IEA Bioenergy

Task 38

Greenhouse Gas Balances of Biomass and Bioenergy Systems

BIOMITRE

Greenhouse Gas Benefits of Biodiesel Use in Croatia in the Context of Joint Implementation

Snjezana Fijan-Parlov (Project Leader)

Marko Liposcak

EKONERG Institute, Ltd.

Abstract

This study evaluates the greenhouse gas (GHG) reduction potential of biodiesel use in Croatia through the context of Joint Implementation (JI). The Republic of Croatia is a signatory to the Kyoto Protocol. Upon its entering into force and its ratification by Parliament, Croatia shall commit to reduce its emissions of GHG by 5 percent in relation to the reference year, over the commitment period from 2008 to 2012. In total 39 measures have been identified to meet the reductions in all sectors. Biomass is seen as a source with great potential in reducing GHG among renewable energy sources. One of the most promising options with respect to liquid biofuels is the production and use of biodiesel in the transportation sector which could play a significant role in reducing GHG emissions. A life-cycle analysis (LCA) of passenger cars and urban (city) buses was conducted to compare the overall GHG emissions of biodiesel and fossil fuel systems for transportation. The mitigation costs for GHG emissions reduction are also analysed and given in € per avoided tonne of CO_2 equivalent (CO_2e). The results demonstrate a significant reduction of GHG emissions by replacing fossil fuels with biodiesel in the transportation sector, with mitigation costs ranging from 243 to 327 € per avoided tonne of CO_2e. GHG emissions reduction per unit in energy in biodiesel is about 47.7 g CO_2e/MJ. This study may help policy makers, utilities and industry to decide on the most cost effective GHG mitigation options, and increase implementation of similar projects, thouse providing Croatia with strategies for meeting its emission reduction targets.

Rapeseed field, Courtesy of EIHP, Croatia

Public Transport in Zagreb, Courtesy of EIHP, Croatia

Scope

and objectives of the study

The main aims of the project are:

- to analyse the LCA GHG emissions of biodiesel for wider use of biodiesel in the transportation sector in Croatia,
- to assess the emission avoidance compared to a baseline scenario without enhanced introduction of biodiesel,
- to asses the benefits related to energy balance of biodiesel,
- to analyse the possibilities of producing biodiesel in the framework of JI including costs of GHG mitigation through biodiesel use.

Methodology and data

For this study the standard methodology developed by IEA Bioenergy Task 38 for GHG balances of bioenergy systems in comparison with fossil energy systems was used.

According to the National Biodiesel project **rapeseed** (Brassica napus L. sspp. oleifera) is the preferred crop for biodiesel production in Croatia, because of very favourably climate conditions.

The scenario approach was used for the purposes of assessing the future annual production/consumption of biodiesel in Croatia. Three scenarios were defined each of them predicting the annual biodiesel production/consumption. "Baseline" scenario and "Additional Measures" scenarios are based on the National Energy Sector Development Strategy. "Maximum potential" scenario is based on the projections of the biodiesel project within the framework of National Energy Programme (BIOEN).

- **"Baseline" Scenario** – "Baseline" is the most probable scenario, assuming the moderate introduction of new technologies and relatively slow introduction of reforms and restructuring in energy sector. Data for the purposes of this study refers to biodiesel energy demand projections in year 2005, 2010 and 2020.
- **"Additional measures" scenario** – This scenario option assumes significant change in the overall orientation of the Croatian industry and economy as a result of the climate change and introduction of sustainable development concepts. This scenario also assumes implementation of additional measures for GHG emissions reduction the more formal recognition that biofuels, particularly biodiesel, are one of the most important measures in the transport sector.
- **"Maximum potential" scenario** – According to the biodiesel project within the framework of National Energy Program (BIOEN), maximum land use for cultivation of oil rape in Croatia is roughly 400 000 ha. This was the starting point in determining the oil rape cultivation needs for biodiesel production, with peak potential in 2020.

Figure 2, presents the comparison between production/consumption of biodiesel according to the "Baseline", "Additional measures" and "Maximum potential" scenario.

