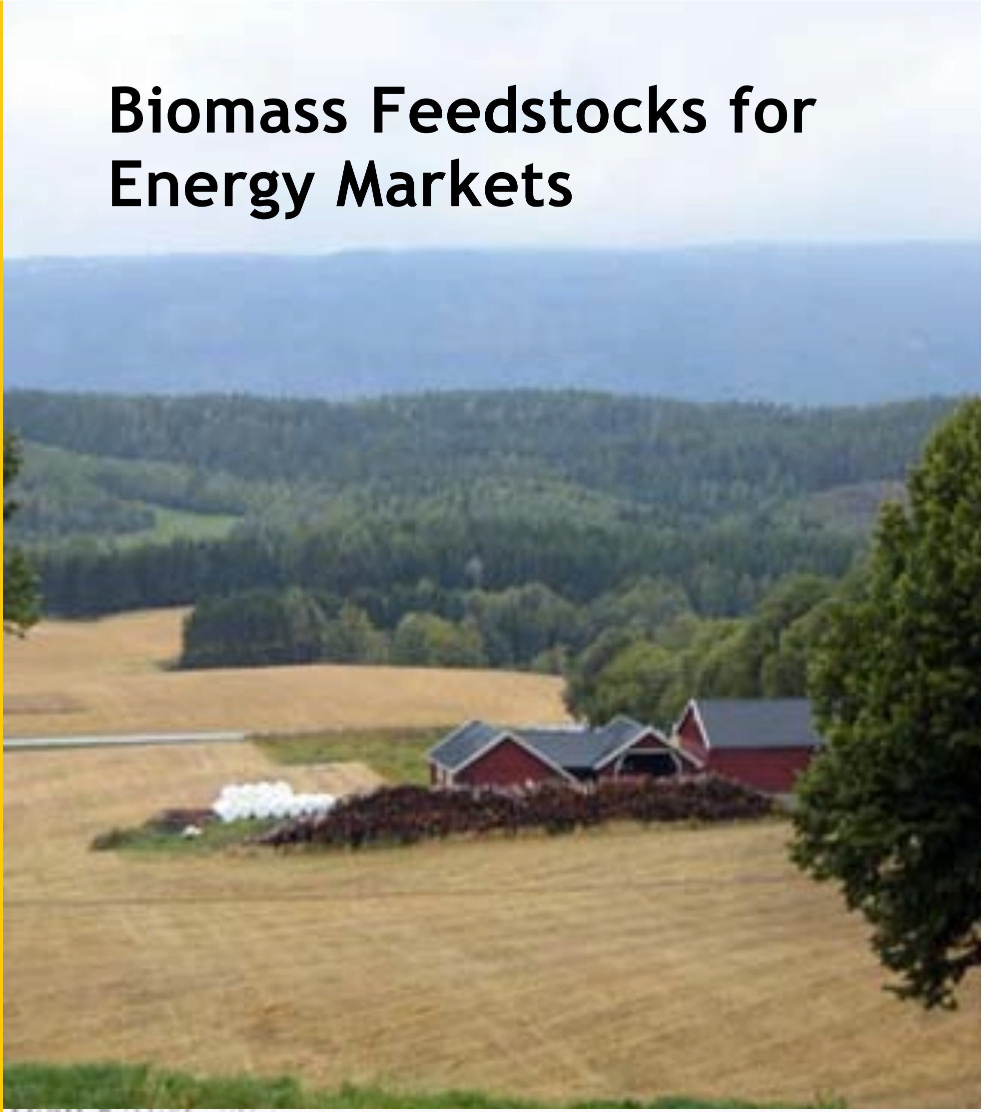
Biomass Feedstocks for Energy Markets



This feature article provides an overview of the work of IEA Bioenergy Task 43: Biomass Feedstocks for Energy Markets

IEA Bioenergy

IEA BIOENERGY TASK 43
OVERVIEW 2013

BIOMASS FEEDSTOCKS FOR ENERGY MARKETS

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KEY MESSAGES

- The global society needs to address heightened uncertainty about energy security, energy cost and environmental impacts that are currently challenging world energy markets.
- The promotion of renewable energy sources is a cornerstone strategy to address these uncertainties and the use of biomass for energy has been increasing in response to policies designed to increase the share of renewables in the energy mix.
- Increased bioenergy production may contribute to rural development by improving energy access, increasing employment and stimulating development in agriculture and forestry.
- Novel developments in bioenergy production systems offer opportunities for the agricultural and forestry sectors to increase the efficiency of biomass use and to find new markets for their products.
- Expanding biomass use for energy, however, raises new concerns over risks of environmental and socio-economic impacts; governance systems are needed that prevent unsustainable practices and promote the development of bioenergy systems that are sustainable and that have significant beneficial outcomes when considered in the wider context.
- IEA Bioenergy Task 43 seeks ways to integrate biomass feedstock production with agriculture and forestry to stimulate productivity, local development and sustainable land use practices. Besides engaging with researchers and practitioners in the bioenergy sector, the Task provides science-based information in support of legislation, regulations and sustainability standards intended to promote sound bioenergy development.

Cover Pictures: C. Tattersall Smith (top) and Stig Larsson (bottom)

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1 INTRODUCTION

In an Energy Vision Article published recently in the journal Energy Strategy Reviews, Maria van der Hoeven, Executive Director of the IEA, concluded that:

'International energy governance is now more important than ever to address heightened uncertainty about energy security, energy cost and environmental impact. Energy markets in 2012 face a particularly daunting set of new challenges and risks. Vigilant analysis and concerted action can do much to mitigate them, and to counter the rise in uncertainty about global energy issues.'

