Annex A

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A framework for evaluating the environmental impact of biofuel use

Jane Feehan and Jan-Erik Petersen, European Environment Agency, Copenhagen.

Abstract

With increasing emphasis on renewable energy, the role of biomass as an environmentally friendly energy source is becoming more important. Transport is a sector where other renewables will not play a major role in the foreseeable future, making the contribution of biomass and biofuels particularly significant. The issue of biofuel use in transport is one of the cross-sectoral themes that the EEA is planning to address during the coming years.

This paper summarises recent EU policy developments regarding biofuels. It then sets out a framework for evaluating the environmental impact of current biofuel use, drawing on existing studies and assessment approaches developed at the EEA and linking with the existing OECD agri-environment indicator structure. This framework is intended to facilitate more integrated, holistic thinking on how best to assess the impact of increased biomass production and use. It aims to set out the parameters of an ex-ante evaluation of measures to expand biomass production and use. Recent policy developments present a range of options for increasing biofuel use in the EU, and it is hoped that the framework will help to develop appropriate approaches for local and regional circumstances. To test our conceptual approach, the framework is applied to two different types of biofuel production. Lastly, the paper draws conclusions from the case study exercise about the usefulness of the assessment framework in evaluating the environmental implications of future biofuel development.

Keywords

Integrated environmental assessment, life cycle assessment, rapeseed, biodiesel, willow, combined heat and power (CHP[*]).

Introduction

There is now a renewed interest in the use of biomass for the efficient and clean production of heat and electricity and for the production of renewable transport fuels. Biomass from agricultural, forestry and waste sources provided over 63% of the EU's renewable energy in 1999, and it appears to be the renewable energy source with the highest potential to contribute to a future sustainable energy supply for the European Union (EEA, 2002a). In Finland, Sweden and Austria, it currently covers 23%, 18% and 12% of the primary energy demand (Groscurth *et al.*, 2000). Biomass is a particularly attractive option for a number of reasons.

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[*] Acronyms used in the text are listed in the 'Acronym Glossary' at the end of the paper.

- It is widespread, diverse and renewable, contributing both to the security of energy supply and to the diversification of energy sources.
- It can produce a low-carbon source of electricity.
- Modern biomass conversion technologies have brought emissions down to very low levels.
- Energy plantations, if carefully planned and managed, can yield benefits such as watershed protection, habitat and amenity value and the rehabilitation of degraded areas.
- Biomass production can provide an alternative market for agricultural production, contributing to agricultural diversification and rural development.

Table 1 shows some of the main agricultural and forestry biomass resources, ranging from dedicated energy crops such as oil and starch crops, to secondary residues such as sawmill waste. Some crops, such as sugar beet, have a high energy yield per hectare but little use can be made of their by-products. Others, such as oilseed rape, have a lower energy yield per hectare but yield a number of useful by-products (high-protein animal feed, glycerine) that contribute to the overall energy balance.

Energy content is only one feature of these crops. Some can only be grown in rotation with other crops, may require more irrigation and chemical inputs than others, and some provide useful cover for wildlife. Some are being exported, while others are already being imported. A simple cost-benefit analysis does not capture the full range of costs and benefits that arise, and nor does a simple comparison between biomass fuels and their fossil alternatives. **An integrated framework for assessing the broader, cross-sectoral environmental impact of expanding biomass production and use is needed to ensure that all the important factors are taken into account**.

This paper attempts to set out such a framework. This framework is not intended to provide a blueprint for assessment, rather to facilitate more integrated, holistic thinking on the approach that is needed. It aims to set out the **parameters of an ex-ante evaluation** of measures to increase biofuel production and use in an environmentally-friendly way. We welcome feedback on the proposed framework and aim to improve it in the future.

Table 1

Agricultural and forestry biomass resources

Biomass type	*Source*
Dedicated crops	• Oil crops (rapeseed, sunflower, soya) • starch crops (sugar beet, sugar cane, wheat, barley) • short rotation forestry (willow, poplar) • high-yielding grasses (miscanthus, switchgrass)
Primary residues / by-products from agriculture and forestry	• Forestry (thinnings, felling residues) • Straw from cereal crops • Other agricultural residues
Secondary residues / by-products	• Manure, slurry (fermentation for biogas) • Sawmill waste • Sewage sludge • Non-agricultural sources (used cooking oil, organic solid waste)

Two uses of biomass: combined heat and power (CHP) and biofuels for transport

This paper examines two uses of biomass: the use of short-rotation coppicing of willow for combined heat and power production (CHP), and the use of oilseed rape for biodiesel generation.

