The Use of Sustainability Assessment of the Harvesting and Utilisation of Forest-based Biofuels

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Abstract:
Global and European, are driving forces for national policies and commercial investments in order to enable the access to raw material and the infrastructure for the energetic and sustainable use of biofuel. However theses wishes cross other interests like the impact on the environment, e.g. emissions, structures deemed as beneficial for biodiversity and maintained biological production.
In a European perspective its forests have a vast potential for energetic use, in spite the fact that several states are already using a large portion of their annual harvests for energy generation. Clearly there is a need for evaluation tools in order to assess an appropriate use of biomass for energy with consideration to other competing interests relevant to environmental, economic and social development. These tools are to be used in from different perspectives, namely for the evaluation of;
- policies,
- investment decisions
These tools are qualitative or quantitative, based on systems for certification, within ISO and CEN organisations and other as FSC. Quantitative tools comprise methods based on mass or substance flow assessment as or similar to LCA (Life Cycle Assessment) where the result is evaluated against a choice of relevant impact categories as e.g. Global Warming Potential. ToSIA (Tool for Sustainability Impact Assessment) makes possible an assessment of energetic efficiency, economic result as costs, profitableness, need for investments or the result for social parameters as employment or social well-being.
Tools are developed by e.g. national or international authorities, organisations with vested interests and the research community.
The complexity of the issue and the various actors and stakeholders involved make the improved use of LCA, LCC and other SIA methods imperative. It is crucial for these methods to be transparent to investors, politicians, decision-makers and the public.

Keywords: biofuel, LCA, SIA, ToSIA, forestry, certification

1 International processes around the sustainability of forests and bioenergy

The 1992 Earth Summit in Rio was a starting point for several international processes governing forestry, Agenda 21, and the Convention on Biological Diversity. After the Earth Summit, the Intergovernmental Panel on Forests (United Nations 2012), continued intergovernmental forest policy dialogue. This is still going on within the UN and is being followed by other processes both internationally (UNFF 2012) and within the European Union. The message for us is that rising population levels and those populations' access to natural resources makes forestry today a global issue, in contrast with the world as it was50 years ago.

Many countries are setting targets to increase the share of renewable energy sources. For the EU, the Council of Europe has established the so-called 20/20/20 targets (European Commission 2008) signifying that the EU should produce 20% of its energy based on renewable sources by 2020. Each member State has an individual target: for example, Sweden should produce 49 % of its energy from renewable sources, while the goal for France is 20 %, and it is 15% for the UK. The Directive for Renewable Energy promotes the use of biomass for energy, a large proportion of which must be forest biomass. The estimated potential annual supply of forest biomass for energy from the EU's forests by 2020 is 200–400 million m^3 (1500–2900 PJ), which is less than 5% of total energy use (Asikainen *et al.* 2008, Verkerk *et* *al.* 2011a). In many countries, forest biomass will play a more prominent role. Sweden, a country with extensive forest resources and a developed forestry sector, has seen a strong increase in demand for forest biomass as a fuel, especially in district heating, combined heat and power production, and within the forest industry itself.

The technically available potential of forest chips in Sweden is approximately 20–25 million m^3 per year (The Swedish Forest Agency 2008). Half the gross supply (56 million m^3 per year) is exempt for ecological, technical or economic reasons.

2 The issues around the sustainable use of with bioenergy

Renewable energy sources with low or no contribution to global warming are in high demand. Forestry products or biofuel from forests, together with other kinds of biomass, may constitute a significant source for providing heat, electricity, or liquid or gaseous fuels. It is estimated that there are vast sources for bioenergy, equivalent to 30% of the global demand by 2050 (Brendan and Cowie 2011) or from forest resources in Europe (Asikainen *et al.* 2008, Verkerk *et al.* 2011a).

The use of bioenergy has impacts on the national and regional economy and employment, as well as on biodiversity and on soil quality. If the use of biofuels is going to mitigate global warming potential, it should have a positive energy balance and a neutral or positive effect on the sequestration of soil organic carbon (SOC).

Increasing interest in growing biomass for energy on any kind of land also implies the use of fertilisers in order to remedy likely physical or chemical effects on the land due to increased harvesting or off-road driving. Intensified land use may result in a possible release of gases contributing to Global Warming Potential (GWP).

3 How to evaluate sustainability

Strong economic development occurred after World War II, although negative aspects of industrialism became apparent. Many people feared that the burden placed on nature would place the very existence of human life at risk. A well-known book that provided a warning of this was Rachel Carson's *Silent Spring* (1962).