Around the world, the promotion of renewable energy sources and measures to reduce the growth rate of our energy demand is a cornerstone strategy to address these challenges and risks. The IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation (2012) reports that renewable energy accounted for almost 13% of the primary energy supply in 2008, with biomass contributing more than 10%. Traditional use of biomass for cooking, space heating, and lighting presently accounts for roughly 80% of global bioenergy use. However, there has been a rapid increase in so-called modern biomass use in response to policies aimed at improving energy security and mitigating climate change. In many countries, the promotion of modern bioenergy is also considered a possible driver of rural development with the potential to improve energy access, increase employment, and stimulate positive development in agriculture and forestry.

At present, modern bioenergy use primarily involves the burning of municipal organic waste, straw, wood and forest industry by-products to provide heat and electricity, anaerobic digestion of organic waste to produce biogas, and the use of conventional agriculture crops such as cereals, oil seeds, and sugar crops to produce biofuels. However, the technologies used to convert biomass to fuels and other products continue to develop into increasingly sophisticated processes. New plant and biomass production systems can utilise a broader resource base. In forestry, new developments in planting, silvicultural treatments and biomass extraction support an increasing harvest from forests. In agriculture, the cultivation of perennial grasses and trees grown on short rotations (both coppice and single-stem plantations) represent new feedstock supply options (Figure 1).

The promotion of bioenergy offers considerable opportunities for the agriculture and forestry sectors, which can find new markets for their products and also make economic use of biomass flows earlier considered to be waste. But there has also been an increase in the number of reports expressing concern about possible negative environmental and socio-economic impacts associated with bioenergy. The view that bioenergy represents an attractive alternative to conventional (primarily fossil) energy options has been challenged – particularly in the case of biofuels for transport.

Policy makers who establish incentives or targets to promote bioenergy are understandably concerned that risks are properly considered when bioenergy projects are being contemplated or incentives designed. It is not self-evident that bioenergy is environmentally (or socio-economically) superior to fossil based energy and consumers may object to bioenergy products because of concerns about the impacts of their production. The fact that renewable feedstocks are used is not sufficient in itself to make bioenergy sustainable. One reason is of course that in many instances the production of bioenergy products relies on non-renewable resources as inputs. Well-to-wheel studies clearly show that bioenergy systems differ greatly in their reliance on fossil inputs and consequently in their contribution to reduced greenhouse gas (GHG) emissions – one major rationale for governments promoting these fuels, and for consumers using them.

Switchgrass, a perennial grass native to North America, is presently grown as forage for livestock or as a ground cover to control erosion. It is established from seed and can achieve high yields with low fertiliser input. It can be cut and baled with conventional mowers and balers – either annually or semi-annually – for 10 years or more, before replanting is needed. Photo: James McKenna.

Eucalyptus species are planted extensively throughout the tropics and particularly in sub-tropical regions, primarily for industrial roundwood. The photo shows one way of integrating bioenergy with food crop production, where *Eucalyptus* has been inter-planted with corn. *Eucalyptus* can also be inter-planted with other crops and used in silvi-pastoral systems. It is suitable as a windbreak and is also planted to lower the water table and thereby reduce soil salinization, primarily in Australia. Photo: Laercio Cuoto.

Willow is a coppicing plant that is planted using cuttings. It can be harvested, using modified agricultural machinery that also chips the stems, every 3-4 years for about 25 years until re-establishment is needed. Willow can also provide environmental services, e.g. as a vegetation filter treating nutrient-rich water and for removal of cadmium from cropland. Photo: Stig Larsson.

Miscanthus is a perennial grass that is established by planting pieces of rhizome from fields where the crop is already established. Rhizomes can be broken up, collected and planted using existing agricultural equipment such as potato harvesters and planters. The crop is normally harvested from year two onwards, but yields continue to improve until they level off around the fifth or sixth year. Photo: Michael Montross.

Figure 1. Selected biomass production systems in agriculture.

The production of renewable feedstocks can also cause other negative impacts. In fact, bioenergy feedstock production is one major component in the bioenergy supply chain that has been in focus in the bioenergy debate in recent years. Much attention has been directed to the possible consequences of land use change (LUC), referring to well-documented effects of forest conversion and cropland expansion into previously uncultivated areas, possibly resulting in biodiversity losses, GHG emissions and degradation of soils and water bodies. Sustainability concerns relating to feedstock supply systems also include direct and indirect social and economic aspects, including land use conflicts, human rights violations and food security impacts.

While vigilant analysis and concerted action can do much to identify risks and mitigate impacts, it is also essential to ensure that these actions reflect well-grounded conclusions considering the costs and benefits of different choices. The bioenergy sector's licence to operate cannot be based upon a complete absence of negative impacts. Human beings have always influenced their habitats and the conversion of ecosystems to land for biomass production is perhaps our most obvious impact on the Earth. Human societies have put almost half of the world's land surface to their service, and human land use has caused extensive land degradation and biodiversity loss. Emissions to air and water lead to impacts such as eutrophication, acidification, stratospheric ozone depletion and climate change.

It is evident that society will continue to set a large 'footprint' on Earth in the future, since our land use provides food and other products necessary for sustaining the increasing human population. It is also evident that society expects that new systems should reduce land use impacts and mitigate risks. The management of natural resources to meet the needs of human society whilst recognising environmental balance is the challenge facing society. Governance of bioenergy development is very much about balancing trade-offs between partly incompatible environmental and socio-economic objectives. In the end, bioenergy development will depend on the priority given to bioenergy products versus other products obtained from land – notably food and conventional forest products – and on how much biomass can be mobilised in total from agriculture and forestry. This in turn depends on natural factors (e.g. climate, soils, and topography) and on the agronomic and forestry practices employed to produce the biomass. It also depends on how society understands and prioritises nature conservation and protection of soils, water and biodiversity - and how the production systems are shaped to reflect these priorities.