Biodiesel is used as a motor fuel in vehicles and machines with internal combustion engines which normally use a fossil based diesel. For the purposes of this study, biodiesel will be used by

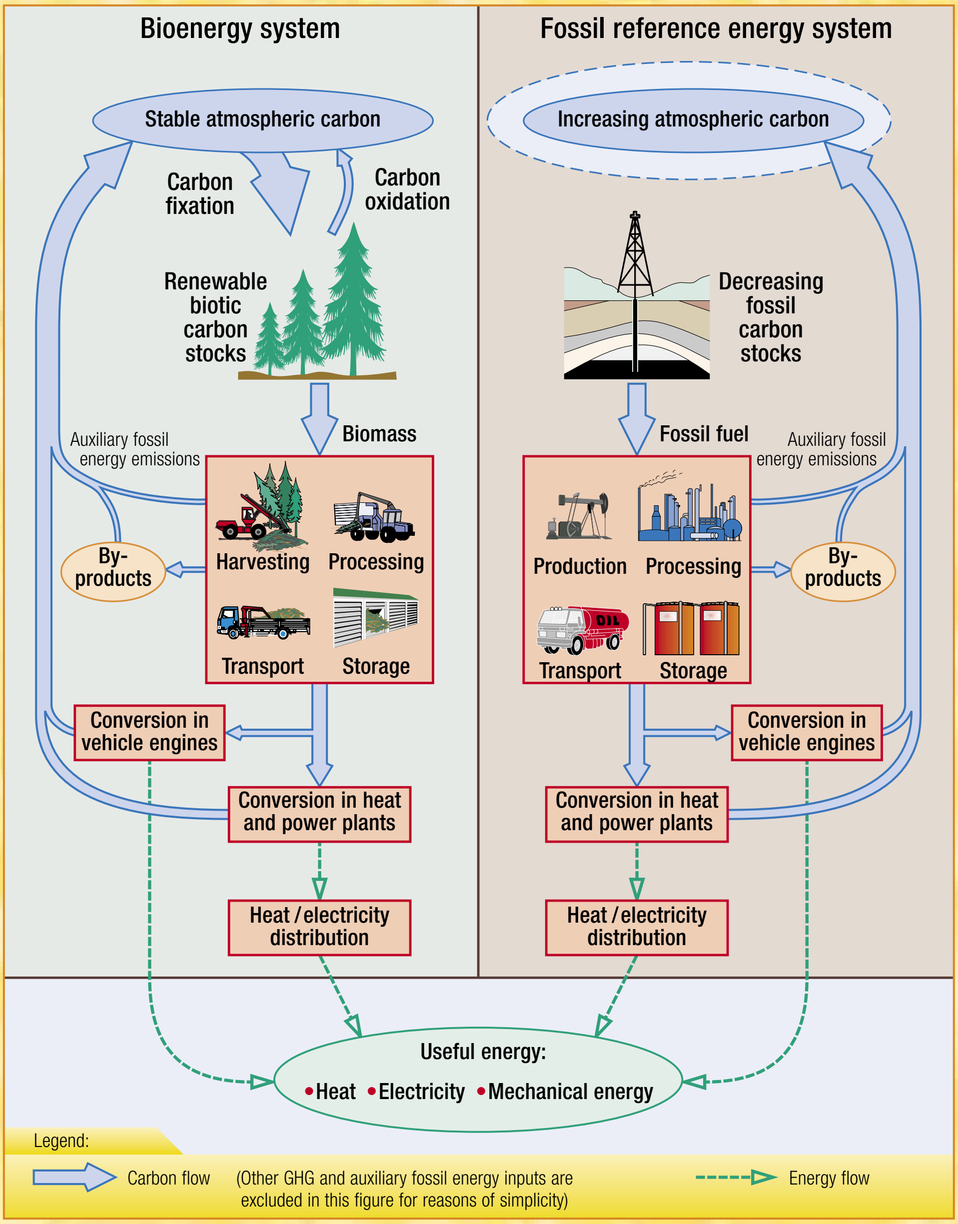

Figure 1: General standard methodology for calculation of GHG balance

Biodiesel fuel pump in Mureck, courtesy of EIHP, Cratia

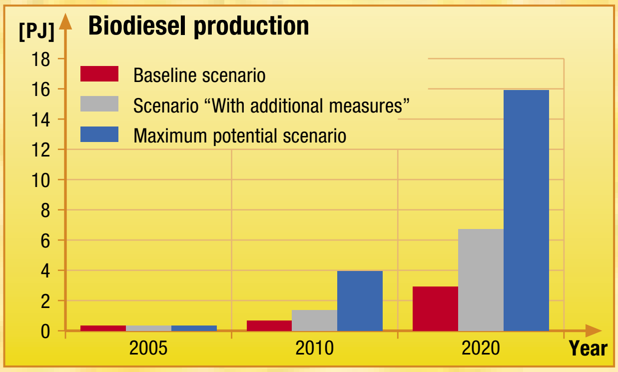

Figure 2: Production of biodiesel expressed in energy units

buses in public transport and passenger cars with internal combustion engines.

According to the IPCC, when calculating the GHG emissions in the transport sector, emissions from the systems using biomass equal zero. More specifically, carbon absorbed from the atmosphere during photosynthesis equals the amount of CO_2 emitted during the energy conversion in the vehicles. However, the LCA of biodiesel is not completely free of GHG emissions. Cultivation of rape, transport and biodiesel production require additional energy from fossil fuels that must be included in the overall emissions balance within the LCA. Furthermore, during the biodiesel production process some by-products are created, such as rape cake in the process of pressing and glycerine in the process of esterification. The GHG emissions reduction strongly depends on how these by-products are used and substituted.

The GHG emissions balance assessment was done by using the **GEMIS** model (**G**lobal **E**mission **M**odel of **I**ntegrated **S**ystems) developed in Öko-Institut in Darmstadt, Germany. Due to insufficient Croatian national data, the majority of data required by the model was taken from the extensive Austrian GEMIS database of different process chains for biodiesel systems occuring in industry, agriculture, transport, power generation, etc. (dataset: "GEMIS-Transportation systems" from JOANNEUM RESEARCH 2003).

Two different national scales were assumed: one to compare the reference fossil to bioenergy/biodiesel system use in buses, and one to compare reference fossil to bioenergy/biodiesel system use in cars with internal combustion engines.

There were three options in the case considering biodiesel use in buses/passenger cars:

- Bus/Passenger car diesel
- Bus/Passenger car biodiesel, energy use of by-products
- Bus/Passenger car biodiesel, material use of by-products

The lifecycle of biodiesel for the purposes of the analysis included:

- Set a side land
- Cultivation of oil rape
- Transport, drying and storage
- Pressing
- Transestering (production of biodiesel)
- Use of by-products with the substitutions of conventional products by the by-products
- Transport of biodiesel to the filling station and filling the biodiesel into the vehicles
- Combustion of biodiesel in vehicles.