Sustainability was conceived of as a political issue formulated in the aftermath of UNCTAD, the Brundtland Commission (Anon., 1987; Humphreys, 1996), followed by the Kyoto Protocol and Agreement, and UNCED (UNFCCC 2012).In forestry, this kind of thinking was expressed as early as the 17th century (Andersson 1960), and in the 18th century by Carlowitz (1732).

Sustainable performance became political goal, which implies erving the present generation without placing future generations at risk. Sustainability encompasses three general principles:

Environmental sustainability, which requires that the ecosystem should be able to support healthy organisms, by maintaining their productivity, adaptability and capability for renewal.

Social sustainability, which reflects the relationship between development and social norms. An activity is socially sustainable if it complies with social norms or does not stretch them beyond a community's tolerance for change.

Economic sustainability requires that the benefits for the parties involved exceed the costs incurred and that the capital is handed down from one generation to the next.

3.1 By certification

Since then there have been a number of initiatives and actions via international bodies for States and the business sector, codified in national or international law or in voluntary standards. Within the International Standards Organisation, ISO (2004), the ISO 1400 family of environmental standards was created, thus enabling a framework for the evaluation of organisations and products.

Methods for evaluation were standardised. Similar processes were organised by non-governmental organisations; for example the FCS (Forest Stewardship Council) standard for forestry was created. The basic idea is that via standards laying down procedures or levels of performance (which basically are developed by the parties concerned), verification that the standards are being fulfilled is carried out by independent parties using audit plans.

Following the success story of forest certification, which has now been accepted worldwide, initiatives have been put forward for creating a system for the certification of sustainable biomass for energy (Ladanai and Vinterbäck 2010). The authors go into the processes implemented and the initiatives taken by organisations and individuals in order to promote this. It is generally accepted that the sound use of bioenergy shall concur with the three principles of sustainability cited above.

The first principle features the very important safeguarding of biodiversity structures and SOC. Intensified use of forests is not without complications. Ericsson and Berg (2007) demonstrated that the two objectives of increased biomass harvests and preserving some structures of biodiversity in the landscape might in fact be conflicting. Increased productivity and a shorter rotation period may decrease SOC (Weslien *et al.* 2009). In fact, a recent study (Verkerk*et al.*, 2011b) based on a modelling study, shows how the amount deadwood in Europe as a biodiversity indicator will decrease as a consequence of increased fellings and the procuring of biomass for energy. Various studies (Brandão *et al.* 2011, Repo *et al.* 2010, Lindholm *et al.* 2011) imply that increased emissions of SOC in the short and long term might be the result of intensive use of biomass, although biomass from forestry brings about less reduction than other crops(Brandão*et al.* 2011).

The various standards for forest certification are market or marketing instruments and their content and emphasis on environmental, economic or social properties will be adjusted as a consequence of the vested interests of various parties. Standards for the sustainable use of biomass for energy are likely to be incorporated into standards for forest certification and guidelines within the European Union.

3.2 By general performance

A number of methods have been developed to keep track of the sustainability impacts of industrial activities, and these may be applied to a production site, a production unit, or entail a landscape perspective. On this occasion, I will refer to LCA (Life Cycle Assessment), LCC (Life Cycle Cost), and SIA (Sustainability Impact assessment).LCA is a method for the assessment of environmental impacts caused by a product or a service during its lifetime (ISO 2006) and has a product or service perspective. Today it is normal procedure for any company or organisation to use LCA in order to evaluate products in production or for it to be a tool for marketing purposes, such as an EPD (Environmental Product Declaration). LCC is a method for product or cost assessment that has been used for a long time now, but it is not as standardised as LCA. Heijungs *et al.* (2012) raises the prospect of combining the two evaluation instruments for a given data set in order to achieve an assessment of eco-efficiency. Tools for SIA are around, and are used as a means of evaluating sustainable forest management (Rosen *et al.* 2012, Lindner *et al.* 2012, Palusuo *et al.* 2010). Several studies performed with the aid of LCA methodology demonstrate the effectiveness of bioenergy chains (Tab.1).

Table 1: Compilation of various studies reflecting the efficiency of bioenergy chains. The boundaries of the studies differ. Thus this data does not provide a comparison but rather offers a general picture of recently published findings: for more detailed information, it is recommended that interested readers consult the original articles.

