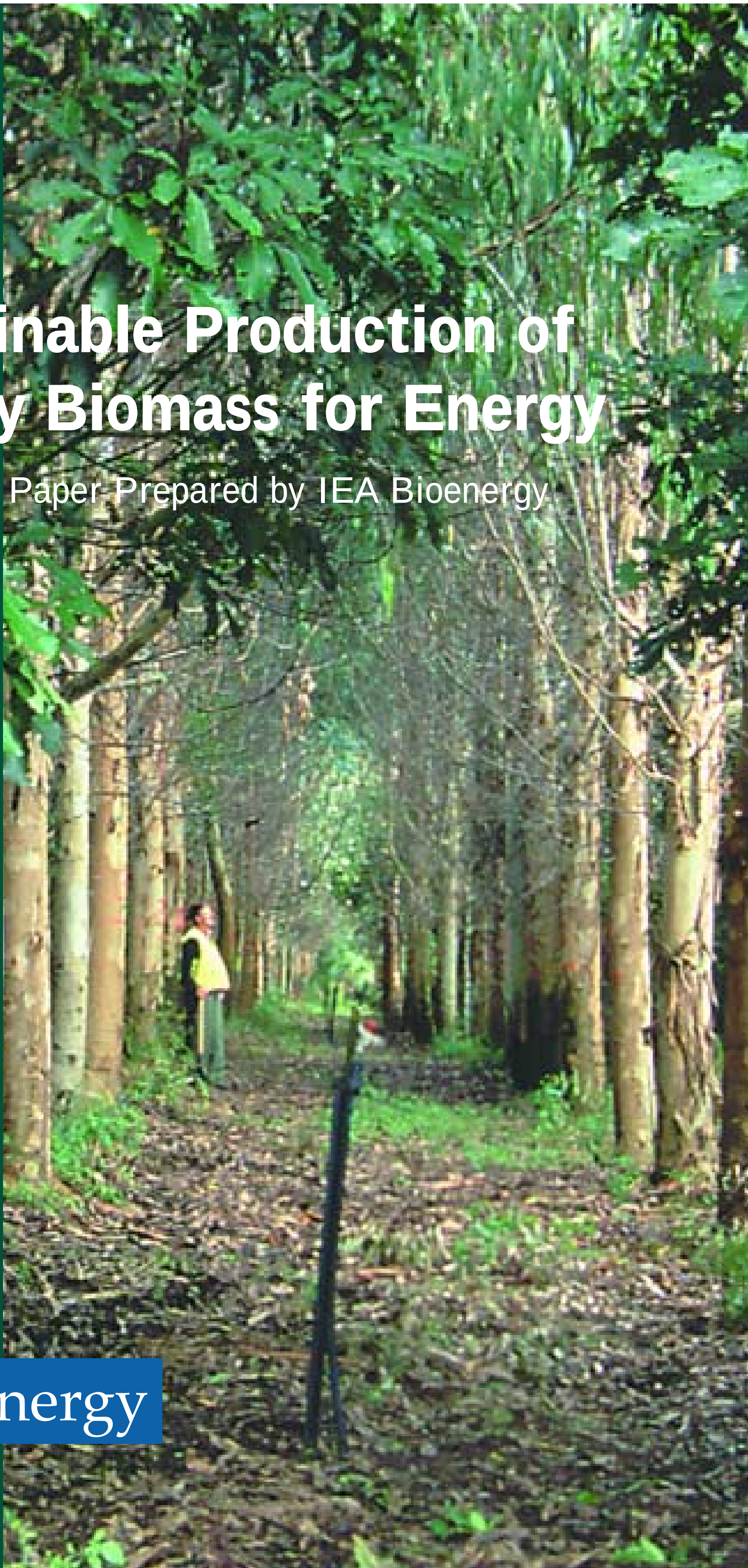
Sustainable Production of Woody Biomass for Energy

A Position Paper Prepared by IEA Bioenergy



IEA Bioenergy

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Introduction

Forests and woody crops are a source of energy through the conversion of woody biomass into convenient solid, liquid or gaseous fuels to provide energy for industrial, commercial or domestic use. Already biomass provides about 11% of the world's primary energy supplies. About 55% of the 4 billion m^3 of wood used annually by the world's population is used directly as fuel wood or charcoal to meet daily energy needs for heating and cooking, mainly in developing countries. In addition, large quantities of industrial wood waste are used to generate heat, steam and electric power in developed countries. Bioenergy systems often use biomass that would otherwise be unmerchantable and the conversion of biomass may involve biochemical, thermochemical, or physical/chemical processes.