There are currently several initiatives to develop sustainability certification systems. These may hedge against some of the undesired consequences of expanding feedstock supply systems and promote positive development when implemented effectively. Complementing sustainability certification, we need to develop competitive business cases that are efficient along the entire bioenergy supply chain, from feedstock production to energy markets. Capturing the benefits of bioenergy requires the creation of incentives to stimulate innovation in land use, including new ways to integrate bioenergy feedstock production with agriculture and forestry so as to stimulate productivity, local development and sustainable land use practices. A critical question to ask is: what are the basic prerequisites for financial investment in developing these biomass production systems?

The objectives of this article are to briefly discuss some of the risks and opportunities associated with bioenergy growth and also consider the role of sustainability certification in the mix of governance mechanisms (e.g. mandatory regulations, local and state best management practices) established to satisfy public demand for sustainable bioenergy. A final section outlines conditions for the mobilisation of sustainable bioenergy supply chains, which will be explored by several Tasks within one of the inter-Task projects that have been established by the Executive Committee.

2 BIOENERGY AND LAND USE CHANGE

It has been well established that practically all bioenergy systems can deliver large GHG savings if they replace fossil-based energy causing high GHG emissions and if the bioenergy production emissions are kept low. However, in recent years there has been considerable debate about the connection between bioenergy and LUC and, in particular, whether there is a risk that GHG emissions associated with LUC could significantly undermine the climate change mitigation benefits of bioenergy, and how this risk can be minimised.

Bioenergy projects can lead to both direct and indirect LUC. Direct LUC (dLUC) involves changes in land use on the site used for bioenergy feedstock production, such as the change from food or fibre production (including changes in crop rotation patterns, conversion of pasture land, and changes in forest management) or the conversion of natural ecosystems. Indirect LUC (iLUC) refers to the changes in land use that take place elsewhere as a consequence of the bioenergy project. For example, displaced food producers may re-establish their operations elsewhere by converting natural ecosystems to agricultural land, or due to macro-economic factors, the agriculture area may expand to compensate for the losses in food/fibre production caused by the bioenergy project. A wide definition of iLUC can include changes in crop rotation patterns and/or intensification on land used for food or feed production.

LUC can affect GHG emissions in a number of ways, for example (i) when biomass is burned in the field during land clearing; (ii) when the land management practice is changed so that the carbon stocks in soils and vegetation change; (iii) when changes in the intensity of land use lead to changes in GHG emissions, in particular N_2O emissions due to fertiliser use; and (iv) when LUC results in changes in rates of carbon sequestration, i.e. the CO_2 assimilation of the land may become lower or higher than would have been the case in the absence of LUC. The impacts of these changes can increase the net GHG emissions (for example when land with large carbon stocks is brought into cultivation) or have a beneficial outcome (for example when energy crops are developed on marginal lands with carbon-poor soils). LUC can also influence the climate through other mechanisms besides GHG emissions, where changes in surface albedo (reflecting power) might be the most important factor.

Studies of LUC emissions associated with bioenergy report widely different results. The inclusion of iLUC in particular adds greatly to the uncertainty in quantifications of LUC effects (Figure 2). It should not be assumed that improved methodology leads to the convergence of estimates towards narrow ranges supporting globally agreed ranking of bioenergy options with regard to their influence on LUC and associated emissions. The drivers behind LUC are multiple, complex, interlinked, and change over time. This makes quantification inherently uncertain, since LUC is sensitive to many factors that can develop in different directions, including land use productivity, trade patterns, prices and price elasticity, and use of by-products associated with biofuels production. Not least, policies and legal measures that directly or indirectly influence land use can have a strong influence on future LUC and associated emissions.

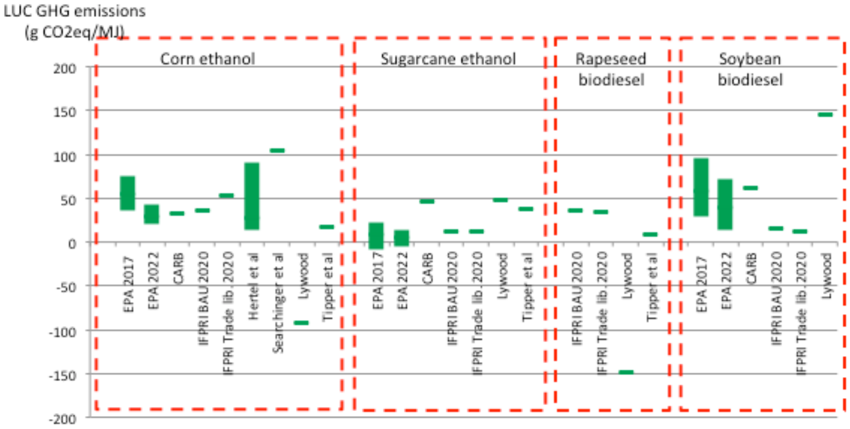

Figure 2. Ranges of model-based quantifications of LUC (dLUC + iLUC) emissions associated with the expansion of selected biofuel/crop combinations. The studies are reported with LUC emissions amortised over 30 years of production for comparison. Source: IEA Bioenergy ExCo 2011:04.

There are many options for avoiding or mitigating the negative impacts associated with LUC and for optimising the climate benefits of bioenergy. First of all, the use of post-consumer organic residues and by-products from the agricultural and forest industries does not cause LUC if these biomass sources are wastes, i.e. were not utilised for alternative purposes. Biomass that is burned, such as straw on fields, is an obvious example. The use of biomass that would otherwise be landfilled, or decompose in wet conditions, can also lead to additional benefits through reduced methane emissions. If not utilised for bioenergy, some biomass sources (e.g. felling residues left in the forest) would retain organic carbon for a longer time than if used for energy. This difference in timing of emissions can be considered a disadvantage for bioenergy in project level evaluations that only use a short time horizon, and is also a relevant factor in longer-term accounting in eco-regions where biomass decomposition is slow. However, proper evaluation also requires consideration of forest bioenergy and associated C flows on a landscape level, as well as consideration of how forest management is affected by the promotion and growth of bioenergy demand. Experience shows that active forest management can ensure that increased biomass output need not take place at the cost of reduced forest stocks on the landscape level (Figure 3).