	FU [1]	Energy balance[2]	Emissions g CO_2 eq g/MJ caloric or generated energy	Transport distance for biomass, km	Share, % energy use for transport
Whittaker et al. 2011	ODT/MWh	9.5 – 13.5	5–7	50	11
Valente et al. 2011a	$1m^3$ sob[3]	37	2[4]	64	32
Valente et al. 2011b	$1m^3$ sob[3]	20	1.4	30	27
Roedl 2010	ODT[5] 1MJ[10]	43[5]	Power 6.3; heat 1.7; FT 9.6; Chips 2.0	50; [5]	33[5]
Gonzalez-Garcia et al. 2009[9]	kg Ethanol	1.3	EA 146.1; MA32.3 [6]	180 (shives);	<10
Lindholm et al. 2010	1MJ DM_{chips}	21–38	1.5 – 3.5	38–70	23– 69
Wehrhahn-Mees et al. 2011	MJ_{heat}	3.4 – 10.5	8.8[7]; 5.2[8]	40–170	40–170
Berg & Lindholm 2005, Lindholm & Berg 2005	$1m^3$ sub[3]	39–41	0.45 – 0.62	n.a	41–57
Wihersaari 2005	1MWh[5]	30–50	1.1 – 1.9[11]	n.a	n.a

[1] Functional Unit; [2] Quota of energy out/in. The author converted the values from MWh to MJ; [3] sob = solid over bark; sub = solid under bark round wood; [4] Converted by the author from 17,600g/$1m^3$ sob[3]; [5] Chipped wood; [6] EA = Economic Allocation; MA = Mass Allocation; [7] Pellets (author´s calculation); [8] Pellets + energy wood + residues (author's calculation); [9] *Linumusitatissimum;* [10]power, heat, FT diesel; [11] The author converted the values from MWh to MJ

The paper by Berg and Lindholm (2005) shows an overall general energy efficiency quota of about 40:1 for the Swedish chains of operations from forest regeneration to the mill gate, allocated to the energy content of industrial wood. Forms of transport from the forest to the mill accounted for about 50 % of the energy used. Several chains for the procurement of forest energy (Lindholm *et al.* 2010) yield 21-31:1 depending on the type of raw material, stumps, brash etc. Transport of biomass accounted for a huge share of the energy used. In Finland, Wihersaari (2005) reported quotas with a range of 30–50:1. Roedl´s study (2010) refers to short rotation forestry for the production of FT diesel and this gives an energy efficiency quota of 43:1 for the procurement of oven dry chips, with transport making 31 % of the input energy. Valente *et al.* contribute with two studies of biomass harvests, the first study within the context of Norwegian natural forest management (2011a) attaining an efficiency level of 37:1 for biomass at the mill, with transport energy input amounting to 31 %. The other study (*Valente et al.* 2011b) shows the results from an alpine logging system with biomass (forest residues and stumps) for energy delivered for heat generation at the heating plant. The energy efficiency compared to the intrinsic energy in the biomass is 20:1 and the share of the input energy used for transport is 27 %. A study of the energy and greenhouse gas balance for the use of forest residues for the generation of bioenergy in the UK (Whittaker *et al.* 2011) demonstrates an efficiency level of 9.5 - 13:1 being assigned to the intrinsic energy content of biomass at a heat plant. A study of the sustainability of various industrial chains in Finland (Weerhahn-Meese *et al.* 2011), using ToSIA (an SIA tool), demonstrated an overall efficiency level ranging from 3 - 10:1 for three chains sized for three kinds of mixes; energy wood, pellets, and logging residues at the heat plant. As it also constitutes a study using ToSIA, values are also represented for economic and social impacts. The economic perspective, as anticipated by Heijung (2012), is in fact also represented in some of the studies cited in Table 1.

Gonzalez-Garcia *et al.* (2009) report a study of ethanol for automobiles based on flax shives as the energy carrier. The energy efficiency is 1.3:1. This paper demonstrates that the allocation methods used for the environmental impact are of crucial importance for the calculated outcome. In fact the GHG emissions level allocated according to the economic value is very high, but is allocated according to mass, giving a negative value, which entails the sequestering of carbon. Another study in Finland with ToSIA (Kolström *et al.* 2011) evaluated the forest use of bioenergy for two types of heating plants; small and medium-sized plants. This study showed that although environmental and social indicators were favourable to the smaller plant, its production costs were higher. However with the support of the Finnish forest energy subsidy programme, the post-subsidy costs did not differ greatly.