Courtesy Dr Arto Timperi, Timberjack and Alhomens Kraft, Finland

Industrial bioenergy.

Energy and bioenergy are becoming increasingly interesting and important subjects for the public, policymakers and decision-makers as a result of rises in the prices of fossil-derived energy coupled with some concerns over nuclear energy. Furthermore, enhanced environmental concerns are encouraging the use of alternative and renewable sources of energy, particularly in developed countries. A focus of these concerns is the Kyoto Protocol (1997) to the United Nations Framework Convention on Climate Change.

Sustainability of natural resources combines economic, environmental, and social/cultural considerations. Sustainability in relation to the use of the forest involves ensuring that forest management and the benefits from forests derived by present generations do not compromise the opportunities for future generations to benefit in a similar fashion. Woody biomass can be a sustainable source of energy, a valuable renewable alternative to finite fossil fuels. The focus of bioenergy initiatives is to ensure the use of land for bioenergy is economically, environmentally and socially sustainable.

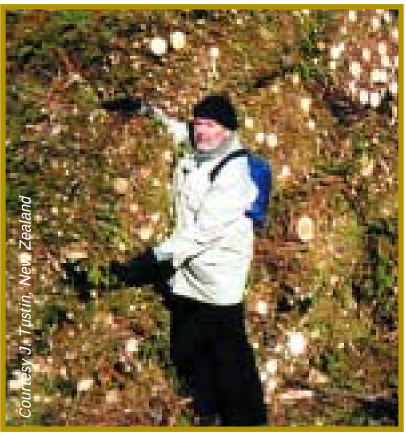
Cover picture
A 3-year-old Eucalyptus globulus *energy plantation on a land treatment irrigation site in New Zealand. Irrigation sprinkler in foreground.*

Biomass Production Systems

Conventional Forestry

Mechanised harvesting of small trees from thinnings for biofuel.

Conventional forestry systems mainly yield biomass for energy as a by-product of timber production systems. However, in certain circumstances, they can also produce biomass for energy as a primary product. The normal life cycle of forests in conventional forestry systems includes reforestation or regeneration, a sapling stage of rapid height growth, an intermediate stage of steady growth in diameter/height/volume, finally reaching maturity/harvest after 30-80 years. Any harvesting operation, whether thinning in young stands, or cutting in older stands for timber or pulpwood, can yield tops and branches usable for bioenergy. Stands damaged by insects, disease or fire are also sources of biomass. Forest residues usually constitute 25-45% of the harvested wood, so implementation of biomass production systems may be a significant part of forest management decisions. Cost-effective handling of biomass requires careful harvesting, handling and transport suitable for different forest conditions and scales of operation and these may have to be modified by integrating operations to enhance efficiency. There are ancillary benefits from intensive harvesting such as improved access for site preparation and planting and reduced risk of fire and damage from insects and disease. In assessing the economic sustainability of biomass harvesting systems, all costs and benefits are important.



Dr Peter Hall with Compacted Residue Logs, Finland.

Forest residues normally have low density and fuel values that keep transport costs per energy unit high, so it is most economic to increase the density close to source. This is done by comminution (reducing residues to small pieces with a chipper, grinder or a flail), or by compaction into bundles, termed *compact residue logs* which can be handled efficiently. Where biomass is used for heating, it can be stored/dried at roadside, a central terminal, or at the conversion facility, and distributed during peak demand periods. Costs are variable and dependent on type of cutting, stacking, chipping, forwarding, and transport to conversion facilities.

Residues from wood processing are also an important source of biomass. Considerable success has been achieved in many IEA countries where there is large-scale use of mill wastes to produce heat and electricity. This has continued in some regions to the point where nearly all available fuels are being used in this fashion.

Felling a poplar stand for biofuel, USA.