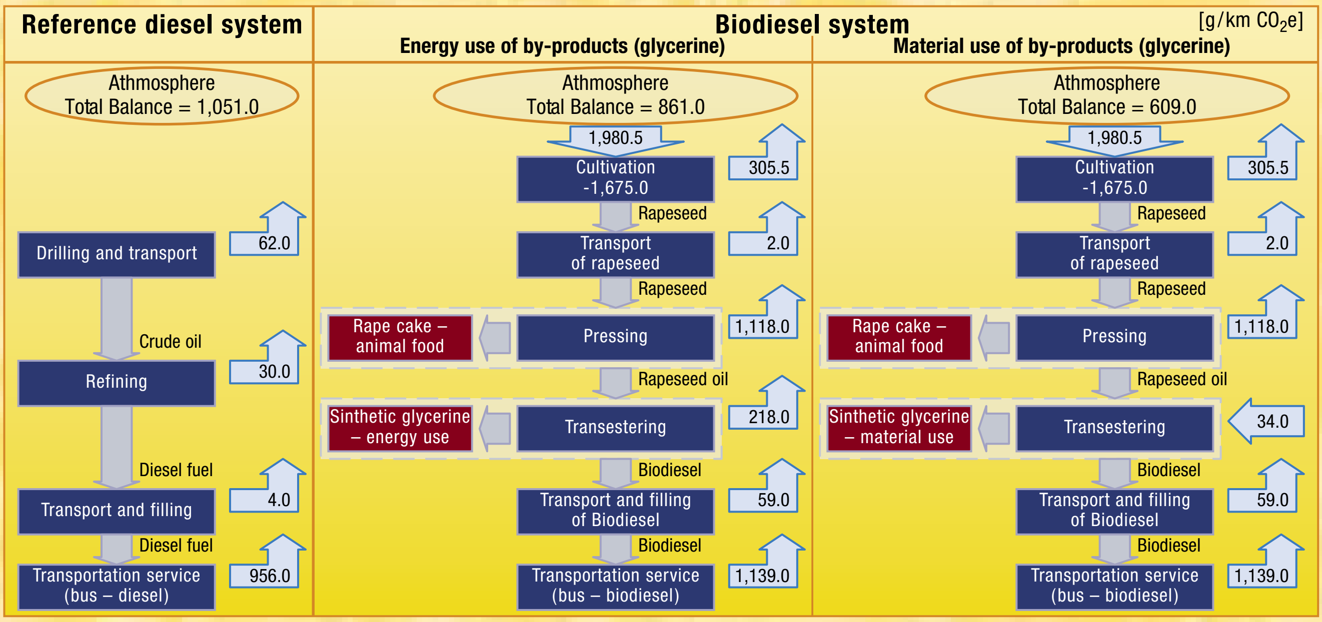

Figure 3: Diesel and biodiesel system flowcharts in terms of GHG emissions for the biodiesel use in buses

Results

GHG emissions balance for bioenergy and fossil reference systems

The results of the calculation within the GEMIS model are expressed in grams of CO_2e per 1 km driven. Figure 3, presents the LCA GHG emissions of the diesel and biodiesel systems in CO_2e in public transport buses in Croatia.

The comparison of GHG emissions from buses and cars with internal combustion engines using biodiesel or fossil fuels is shown in Figure 4, per 1 km driven. The share of CO_2, CH_4, and N_2O on the total CO_2e emissions is also shown.

The results demonstrate that GHG emissions reduction per unit energy in biodiesel is about 47.7 g CO_2e/MJ. The comparison of GHG emissions illustrates that the LCA GHG emissions of the biodiesel system are lower and even much lower than the fossil fuel reference system, regardless of the type of vehicle and use of biodiesel production by-products.

Overall GHG emissions avoided for the defined scenarios

The LCA performed using the GEMIS model provided the detailed data of specific GHG emissions per 1 km driven on either biodiesel or diesel fuel. Based on this overall GHG emissions avoidance data, a national perspective is considered.

Since the GHG emissions are highest in the "Baseline" scenario, the emission reduction potential in case of other two scenarios was obtained by subtraction of GHG emissions in respective scenario from the GHG emissions in "Baseline". Emission reduction potential for the "Additional measures" and "Maximum potential scenario" is given in Table 1.

Possibilities of producing biodiesel in the framework of JI

The JI mechanism provides the possibility of a more cost-effective and flexible way to comply with the Kyoto protocol. JI projects result in emission reduction units (ERUs) which can then be used by investing Annex I parties to help meet their emission targets. The Republic of Croatia, as a party included in Annex I to the protocol, has the possibility to participate in the GHG emissions reduction projects within the framework of the JI mechanism.

On the basis of the calculated annual emission reduction potential given in Table 1, the emission reduction potential for Kyoto commitment period (2008–2012) was calculated (Table 2).

From these results it can be concluded that there is a potential for implementation of GHG emissions reduction through biodiesel projects in Croatia by the JI mechanism.

Costs of GHG mitigation through biodiesel use

The GHG mitigation costs were analysed based on the economic comparison of the total transportation costs in the case of biodiesel and diesel use respectively. According to a feasibility study introducing the biodiesel fuel production in Republic of Croatia, the production cost of biodiesel from rapeseed without subsidies from Government would be between 0.0263 and 0.0306 €/MJ. The production costs of diesel fuel including taxes is about 0.0194 €/MJ.