The studies discussed in this chapter basically use the LCA methodology. The functional units are different and so too are the boundaries. What is important is that the basis for interpretation and judgment must be transparent both to readers and decision-makers. The studies demonstrated a wide range of efficiency levels, depending on the boundaries (the starting point and the end point), but it is evident from these studies that the energy used for transport from source to the mill/plant is substantial, especially considering the fairly short transport distance for biomass in comparison to forms of transport to forest industries (Table 1) which is shorter than for forms of transport to traditional forest industries (Berg and Karjalainen 2003). For all forestry chains, the emissions of fossil CO_2 equivalents are below 10 g/MJ of energy. This is very low in comparison with fossil fuels such as petrol or diesel (Uppenberg*et al.* 2001).

3.3 By going into logistics

Biomass is an energy carrier with a low energy density, high moisture content adds mass while decreasing the lower energy value. The heterogeneous texture makes handling technically difficult (Björheden and Eriksson 1990). This places emphasis on the logistics of the chain, especially for late operations comminute on, and transport to the energy plant, which was identified as being very important mainly from a costs perspective (Eriksson and Björheden 1989, Flisberg*et al.* 2012). This perspective has been widened to include a sustainability point of view (Forsberg 2000) and efforts have been made to make forward progress with instruments containing several sustainability indicators (Chesneau*et al.* 2011) in order to improve the decision-making climate for investors and decision-makers in industry and government.

The principal aim is the concentration of dispersed raw material into a form that is suitable for subsequent handling, processing and consumption. The forest resources are distributed over an area while conversion into commodities occurs at specific points such as conventional forest industries, bio refineries or heating and CHP plants. The required quantities and qualities of wood are accumulated and delivered to the various points, nodes, of demand. Transport is thus a key element of forest fuel production. Efficient transport technology minimises the cost of moving goods and also its environmental impact.

The transport system consists of facilities such as cranes, roads, tracks and so on that make up a network of links joined at nodes (intersections, terminals etc.), and transport entities such as such as grapples and buckets, vehicles, railroad cars, containers, conveyors etc., which constitute the traffic at the facilities (Papacostas 1987).

The spatial nature of forestry, and legislation concerning the maximum gross vehicle weight etc., increase the fragmentation of transportation in spite of the obvious economies of scale (Björheden and Axelsson 1991). Transportation begins when biomass is moved from the source and includes several steps of concentration of the harvested material. The logistical conditions are improved by increased concentration, justifying heavier investment in entities and facilities as we move downstream from the transport chain (Andersson *et al.* 2002).

Bulk density may be increased by compaction or by chipping. Processing into chips will decrease durability under storage. Green chips are highly vulnerable to exothermic microbiological, physical and chemical degradation which can cause health hazards, loss of substance, and loss of energy content and the risk of self-ignition (Björheden and Eriksson 1990, Kofman 1994).

System flexibility and applicability for a variety of goods is an important consideration. This affects planning and allows a more efficient use of the transport fleet than when highly specialised vehicles are used. Selection of transport systems is affected by the quality and structure of the forest road network and by conditions at the landings. Transport systems may therefore be selected on other than purely transport-economic grounds for biomass.

4 Discussion and conclusions

The scientific works that have been assessed within this context reveal that forest biomass for energy is an efficient, and possibly a very efficient, source for renewable bioenergy. Its practical use and economic development is hampered by difficulties in the construction of logistics chains and nodes for operations. Forestry is a large-scale activity and the nature of the problem, being dependent on local conditions and the end energy product, also makes the logistical solutions large-scale. There is a need for competence, available risk capital for investments, and benevolent physical, commercial and political structures.

The utilisation of biomass for energy is increasingly governed by international or interstate processes or legislation and also conflicts with other focus points such as biodiversity, and SOC. When properly used it is important for the mitigation of global warming and might benefit sustaining employment in forested regions. This means that forest biomass for energy is a potent political and social issue where the electorate is expected to have a say.

The use of biomass is a business. Cost and income decides profit. Subsidies for the use of bioenergy may affect the long-term sustainability of this activity. In fact the energy efficiency quota might be a very good indicator of long-term sustainability. This quota is, to my judgement, an indicator of the internal interest in making an investment in bio energy chains. A quota of 40 or 20 makes a difference for the rate of return. A chain with a low quota might be unattractive for large investments. And the business climate is pivotal.

The complexity of the issue and the various actors and stakeholders involved make the improved use of LCA, LCC and other SIA methods imperative. It is crucial for these methods to be transparent to investors, politicians, decision-makers and the public.

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