Woody Crops

Dedicated energy crops are another source of woody biomass for energy. Short-rotation (3-15 years) techniques for growing poplar (*Populus*), willow (*Salix*), *Eucalyptus* spp., or even non-woody perennial grasses (e.g., *Miscanthus*) have been developed over the past 2-3 decades. Crop improvement through selection for rapid growth, tolerance to pests, and matching to site and soil conditions has identified a number of clones for production. Operational yields in the Northern Hemisphere approach 10-15 tonnes/ha/yr. This means that 11,250 ha of plantations can produce enough biomass for a 30 MW power station which will supply enough electricity for a medium sized community - approximately 30,000 houses. Thus it is possible to manage land simultaneously as a carbon sink, for the production of solid wood products, and for biomass for energy.

Four-year-old willow crop, United Kingdom.

Large-scale production of biomass with willows and poplars (mainly undertaken in the Northern Hemisphere) is done through agricultural approaches, and the silvicultural systems used resemble agricultural ones. These systems include site preparation by ploughing, discing, harrowing and herbicide application, followed by machine or hand planting of dormant cuttings about 20-25 cm long. The application of fertilizers and herbicides ensures sufficient nutrient levels and weed control. Stems may be cut back after the first growing season to stimulate sprouting and the crop is usually harvested at 2-4 year intervals for willow, or 8-15 years for poplar. Harvesting usually occurs in the winter using purpose-built harvesting equipment. Harvested stems are often converted to chips on the site and then transported to the conversion plant. After harvesting, willow stumps are left to coppice and another crop is grown in 2-4 years. Poplars can also be coppiced but are generally grown as single stem crops and replanted after each harvest with new and improved varieties.

Sustainability Issues

The growing diversity of uses and public expectations related to forests has led to the concept of sustainable forest management as a central purpose in managing forests. Sustainable forest management is yet to be defined; however, governments and other organizations have developed *Criteria and Indicators* so that the range of forest activities can be assessed and their management adapted accordingly. These *Criteria* (values) and *Indicators* (measurements of values) are designed to be implemented on regional, national and international scales. Environmental criteria evaluate the health, productive capacity, biodiversity, soil, water, nutrient and carbon budgets. Economic criteria consider levels of employment, price of wood and other forest products, and social criteria such as public participation in forest management decisions, and the use of forests for their spiritual and aesthetic characteristics. These all combine to permit assessments of sustainability. Since biomass for energy is a product from forests it can be monitored using *Criteria* and *Indicators* to ensure sustainability.

List of Sustainability Indicators

- Conservation of biological diversity
- Maintenance of productive capacity of forest ecosystems
- Maintenance of forest ecosystem health and vitality
- Conservation and maintenance of soil and water resources
- Maintenance of forest contribution to global carbon cycles
- Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies
- Legal, institutional and economic framework for conservation and sustainable management

Certification, an independent attestation that the products of forests are generated from sustainably managed lands, is another consideration which is beginning to affect biomass production for energy. Certification is done to secure continued access to public forest lands through improved public acceptance of forest management activities. In some countries certified environmental benefits of power production systems are being used for "green marketing". As "green power" gains acceptance the trend will be to greater levels of certification.

Economic Sustainability of Biomass Production

The development of bioenergy markets can have many positive economic benefits including:

- creating markets for biomass wastes,
- improving the economic viability of thinning and harvesting operations,
- promoting new crops to farmers, especially on marginal or unused agricultural land,
- creating employment in biomass production, harvesting, transport and conversion to useful energy, and
- providing a saleable energy product.

Biomass from integrated harvesting operations can improve the financial return from harvesting and make operations in previously marginal areas economically viable. Here harvesting operations should target stands where conditions are most favourable for recovery and the scale of operations should allow full utilization of equipment. In many areas there is a growing trend towards joint ventures, agro-forestry or land leasing arrangements with farmers, so that rural communities are not displaced by expansion of planted forests. Already on some farms, willow or spruce (*Picea*) are being planted and economic opportunities for non-food crops are showing promise.

Courtesy Alholmens Kraft, Finland

Alholmens Kraft CHP plant, Pietarsaari, Finland. The largest biofuelled power plant in the world.

