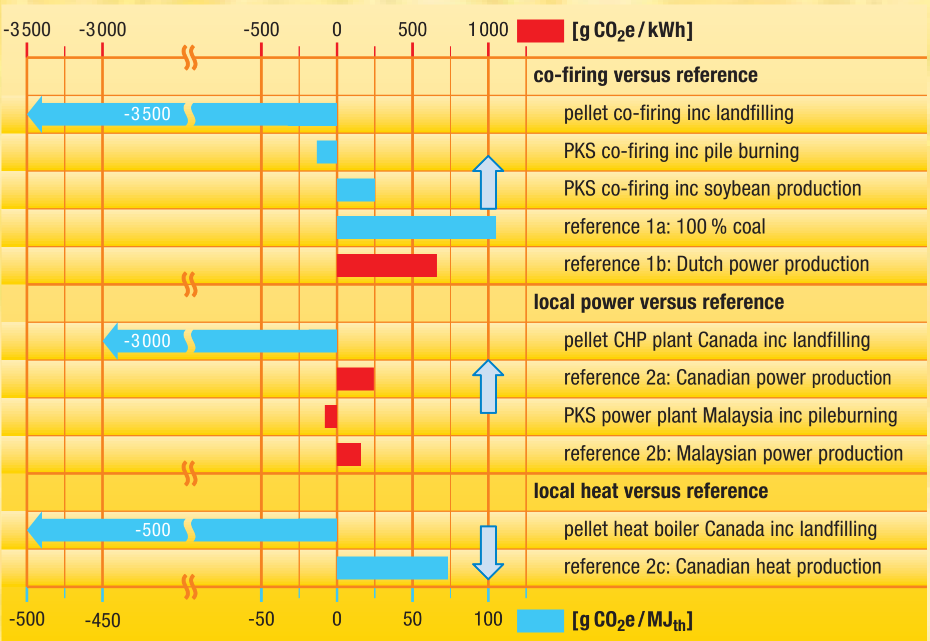


Figure 3. GHG emissions of pellet and PKS import and co-firing (7 %) and use as fuel in stand-alone combustion systems in country of origin versus reference power/heat production. Axis above: CO_2 equivalents (CO_2e) for electricity systems (g/kWh). Axis below: CO_2e for heat systems (g/MJ_{th}).

The fate of PKS when it is not used as fuel determines whether net GHG emissions are positive or negative, although in both cases net GHG emissions are significantly lower compared to the reference electricity/heat systems. When the shells are burned in the open air, net GHG emissions are slightly negative due to avoided CH_4 and N_2O emissions. If PKS would be used as resource for fodder production, there is a net positive GHG emission, caused by the relatively high GHG emissions of soybean cultivation and transport.

Table 1. Net avoided GHG emissions (emission of 1 kWh "green" electricity minus emission of 1 kWh of "reference" electricity)

Option	Net avoided GHG emission [g CO_2e/kWh]
Biomass co-firing (7 %) in the Netherlands	
pellet co-firing inc landfilling versus 100 % coal	1388–4542
pellet co-firing inc landfilling versus Dutch power production	990–4144
PKS co-firing inc pile burning versus 100 % coal	1179
PKS co-firing inc soybean production versus 100 % coal	791
PKS co-firing inc pile burning versus Dutch power production	794
PKS co-firing inc soybean production versus Ducth power production	406
Local biomass use in stand-alone plants	
pellet CHP plant Canada versus Canadian power production	438–3345
pellet heat boiler Canada versus Canadian heat production [g/MJ_{th}]	99–571
PKS power plant Malaysia versus Malaysian power production	252

Discussion and Conclusions

The prospects of biomass transport to the Netherlands for co-firing purposes are generally more promising than the prospects of pellet and PKS utilization as fuel in stand-alone combustion systems in the country where the biomass is produced, in spite of energy use and emissions caused by sea transport over a large distance. This is explained by the lower efficiency of those relatively small-scale systems in comparison to the coal fired power plant and the relatively high energy use and emissions of coal mining and transport to the Netherlands. A third reason that makes export preferable above intern use in these cases, is the large share of hydro-electricity in the electricity mix of Canada and gas in Malaysia, which are relatively efficient and less GHG intensive in comparison to 100 % coal or the Dutch electricity mix.

Net GHG emissions of the biomass co-firing chains are in the range of -3500 to 250 g/kWh, depending on biomass type and alternative application, versus 650 to 1050 g/kWh for the fossil fuel reference systems. The low emissions for biomass co-firing chains in comparison to 100 % coal is mainly explained by the fact that coal mining and transport to the Netherlands cause high emissions of especially CH_4, (and other pollutants). Also the avoided emissions of CH_4 caused by decomposition of wood residues at landfills in Canada and CH_4 caused by palm kernel shells burning in the open air in Malaysia contribute to the positive impact of biomass import and co-firing.

This study has shown that the choice of the biomass resource, origin and reference system is important for the environmental performance of biomass import and co-firing. The country/region of interest where a biomass potential exists, local conditions and market effects of biomass trade should be considered with care. Crucial aspects are biomass composition and potential, application of the biomass when it is not exported, internal demand, competition with other applications and the energy system of importing and exporting country. The full report is documented under: www.joanneum.at/iea-bioenergy-task38/projects/task38casestudies/nl-fullreport.pdf

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Acknowledgement

Essent Duurzaam is acknowledged for their financial contribution. The authors wish to thank Remco de Vos, Rob Remmers and Martijn Wagener (Essent Duurzaam), Dimitris Athanassiadis (Swedish University of Agricultural Sciences), Wijnand Schonewille (Port of Rotterdam) for their input in this study.