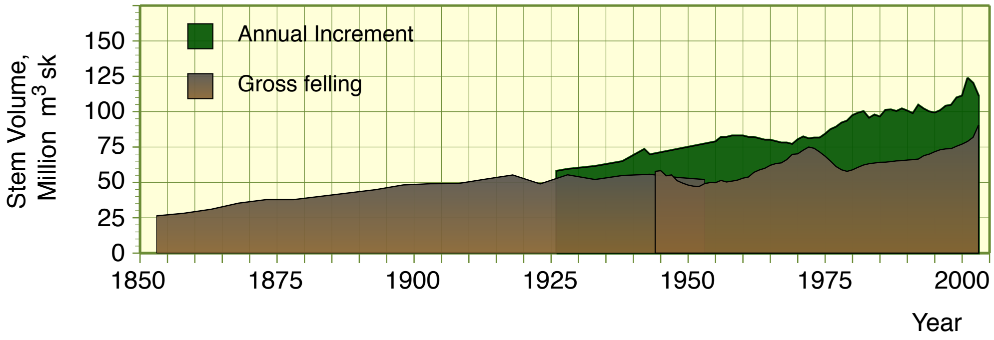

Figure 3. Historic overview of gross felling (1853–2003) and – placed behind the area showing gross felling – the annual increment (1926–2003) in the Swedish forest. The method of estimating felling changed between 1945 and 1955, resulting in two overlapping curves. In recent decades Sweden has had a very strong increase in bioenergy displacing much of the fossil fuel use in the stationary energy sector. At the same time as increasing volumes of biomass have been extracted from the forest, there has also been an increase in forest stocks as a result of changing forest management and planning for a future with higher biomass demand for both materials and energy. Source: IEA Bioenergy ExCo 2011:04.

One promising way of reducing emissions from LUC is to increase the amount of lignocellulosic feedstocks for bioenergy that are grown on low carbon pasture land less suitable for annual crops, thereby decreasing the pressure on prime cropping land. Since the production of lignocellulosic feedstocks commonly requires less fuel, fertiliser and other inputs, there is also scope for higher GHG savings than when biofuels are produced from conventional crops such as cereals and sugar beet. However, a mix of lignocellulosic material and conventional food/feed crops is likely to be used for bioenergy feedstocks during the coming decades to supply biofuels and the heat and power markets. Strategies to increase agricultural productivity, especially in developing countries, will be critical to minimising LUC impacts.

Food, fibre and bioenergy crops can be grown in integrated production systems, thereby mitigating displacement effects and improving the productive use of land. The targeting of unused marginal and degraded lands can also mitigate LUC emissions associated with bioenergy expansion. Biomass extraction for energy as part of fire prevention management reduces the risk of wildfires with resulting emissions and other impacts. Bioenergy plantations can in many ways improve the productive use of land and can provide several benefits in addition to the GHG savings, as discussed in various places in this article. Thus, displacement of an existing land use should not necessarily always be avoided. Conversely, the opportunity to shift from unsustainable cultivation of annual food crops (e.g. intensive cultivation causing extensive soil losses and degradation on sloping lands) to perennial bioenergy plantations may represent an important step towards more sustainable land use. Income from such bioenergy cultivation may be invested in improving the productivity of food production on more suitable lands.

Bioenergy’s contribution to climate change mitigation needs to reflect a balance between near-term GHG targets and the long-term objective to hold the increase in global temperature below 2°C (Copenhagen Accord). Sound bioenergy development requires adequate and transparent criteria that can be applied in a robust, predictable way. Policy measures to minimise the negative impacts of LUC should be based on a holistic perspective, recognising the multiple drivers and effects of LUC and taking into account the dynamics of both energy and climate systems. A balanced approach is likely to include incentives that discourage systematic decreases in biospheric carbon stocks while encouraging the sustainable use of biomass to replace fossil fuels instead of merely prioritising natural decay.

While emissions from LUC can be significant in some circumstances, the simple notion of LUC emissions is not sufficient reason to exclude bioenergy from the list of worthwhile technologies for climate change mitigation. What matters is the size of carbon stock reductions, and the drawback of such reductions needs to be weighed against the benefits of bioenergy expansion. For instance, forest carbon stock losses may well reflect a re-orientation of forest management to develop a new forest state that provides biomass for bioenergy as well as other forest products. Whether this new forest state can be characterised as sustainable depends on a wide range of factors in addition to the forest carbon stock, which together determine a forest's biodiversity, productivity, regeneration capacity, vitality and potential to fulfil relevant ecological, economic and social functions. In any case, we recommend carbon stock losses or gains be determined through appropriate monitoring systems, perhaps in conjunction with certification schemes involving third party audits.

3 BIOENERGY AND WATER

Agriculture accounts for about 70% of fresh water taken from rivers, lakes, and aquifers – more than 90% in some developing countries. Growing populations and changing dietary trends mean a rising demand for food and feed crop cultivation, implying further growth in agricultural water use. At the same time, fresh water is already scarce in some regions of the world and the population at risk of water stress could increase substantially under the impact of climate change.

Water scarcity can limit opportunities for both intensification and expansion of agriculture. Investment in increased irrigation can enhance water use competition in water scarce areas, but rain-fed cultivation can also impact on other production by reducing groundwater recharge and stream flows. Human land use and other activities also impact the quality of water in lakes, rivers and aquifers, with consequences for the health of aquatic ecosystems and also for human water use. Demand for bioenergy further adds to the growing pressure on water resources, and water scarcity has been proposed as a possible major obstacle for bioenergy expansion. However, it has also been recognised that bioenergy demand might open up new opportunities to adapt to water related challenges and to improve the productivity of water use.