Compared to agricultural food crops, energy crops are typically low value products whose profitability is based on low production costs. Changes in agricultural policy (and subsidy levels) may improve the competitiveness of energy crops, but it is important that agricultural, forestry and energy policies are coordinated. Effective policies will need to be transparent, cost-effective in achieving objectives and "fair" as regards renewable versus non-renewable energy systems.

In many regions bioenergy production systems are already profitable under the current energy, forestry and agricultural policies. The potential for mixed forestry-biomass-carbon sequestration plantations may make tree farming an increasingly attractive economic proposition, particularly where carbon emissions trading occurs or carbon taxes are introduced.

Environmental Sustainability of Biomass Production

There are environmental impacts arising from the production of biomass, as there are in managing many natural resources. Three of the more important ones relate to site productivity, biodiversity, and greenhouse gas balances.

Site Productivity

A commonly expressed environmental concern about harvesting biomass for energy is that soil nutrients, organic matter and moisture-holding capacity may be depleted by intensive harvesting methods. Impacts on the inherent fertility of sites are a function of harvest intensity and the short rotation periods.

Nitrogen and other elements are abundant in twigs and foliage so that harvesting

Returning nutrients to the forest by spreading ash from wood fuel combustion.

all above-ground biomass could theoretically remove a large proportion of nutrients. In practice this does not occur since harvesting practices remove only a small portion of the branches and tops and leave sufficient biomass to conserve organic matter and nutrients. Furthermore, if nutrients are returned to the forest through ash from combustion of the residues, this ash fertilization normally alleviates nutrient losses. On nutrient-poor sites the ash should be recycled once per forest rotation. Thus forest residues can be utilized much more than they are today without significant negative environmental impacts. Short-rotation crops are relatively more demanding in terms of nutrient and cultural treatments than crops from natural forests. Nevertheless, the same principles apply. Maintenance of productivity by the appropriate silvicultural practices can ensure sustainability of crops in the presence of intensive utilisation. Science-based studies of site productivity and harvesting have allowed the development of operational guidelines. By using these, the intensity of harvesting operations can be adjusted to the biological requirements of the site.

Protection of soil relies on careful harvesting practices to reduce physical soil disturbance and compaction or removal of organic matter layers on the soil surface. Where roads and extraction tracks disturb organic layers, there is a need to manage water flows and runoff to reduce contamination of streams and waterbodies by soil and silt. Soil compaction, which reduces the extent and time of root growth, can be minimized by operating when soils are dry or frozen and by avoiding repeated passes of heavy equipment. Regulations governing harvesting practices are well-established and can be readily implemented in natural or planted forests.

Biodiversity

Biodiversity concerns arise at the generic, species and landscape levels. Biodiversity conservation is a central issue to forest management and is a significant public policy issue. Management of natural forests emphasizes conservation of extant biodiversity by protecting unique ecosystems and critical habitat, and balancing the vegetation structure, growth stages and forest ecosystem types over time. In managing planted forests there is emphasis on retaining patches or riparian corridors of natural vegetation, and in some cases re-establishing native vegetation as part of the overall plantation development. Natural or non-planted forests have traditionally had a greater role in biodiversity conservation than plantations which are prized for production of wood fibre over other products. However, careful forest management in natural and/or planted forests can contribute to the conservation of biodiversity and to water regulation, carbon sequestration and recreational benefits.

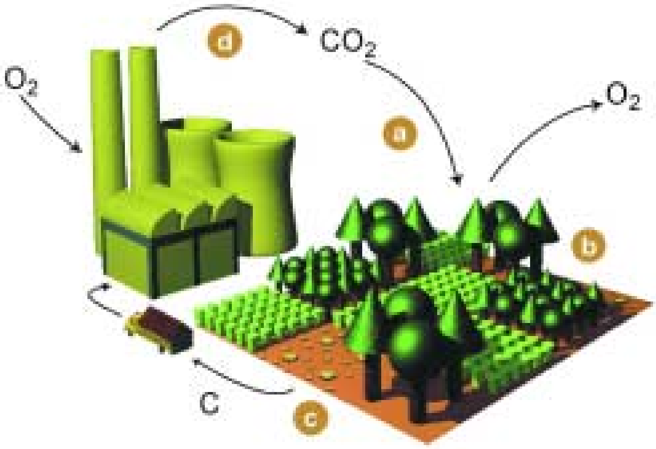
A diverse landscape of planted and natural forest in New South Wales, Australia.