IEA Bioenergy

Task 38

IEA Bioenergy (www.ieabioenergy.com) is an international collaborative agreement, set up in 1978 by the International Energy Agency (IEA) to improve international cooperation and information exchange between national bioenergy research, development and demonstration (RD & D) programs. IEA Bioenergy aims to realize the use of environmentally sound and cost-competitive bioenergy on a sustainable basis, thereby providing a substantial contribution to meeting future energy demands.

IEA Bioenergy Task 38 brings together the work of national programs in 13 participating countries on GHG Balances for a wide range of biomass systems, bioenergy technologies and terrestrial carbon sequestration. As one example of work, case studies have been conducted by applying the standard methodology developed by the Task 38. In the case studies GHG balances of different bioenergy and carbon sequestration projects in the participating countries have been assessed and compared, of which that of New Zealand is one example.

Task Coordination

Bernhard Schlamadinger
Joanneum Research
Elisabethstrasse 5, A-8010 Graz, AUSTRIA
Phone: +43 316 876-1340 • Fax: +43 316 8769-1340
e-mail: bernhard.schlamadinger@joanneum.at

Kimberly Robertson
New Zealand Force Consulting
444 Pukehangi Rd., Rotorua, NEW ZEALAND
Phone: +64 7 343-9559 • Fax: +64 7 343-9557
e-mail: kimberlyrobertson@xtra.co.nz

National Team Leaders

AUSTRALIA
Annette Cowie
State Forests New South Wales
P. O. Box 100 Beecroft, New South Wales 2119
Australia
Phone: +61 2 9872-0138 • Fax: +61 2 9871-6941
e-mail: annettec@sf.nsw.gov.au

AUSTRIA
Susanne Woess-Gallasch
Joanneum Research
Elisabethstrasse 5, A-8010 Graz, Austria
Phone: +43 316 876-1330 • Fax: +43 316 8769-1330
e-mail: susanne.woess@joanneum.at

CANADA
Terry Hatton
Canadian Forest Service, Natural Resources Canada
580 Booth St., Ottawa, Ontario
K1A OE4 Canada
Phone: +1 613 947-9077 • Fax: +1 613 947-9020
e-mail: thatton@ncran.gc.ca

CROATIA
Snjezana Fijan-Parlov
EKONERG
Koranska 5, PP 144, HR-10000 Zagreb, Croatia
Phone: +385 1 6000-122 • Fax: +385 1 6171-560
e-mail: sfijan@ekonerg.hr

DENMARK
Niels Heding
Danish Forest and Landscape Research Institute
Hoersholm Kongevej 11
DK 2970 Hoersholm, Denmark
Phone: +45 45 763-200 • Fax: +45 45 763-233
e-mail: NIHE@kvl.dk

FINLAND
Sampo Soimakallio
VTT-Processes
P.O. Box 1606,FIN-02044 VTT (Espoo)
Phone: +358 9 456-6767 • Fax: +358 9 456-7026
e-mail: sampo.soimakallio@vtt.fi
Kim Pingoud
Finnish Forest Research Institute
Unioninkatu 40 A, FIN-00170 HELSINKI
Phone: +358 10 211 2063, Fax: +358 10 211 2104
e-mail: kim.pingoud@metla.fi

IRELAND
Kenneth Byrne
Centre for Hydrology, Micrometeorology & Climate Change, Department of Civil and Environmental Engineering, University College Cork
Phone: +353 21 490-3025 Fax: +353 21 427-6648
e-mail: k.byrne@ucc.ie
Carly Green
Forest Ecosystem Research Group
University College Dublin
Phone: +353 1 716-7673, Fax: +353 1 716-1102
e-mail: carly.green@ucd.ie

THE NETHERLANDS
Kees Kwant
NOVEM
Catharijnesingel 59, Postbus 8242, 3503 RE Utrecht
The Netherlands
Phone: +31 30 2393-587 • Fax: +31 30 2316-491
e-mail: a.de.zeeuw@novem.nl

Andre Faaij
Utrecht University, Copernicus Institute
Heidelberglaan 2, 3584 CS Utrecht, The Netherlands
Phone: +31 30 2537-643 • Fax: +31 30 2537-601
e-mail a.p.c.faaij@chem.uu.nl

NEW ZEALAND
Kimberly Robertson
Force Consulting
444 Pukehangi Rd., Rotorua
New Zealand
Phone: +64 7 343-9559 • Fax: +64 7 343-9557
e-mail: kimberlyrobertson@xtra.co.nz

NORWAY
Birger Solberg
Agricultural Univ. of Norway, Dep.of Forest Sciences
P. O. Box 5044, N-1432 Ås, Norway
Phone: +47 64 94 88 80 • Fax: +47 64 94 88 90
e-mail: birger.solberg@isf.nlh.no

SWEDEN
Leif Gustavsson
Mid Sweden University
SE-831 25 Östersund, Sweden
Phone: +46 63 165-979 • Fax: +46 63 165-450
e-mail: leif.gustavsson@mh.se

UNITED KINGDOM
Robert Matthews
Forest Research – Alice Holt Research Station
Wrecclesham, Farnham
Surrey GU10 4LH United Kingdom
Phone: +44 1420 526-235 • Fax: +44 1420 234-50
e-mail: robert.matthews@forestry.gsi.gov.uk

UNITED STATES
Matthew Ringer
National Renewable Energy Laboratory
1617 Cole Blvd. MS-1613, Golden, Colorado, U.S.A.
Phone: +1 303 384-7747 • Fax: +1 303 384-6363
e-mail: matthew_ringer@nrel.gov

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IEA Bioenergy: T38: 2005: 02
This folder was designed and published on behalf of IEA Bioenergy Task 38
by JOANNEUM RESEARCH Forschungsgesellschaft mbH, Steyrergasse 17, 8010 Graz, Austria. February 2005.