Water scarcity can be partially alleviated through on-site water management and the productivity of agriculture could be improved in many parts of the world through improved soil and water conservation. Investment in agricultural research, development and deployment could produce a further increase in both water productivity and land use efficiency. In this context, bioenergy demand may offer new opportunities leading to the development of new types of crop production systems that utilise key pathways of the hydrological cycle more efficiently.

As an illustration of possible land use options and associated consequences for water, Figure 4 shows water pathways at the cropland level. If the non-productive evaporation (E) is reduced in favour of plant transpiration (T), total biomass production may increase without necessarily reducing the downstream availability of water. Capture and recirculation of run-off water to fields can also increase the share of water going to plant transpiration and hence enhance biomass yields. An increase in total evapotranspiration (ET, which is the sum of E and T), however, can have consequences for both groundwater recharge and run-off.

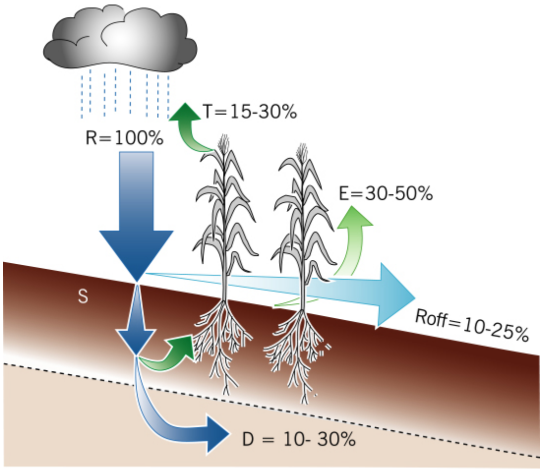

Figure 4. Overview of rainfall (R) partitioning. Run-off (Roff) and drainage (D) are lost from the field, but are potentially available for downstream use, although part of Roff is lost as evaporation as it flows through the landscape. Field evaporation (E) corresponds to a non-productive water loss, while transpiration (T) by the cultivated plants represents productive water use. The percentages shown correspond to conditions in the semi-arid tropics in sub-Saharan Africa. Source: Conservation Ecology 3(2):5.

ET can increase both as a consequence of measures to enhance the yields of presently cultivated crops, or as a consequence of LUC such as when high-yielding biomass plantations are established on lands with sparse vegetation, for example degraded pastures. Such LUC may lead to substantial reductions in downstream water availability, which may become an unwelcome effect requiring management of a trade-off between upstream benefits and downstream costs. However, it should be noted that consequences of increased ET need not always be negative. Examples of positive consequences include when biomass plantations are used for salinity management (Figure 1) or when plantation establishment on degraded lands reduces run-off intensity and the associated risks of flooding of cultivated areas.

New crops and biomass production systems may also facilitate utilisation of previously little used components of the hydrological cycle. For instance, hardy and drought tolerant plants can be cultivated in areas where water scarcity prevents cultivation of conventional food and feed crops. Salt-tolerant plants that can grow in conditions of high salinity are being studied as potential bioenergy crops with the ability to use saline water not suitable for most crops. The use of perennial plants and various agroforestry systems for food and bioenergy feedstock production can also increase productivity in rain-fed agriculture by capturing a larger proportion of the annual rainfall in areas where much of the rainfall occurs outside the normal growing season.

Thus, one strategy for adaptation to water scarcity can be to use biomass production for energy as a tool for increasing the spatial and temporal accessibility of water resources and at the same time improving the quality of freshwater flows. By concurrently introducing efficient water management techniques and providing a wider range of land use options to optimise the use of land and water, bioenergy development provides opportunities to improve water productivity and increase access to water. Catchment basin level planning could include biomass production as a land use option with the potential for combining, for example, erosion control and flood prevention with income generation from carbon sink generation and biomass sales for energy.

Bioenergy projects can also affect the quality of water. As with many other industrial activities, biomass conversion to energy products can require substantial volumes of water. Most of this process water is returned to rivers and other water bodies and is thus available for further use, albeit in changed (and sometimes degraded) states. These biomass conversion processes need to be monitored to minimise negative impacts due to chemical and thermal pollution of aquatic systems. This is not an issue affecting only the biomass-based industry on its own, but a general challenge for society, not least in countries with less stringent environmental regulations or limited law enforcement capacity.

In forests, water quality impacts can occur at different phases of the forest rotation. Excluding large-scale disturbances such as fires, storm losses and insect infestations, forest harvesting (including road construction) and the subsequent site preparation for forest regeneration are the largest disturbances in managed forests. However, the use of fertilisers, herbicides and other chemicals associated with intra-rotation silvicultural operations can also have water quality impacts. Short-term water quality effects have been reported – most notably increased sediment movement in stream flows and also increases in, e.g. nitrates, phosphates, and cations – but there is no evidence of long-term adverse impacts in forest catchments subject to normal management operations. Given use of existing best management practices that are designed for environmental protection and include nutrient management principles, forest bioenergy programmes are judged to be compatible with maintaining forest productivity as well as high-quality water supplies in forested catchments. In some situations, bioenergy schemes can improve the water quality in forested catchments. For instance, residue extraction in areas subject to high levels of atmospheric N deposition reduces the eutrophication load.

Due to more intensive land use, water catchments where agriculture is the dominant land use generally produce lower quality water than forested catchments. A large proportion of the fertilisers, pesticides and other chemicals that are lost from croplands end up in waterways and aquifers where they can have a negative influence on the quality of surface water and groundwater as a result of eutrophication and other pollution impacts. Extraction of harvest residues as bioenergy feedstock can cause soil erosion resulting in increased sediment flows impacting on aquatic ecosystems (see Figure 5). The cultivation of conventional agricultural crops, such as cereals and oil seed crops, for the production of so-called 1st generation biofuels for transport will lead to the same water quality consequences as when such crops are produced for food and feed. Thus, further negative water quality impacts may occur in a scenario where growing demand for both food and 1st generation biofuels drives a strong increase in conventional crop cultivation.