It is encouraging that experience indicates that normal utilisation of residues after forest operations has little negative impact on biodiversity. When energy crops are planted on agricultural land, species diversity may increase since diversity is low where single agricultural crops are grown. Short-rotation crops have much higher productivity than forests and so smaller areas are needed to produce biomass, thus reducing the area under intensive forest management. The creation of structurally and species-diverse forests also helps to reduce the impacts of insects, diseases and weeds. Similarly, the artificial creation of diversity is essential when genetically modified or genetically identical species are being planted. An emerging issue is the impact of catastrophic fires in countries such as Australia and USA. It is now being suggested that in place of controlled burning the use of such material for bioenergy could help reduce the risk of wild fires which can disrupt natural patterns of biodiversity.

Finally, it is expected that concerns over the compatibility of bioenergy and biodiversity can be met by keeping biodiversity as a key factor in the forefront of production planning and management.

Greenhouse Gas Balance

Bioenergy systems offer significant possibilities for reducing greenhouse gas emissions when bioenergy replaces fossil fuel in energy production. The greenhouse gas balance of producing bioenergy is positive, so replacement of fossil fuel derived energy with bioenergy reduces emissions. Potentially, bioenergy systems can also enhance carbon sequestration since short-rotation crops or forests established on former agricultural land act as carbon sinks by accumulating carbon in the vegetation and soil. Afforestation alone is a temporary carbon sink, whereas bioenergy provides long-term benefits. Bioenergy usually provides an irreversible mitigation effect by reducing carbon dioxide at source, but it may emit more carbon per unit of energy than fossil fuels unless biomass fuels are produced sustainably.



An Illustration of the recycling of carbon as biomass accumulates in energy crops and forests and is consumed in a power station. a: CO_2 is captured by the growing crops and forests; b: oxygen (O_2) is released and carbon (C) is stored in the biomass of the plants; c: carbon in harvested biomass is transported to the power station; d: the power station burns the biomass, releasing the CO_2 captured by the plants back to the atmosphere. Considering the process cycle as a whole, there are no net CO_2 emissions from burning the biomass.

Courtesy R. Matthews, United Kingdom

Fossil energy consumed in producing bioenergy is usually a small fraction of the energy produced. Typical energy balances for forestry and agriculture systems indicate that 25 to 50 units of bioenergy are produced for every unit of fossil energy consumed in production. Producing liquid bioenergy requires more input energy, with roughly four to five units of energy produced for each unit of fossil energy consumed. Net carbon emissions from generation of a unit of electricity from bioenergy are 10 to 20 times lower than emissions from fossil fuel-based electricity generation.

The Kyoto Protocol is stimulating policies directed towards the limitation of greenhouse gas emissions, particularly carbon dioxide (CO_2). The two main causes of rising CO_2 concentrations are the burning of fossil fuels and land-use changes, particularly deforestation. Bioenergy presents many opportunities for society to reduce greenhouse gas emissions through fossil fuel substitution and reversal of deforestation by afforestation. Estimation of the greenhouse benefit of fossil fuel substitution and land-use change will require an effective carbon accounting system. The United Nations Framework Convention on Climate Change and the Kyoto Protocol emphasize carbon reporting and accounting in all areas of the economy.

Social Sustainability of Biomass Production

The essence of social sustainability is how biomass production is perceived, and how different societies benefit from biomass production. Biomass production systems require people to operate them, thus creating jobs, and public perceptions of bioenergy systems may place different values on forests and landscapes.

Most residue harvesting operations are conducted by contractors who might supply biomass for a small district heating plant, or who collectively supply larger plants. The impact on employment is primarily in rural areas. In many countries there remains a strong cultural tradition for the place of fuel wood in the energy supply. However, as the efficiencies of scale increase, or as integrated harvesting systems are used, fewer people tend to be employed per volume of biomass harvested.