Table 1: Annual emission reduction potential CO_2e [kt]

Annual emission reduction potential in CO_2e [kt]			
Year	**2005**	**2010**	**2020**
Scenario "With additional measures"	0.00	38.63	183.12
Maximal potential scenario	2.46	158.57	624.25

Table 2: Emission reduction potential for Kyoto commitment period in CO_2e [kt]

Emission reduction potential for Kyoto comitment period in CO_2e [kt]						
Year	2008	2009	2010	2011	2012	Total
Scenario "With additional measures"	13.91	24.37	38.57	47.22	57.00	181.08
Maximal potential scenario	67.95	107.69	158.52	188.50	221.73	744.38

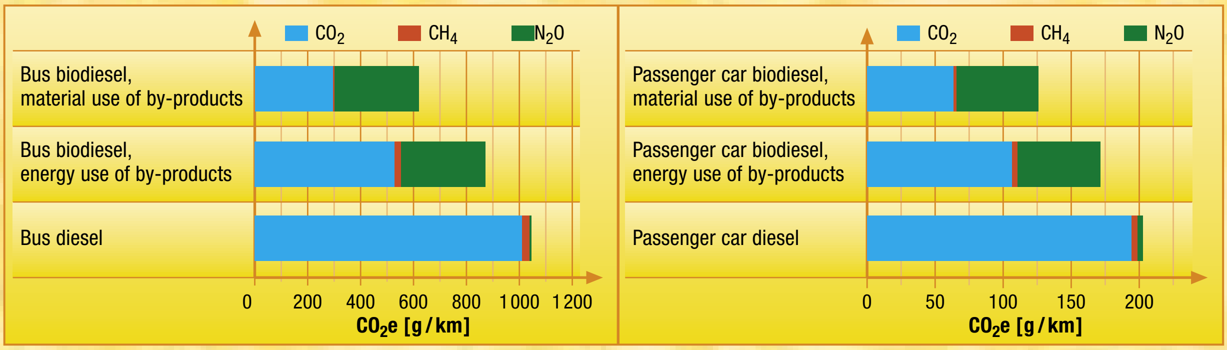

Figure 4: Comparison of GHG emissions of cars with internal combustion engine driven with biodiesel and diesel

Because of high uncertainty regarding production costs of biodiesel in Croatia, two options were taken into consideration:

- **Option I –** production cost of biodiesel = 0.0263 €/MJ
- **Option II –** production cost of biodiesel = 0.0285 €/MJ

The combination of GHG emissions and transportation cost contributed to mitigation costs for GHG reduction, of € per avoided tonne of CO_2e. These mitigation costs of replacing diesel by biodiesel are shown in Table 3.

Table 3: Mitigation costs for GHG reduction with biodiesel in the transportation sector

€/t CO_2 equivalent avoided	
Substituted fossil system	**Diesel**
Biodiesel/rapes – option I	243
Biodiesel/rapes – option II	327

Conclusions

This study provides information on the LCA GHG emissions, national emission reduction potential and GHG emissions mitigation costs in using biodiesel as a substitution fuel in Croatia. The results of the study demonstrate that using biodiesel in the Croatian transportation sector results in much lower GHG emissions than when using fossil fuels. In that sense, enhanced use of biodiesel in the transportation sector could be a valuable contribution to meet Croatia's GHG emissions reduction commitments under the Kyoto protocol. The mitigation costs of replacing diesel by biodiesel are in the range 243–327 € per avoided tonne of CO_2e. These results demonstrate that GHG emissions reduction per unit energy in biodiesel is about 47.7 g CO_2e/MJ. Nevertheless, the results of the study illustrate that there is a potential for achieving GHG emissions reduction through biodiesel projects through the JI mechanism. The primary barrier implementing this type of JI project in Croatia is that Croatia has not resolved its baseyear inventory data yet.

The results of this study should help policy makers evaluate the GHG emissions reduction potential of biodiesel projects in Croatia and the compilation of reduction scenarios in connection with the Kyoto Protocol. For more detailed information please see the full report (www.joanneum.at/iea-bioenergy-task38/projects/task38casestudies/cro-fullreport.pdf)

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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 Greenhouse Gas (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@ekoneg.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 14, 3584 CH 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
Forestry Commission. Research Agency,
Mensuration Branch
Alice Holt Lodge, Wrecclesham, Farnham, Surrey
GU10 4LH United Kingdom
Phone: +44 1420 526-235 • Fax: +44 1420 234-50
e-mail: r.matthews@forestry.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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