On the other hand, integration of other types of bioenergy plants into agriculture landscapes can mitigate some of the water quality impacts associated with conventional crop cultivation. Examples include perennial grasses and woody plants grown on multi-year rotations, which commonly require less fertiliser and other chemical inputs than conventional annual crops. The cultivation of such plants can help improve water quality and can also positively influence soil qualities such as texture and structure, which in turn improve water infiltration, permeability, and water-holding capacity. The possibility of combining biomass production for energy with the provision of additional environmental services is discussed further in the next section.

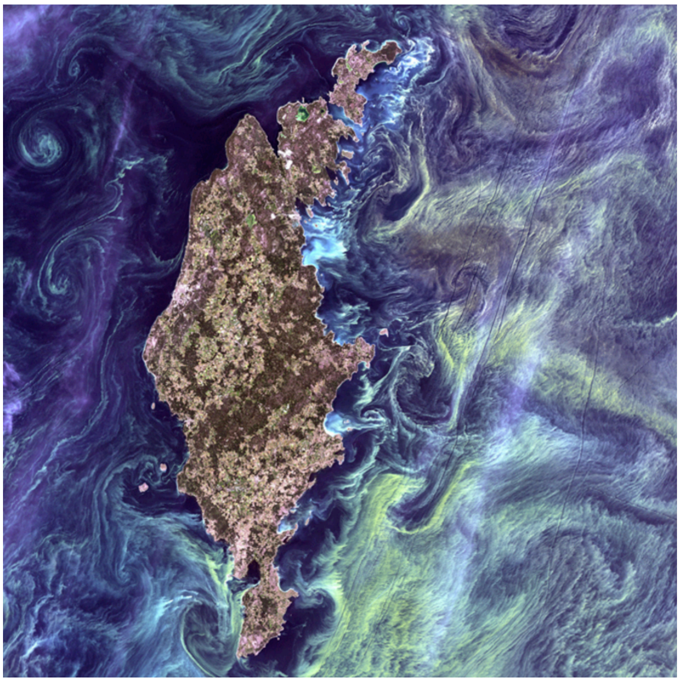

Figure 5. Algal blooms in the water around Gotland, a Swedish island in the Baltic Sea. Fertiliser run-off to the Baltic Sea from surrounding agricultural land contributes to a large nutrient load, primarily via river discharges. This run-off has changed it from an oligotrophic clear-water sea into a eutrophic marine environment experiencing summertime algal blooms. Courtesy: NASA's Goddard Space Flight Center/USGS.

4 BIOENERGY AND ENVIRONMENTAL SERVICES

As already discussed, bioenergy systems can – through well-chosen site location, design, management and system integration – offer additional environmental services that, in turn, create added value for the systems. Some bioenergy systems may be established to provide environmental services that are only relevant in specific conditions, for example when trees are established as a windbreak to reduce wind erosion. Others are systems that provide environmental services of a more general nature, for instance soil carbon accumulation leading to improved soil fertility and enhanced climate benefit.

While the concept of shaping biomass production systems so as to deliver specific ecosystem services might appear a recent invention, the underlying idea – that certain plants can be produced in certain ways to provide various benefits in addition to the harvest – has probably always influenced land use strategies. Specifically, integration of different perennial grasses and short rotation woody crops has been suggested as a way of remediating many environmental problems, including biodiversity loss. These perennial crops differ from most arable crops in physical traits and management practices. Results so far imply many positive environmental benefits associated with implementation of bioenergy feedstock production using such crops, although the effects on the environment depend on the existing or previous land use, the scale of planting and the management practices applied.

Examples of bioenergy systems that are established for the purpose of providing specific environmental services include soil-covering plants and vegetation strips located to limit water erosion, reduce evaporating surface run-off, trap sediment, and reduce the risks of shallow landslides; tree plantations that are used for salinity management on land subject to productivity losses due to soil salinity induced by rising water tables; and plantations of suitable species that are used to remove cadmium and other heavy metals from cropland soils. In general, integration of specific biomass plantations in the agricultural landscape can contribute to a more varied landscape, increased biodiversity and more animal life. More specifically, plantations can be located in the agricultural landscape so as to provide ecological corridors that provide a route through which plants and animals can move between spatially separated, natural and semi-natural ecosystems. In this way, plantations can reduce the barrier effect of agricultural lands.

Specific bioenergy applications can also prove economically attractive compared to other approaches to addressing these problems. As an example, Figure 6 shows a willow plantation that is irrigated with secondary treated municipal wastewater effluent. In this case, the municipality covered all costs of the storage ponds, pumps, automatic filters and irrigation pipes (which were cheaper than the estimated cost of installing improved conventional nitrogen treatment). The farmer/landowner planted the willows and is responsible for their cultivation and the maintenance of the irrigation pipes. The willow producer obtains economic benefits from lower costs for conventional fertilisers and the irrigation contributes to higher yields and lower vulnerability to drought.

Plantations like the one shown in Figure 6 can also be used as vegetation filters for the treatment (via irrigation) of collected run-off water from farmlands and leachate from landfills. Plantations can also be located in the landscape and managed as buffer strips for capturing the nutrients in passing run-off water. Sewage sludge from treatment plants can also be used as fertiliser in vegetation filters. Low-input bioenergy plantations can also be a land use option in areas where conventional agriculture practices are not allowed due to impacts on groundwater quality.