In some places cultural traditions are being revived by the increased use of woody biomass for bioenergy. In the boreal forest, many aboriginal communities have no year-round road or connections to the national electricity grid, and are dependent on diesel generators supplied by fuel flown or barged in at high cost. These communities are often surrounded by forest that could provide the necessary biomass for energy generation. This would make the community more self-sufficient, reduce costs, provide employment, and integrate well with a forest-based culture. There are examples where a shift to locally-produced bioenergy has been very successful and these successes need to be encouraged.

Urban attitudes to biomass production are related to conventional forestry systems and agricultural issues generally, and to broader concerns for the environment. Better communication needs to be encouraged to promote an awareness and understanding of biomass production and use. The examples of bioenergy applications in Helsinki, Stockholm and some other European cities also illustrate that bioenergy is not just about local, rural communities - it is important for cities too.

Wood fuel production for heating and cooking has been a strong element of the rural culture.

Biomass energy developments will be strongly influenced by policies and incentives in society to stimulate a reduction in greenhouse gas emissions. These frameworks need to ensure a positive climate for investment in biomass energy and the protection of the environment during the production of biomass to achieve social sustainability.

Conclusion

There is increasing recognition of the local and global environmental advantages of bioenergy. It is the most widely used renewable energy source, representing nearly a billion tonnes of oil equivalent - consumption levels comparable to natural gas, coal and electricity. The trend towards cleaner, greener, smaller and more decentralized energy production facilities has a positive effect on demand for biomass energy. A diversification of public expectations for goods and services from forests has increased demand for sustainable forest management as a goal to be pursued by society. The issues of sustaining forest cover, slowing deforestation, regenerating natural forests, engaging in intensive forest management, and improving the management of agricultural and rangeland soils, can all be addressed through increasing bioenergy production.

Well-managed short-rotation forests are a sustainable resource that can be renewed in perpetuity, are CO_2 neutral, and can help replace a finite fossil fuel supply. Such systems can be used in combination with the disposal of sewage waste, enabling short-rotation crops to act as an effective soil ameliorator and biological filter. They may often be a good crop for unused or set-aside agricultural lands and may be able to support more floral and faunal diversity than most agricultural crops, while at the same time providing a source of employment and social stability.

There are no technical reasons to prevent a major increase in utilisation of bioenergy from forests or agricultural land, and there are clear environmental benefits if this were to occur. Given a supportive policy environment, bioenergy can provide a sustainable solution to future energy demands. IEA Bioenergy identifies and addresses the production and use of bioenergy, develops sustainable bioenergy systems, encourages the appropriate use of biomass resources for energy, and increases the contribution of bioenergy to meet global energy demands.

Recommended Reading

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IEA Bioenergy Contacts

Secretariat

John Tustin
PO Box 6256
Whakarewarewa
Rotorua
NEW ZEALAND
Phone: +64-7-348-2563
Fax: +64-7-348-7503
Email: jrtustin@xtra.co.nz

Website

www.ieabioenergy.com

Relevant Task Leaders

Task 29: Socio-economic aspects of bioenergy systems
Julije Domac
Energy Institute 'Hrvoje Pozar'
Savska 163, P.B. 141
10001 Zagreb, CROATIA
Phone: +385-1-632-6109
Fax: +385-1-604-0599
Email: jdomac@eihp.hr
Website: www.iea_bioenergy-task29.hr

Task 30: Short rotation crops for bioenergy systems
Theo Verwijst
Department of Short Rotation Forestry, SLU
PO Box 7016
SE-750 07 Uppsala,
SWEDEN
Phone: +46-18-67 25 50
Fax: +46-18-67 34 40
Email: Theo.Verwijst@Lto.slu.se

Task 31: Conventional forestry systems for sustainable production of bioenergy
Jim Richardson
1876 Saunderson Drive
Ottawa, Ontario
CANADA K1G 2C5
Phone: +1-613-521-1995
Fax: +1-613-521-1997
Email: jrichardson@on.aibn.com

Task 38: Greenhouse gas balance of biomass and bioenergy systems
Bernhard Schlamadinger
Joanneum Research
Elisabethstrasse 5, A-8010 Graz
AUSTRIA
Phone: +43-316-876-1340
Fax: +43 316-876-1320
Email: bernhard.schlamadinger@joanneum.at
Website: www.joanneum.at/iea-bioenergy-task38