Figure 6. View of the Enköping municipal wastewater plant in Sweden, showing the water storage ponds and willows used as a vegetation filter. A 75 ha willow plantation treats and utilises decanted water from the dewatering of sewage sludge. The water contains approximately 25% of the N entering the wastewater treatment plant, but less than 1% of the water volume. By treating the water separately in the willow vegetation filter, instead of pumping it back into the treatment plant, the total N load is reduced by 25%. The biomass produced is used in the local district heating plant, contributing to the local supply of heat and electricity. Ash from the boiler is recycled back to the willow plantation. Courtesy: Per Aronsson, Swedish University of Agricultural Sciences, Sweden.

The environmental and socio-economic benefits from large-scale bioenergy plantations designed to provide various environmental services could be substantial. One key issue is to identify suitable mechanisms to put a premium on the environmental services that can be provided. Given that additional revenues can be linked to the bioenergy systems, the competitiveness of the produced biomass on the market could be significantly improved. In some cases, actors can be identified who are willing to pay for a specific environmental service. In other situations, information campaigns and innovative government measures that credit the biomass producer may be required. A challenge when implementing such measures lies in the coordination of different policies in the energy, environmental and agricultural sectors.

5 SUSTAINABILITY CERTIFICATION

The previous sections of this article have identified some ways in which intelligently designed bioenergy feedstock production systems can significantly offset GHG emissions associated with fossil fuel based energy systems, and at the same time lead to increases in ecosystem services. We must always seek to develop new systems that are sustainable and that have significant beneficial outcomes when considered in the wider context. Government policy makers should always determine whether new systems receiving incentives might have serious, unintended consequences.

In 1987, the World Commission on Environment and Development (WCED), which had been set up in 1983, published a report entitled ‘Our common future’. The document came to be known as the ‘Brundtland Report’. Since that time, there has been considerable effort spent on defining sustainable land use systems, especially with relevance to the forestry and agriculture sectors. For example, in 1993 the countries involved in what came to be known as the Montreal Process agreed upon seven criteria for sustainable forest management. This agreement was significant globally, since the member countries represent about 90% of the world's temperate and boreal forests in the northern and southern hemispheres. This amounted to 60% of all of the forests of the world. Europe's forests were addressed by the Helsinki or Pan-European Process.

The seven criteria upon which the Montreal Process is based have been broadly accepted internationally and are similar to the foundation principles for practically all sustainability standards developed since that time. While originally conceived with forest management in mind, these seven criteria have also been adapted to sustainable trade in forest products including bioenergy feedstocks, so it is possible to verify whether wood products purchased by consumers were produced from timber or biomass harvested from sustainably managed forests. It can be argued that the proliferation of systems defining sustainable forest management (SFM) globally are merely local adaptations of the tenets originally agreed upon in the Montreal Process. It also appears that more recent developments related to international standards for sustainable bioenergy are based on a similar set of criteria, even if their starting point and community of actors come from different sectors. This is reassuring, as it indicates that the careful thought given to definitions of sustainable systems is standing the test of time, even if the current level of complexity in system proliferation suggests otherwise.

Even if forests are managed according to the principles defining SFM, the public has been typically and understandably reluctant to accept the sustainability claims of producers - and especially industry - at face value. SFM certification schemes were first developed in Toronto in 1993 to formalise the process of evaluating forests to determine if they are being managed according to an agreed upon set of standards or principles. All schemes that have developed since that time utilise some process of developing standards of sustainability based upon input from relevant stakeholders. The evaluation process involves third party audit of both a company's management documentation and the condition of their managed forests according to the standards of the certification scheme (e.g. Programme for the Endorsement of Forest Certification (PEFC) or Forest Stewardship Council (FSC)). These basic processes for developing sustainability standards and conducting third party audits have been adapted by sustainability certification schemes for bioenergy systems, whether for feedstocks produced on agricultural lands or plantations or managed natural ecosystems.

It has been clearly established that sustainability certification schemes are not sufficient to achieve sustainable forest or agriculture management without additional governance mechanisms (e.g. local or state regulations, Best Management Practices or international trade standards) with which management must comply. In fact, certification schemes always make direct reference to applicable regulations with which management must comply, and audits must verify whether the company's practices are in compliance, or not. Forest bioenergy supply chains therefore currently must pass several layers of governance, which must work together to ensure the sustainability of bioenergy feedstocks sold in the marketplace (Figure 7). It is apparent that our aspirations for sustainable bioenergy production systems and supply and value chains can only be achieved through careful coordination among all the parties to ensure that all necessary governance mechanisms are in place and capable of fulfilling the appropriate standards setting, control, governance and assurance roles required.

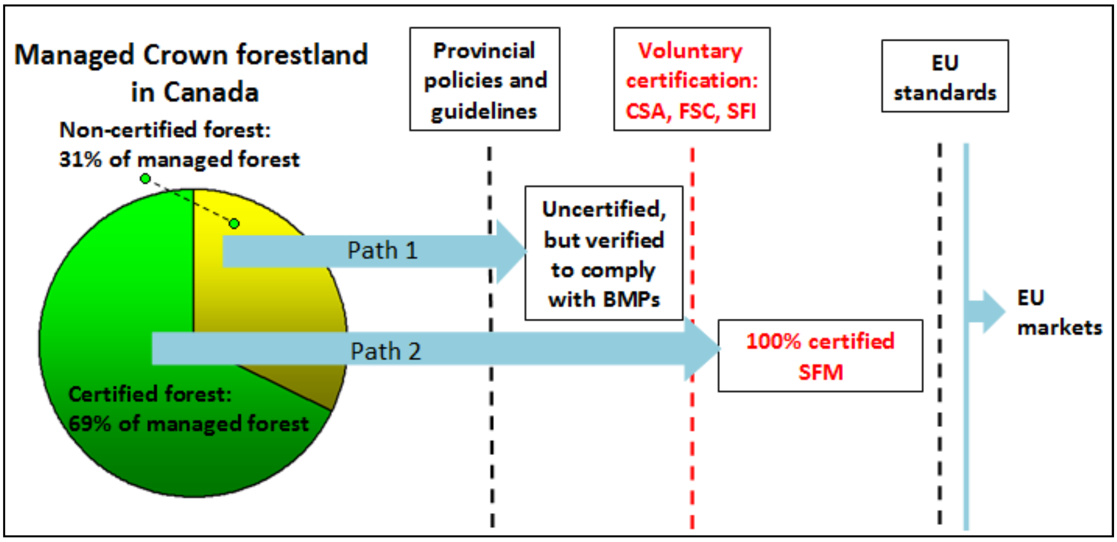

Figure 7. Multiple levels of sustainability claims can be made for Canadian wood pellets that are sold in domestic markets and exported to Europe. At this point, it is uncertain if the governance mechanisms and certification schemes that ensure the sustainability of the Canadian forest sector, and thus exports, will satisfy anticipated new EU-RED standards for solid bioenergy feedstocks. Source: Jessica Murray, University of Toronto; adapted from Kittler, B., W. Price, W. McDow and B. Larson. 2012. Pathways to Sustainability. Environmental Defence Fund. 54 pp. Available on line at edf.org/bioenergy.

Current investigations and international discussions suggest that the mix of governance mechanisms in place for the wood pellet trade, for example, may not be sufficient, according to some parties, to ensure and facilitate sustainable trade. This is rather striking given the fact that SFM systems in North America and the Nordic countries have been under intense development for over two decades. Furthermore, it is apparent that there is a huge amount of confusion around the world as a result of the fragmentation among key players, lack of consistency in standards development and lack of agreement on roles and responsibilities. There is an urgent need for careful coordination among all key parties to move the sector ahead.

It is also clear that sustainability certification and other tools for governance of bioenergy development need to aim for global coverage and coordination as a longer-term goal. Markets requiring sustainability certification may simply not be attractive for producers if production for other markets with less stringent requirements offers an easy way to avoid red tape and certification costs. Such leakage effects - impacting the effectiveness of recurrent revision of certification systems, standards and other governance mechanisms as a strategy for moving the sector further towards sustainability - may also arise because bioenergy feedstock production is an integrated part of forest and agriculture operations. Producers can decide to target the food sector or to produce feedstock for the production of various bio-products. Thus, the ultimate goal should be that biomass production complies with the same sustainability requirements regardless of whether the produced biomass is used as bioenergy feedstock or for other purposes.

6 MOBILISING SUSTAINABLE BIOENERGY SUPPLY SYSTEMS

Previous sections of this article have described how sustainable forest and agricultural bioenergy feedstock production systems can significantly reduce our dependence on fossil fuels and reduce greenhouse gas emissions while also sustainably increasing the environmental and social and economic services accrued by society. Yet it is clear that serious challenges to achieving this noble and essential goal remain to be solved. Our collective sense of priorities suggests the need to build teams that will focus intensively on those factors that hinder our current ability to realise the potential that we know is realistically possible – and thus mobilise sustainable bioenergy supply chains.

As summarised in the strategic inter-Task project that was approved during ExCo69, the challenges to resolve in mobilising sustainable bioenergy supply chains include:

1. Developing competitive feedstock supply and value chains, based on identification of appropriate feedstock and conversion technologies, including co-produced bio-based products and their substitution for alternative products.

2. Quantifying the positive and negative environmental and socio-economic consequences of different bioenergy supply chains, including benefits of co-products.

3. Assessing the effects of adoption of sustainability risk mitigation techniques on feedstock availability and cost.

4. Developing governance of sustainable supply chains that provides sound operating conditions for participants along the supply chains, while addressing concerns about various risks associated with bioenergy. As feedstock production is dependent on geographical factors, another layer of complexity is added as site-specific issues need to be reconciled within the context of global supply chains.

The concerns outlined above indicate a need for a comprehensive understanding of the many elements involved in bioenergy mobilisation, in order to create a truly sustainable, economic business case for bioenergy within the bio-economy framework. The Tasks in IEA Bioenergy have over recent years cooperated in diverse and inter-disciplinary teams to deal with increasingly complex issues. This trend is gaining momentum as the current triennium draws to a close and we complete strategic planning for the next three years of work. It is pleasing to see how the formation of Tasks to address complex issues places IEA Bioenergy in a strong position with significant impact on the way others view the opportunities and challenges we face in developing bioenergy systems, with the expectation that these will provide a substantial part of our future energy needs.

ACKNOWLEDGEMENTS

This work was funded by IEA Bioenergy Task 43. John Tustin provided editing support.

IEA Bioenergy

IEA Bioenergy is an international collaboration set up in 1978 by the IEA to improve international co-operation and information exchange between national RD&D bioenergy programmes. IEA Bioenergy's vision is to achieve a substantial bioenergy contribution to future global energy demands by accelerating the production and use of environmentally sound, socially accepted and cost-competitive bioenergy on a sustainable basis, thus providing increased security of supply whilst reducing greenhouse gas emissions from energy use. Currently IEA Bioenergy has 22 Members and is operating on the basis of 13 Tasks covering all aspects of the bioenergy chain, from resource to the supply of energy services to the consumer.

IEA Bioenergy Task 43 – Biomass Feedstock for Energy Markets – seeks to promote sound bioenergy development that is driven by well-informed decisions in business, governments and elsewhere. This will be achieved by providing to relevant actors timely and topical analyses, syntheses and conclusions on all fields related to biomass feedstock, including biomass markets and the socioeconomic and environmental consequences of feedstock production. Task 43 currently (Jan 2011) has 14 participating countries: Australia, Canada, Denmark, European Commission - Joint Research Centre, Finland, Germany, Ireland, Italy, Netherlands, New Zealand, Norway, Sweden, UK, USA.

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This publication was produced by Task 43 within the Implementing Agreement on Bioenergy, which forms part of a programme on international energy technology collaboration undertaken under the auspices of the International Energy Agency.