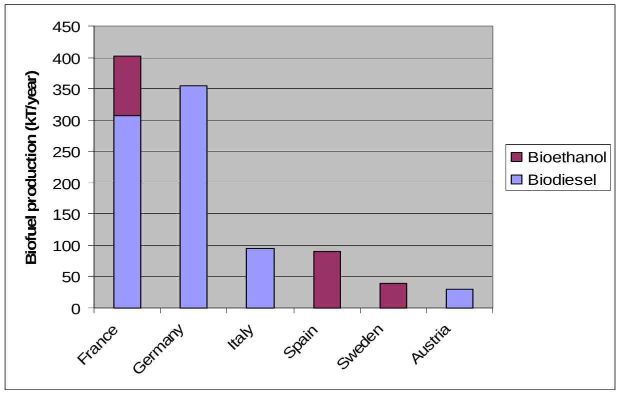
Bioelectricity represents about 1% of the electricity production capacity in OECD countries, with an installed capacity of about 18.4 GW. Most plants are of the **CHP** type, where heat is generally used for industrial purposes or district heating (Bauen *et al.*, in print). A well-developed bioelectricity sector depends on ready availability of a biomass feedstock, and most bioelectricity production in OECD countries is associated with forestry and wood processing industry activities. Some countries – Finland in particular – have considerable experience with co-firing biomass with fossil fuels and waste. For the OECD area, an ambitious but realistic target for bioelectricity by 2020 could consist of the exploitation of 25% of potentially harvestable residues from agriculture and forestry, and by dedicating 5% of the crop, forest and woodland area to biomass growth for energy (Bauen *et al*., in print).

Transport is a sector with limited renewable fuel options. Energy sources such as wind and solar power cannot be harnessed for transport in the foreseeable future, and so the EU's transport sector is set to increase the use of **biofuels** in the coming years. With transport's 98% dependence on oil, a shift towards biofuels offers some attractive advantages: a reduction in CO_2 emissions, a fostering of improved security of energy supply, a new path for the diversification of agriculture and a medium-term stepping stone to the more distant technology of hydrogen fuel cells. It has been suggested that wood crops converted to alcohol or hydrogen could in the long term satisfy most UK road transport fuel demand (Eyre *et al.,* 2002).

A recent Directive (2003/30/EC) on increasing the use of biofuels in the EU is promoting the use of biomass for transport fuel. Currently, almost all biofuel use in the EU is accounted for by six Member States (Figure 1), and much of this is biodiesel manufactured from rapeseed or sunflower oil. The Directive sets out a wide range of alternative fuel options to encourage a diversification of fuel supply. National targets for the use of biofuels are to be set across the EU, aiming towards the indicative goal of replacing 5.75% of all transport fossil fuels by 2010. Countries will be asked to report on the environmental impact of planned biofuel-encouraging measures, including factors such as land use, the degree of intensity of cultivation, the use of pesticides, the protection of watercourses and energy efficiency. Appropriate environmental measures will need to be taken to reduce the impact of biofuel crop cultivation. The overall goal is to expand the use of biofuels in a considered way on the basis of clear evidence of their environmental benefits, while taking into account competitiveness and security of supply. There is a need to develop complementarity between the different biofuel options available in the EU.

Figure 1

Use of biofuels for transport in the EU, 2001.



Source: The Altener (Alternative Energy) Programme, DG Energy and Transport

Current tools for conducting environmental assessment

Straightforward impact assessments are often partial, looking only at certain sets of impacts and making it more difficult for policy makers to assess trade-offs and to compare different scenarios when deciding on a specific course of action (Willis, 2002). Integrated environmental assessment (IEA) and life cycle analysis (LCA) attempt to overcome this limitation by including a broader set of impacts. Features of these tools are useful for assessing more comprehensively the environmental consequences of biomass production and use.

A current focus of work in the EEA is to develop expertise in **integrated environmental assessment** (IEA) in order to evaluate policy effectiveness. IEA is a process that requires a broad, systemic approach to building environmental knowledge, and it must be relevant and useful to policy development processes (Rothman and Robinson, 1996). Because of its integration of policy relevance with a multi-disciplinary approach, IEA is increasingly recognised as an important technique for managing the environmental impacts of human actions.

Integration is a continuous spectrum, and there are many ways to approach it. The most frequent way is so-called ***vertical integration***, which incorporates the whole causal chain of socioeconomic driving forces, pressures on the environment, the resulting state of the environment, the impacts and the required responses from policy and society. The DPSIR framework (Driving force, Pressure, State, Impact, Response), summarises this end-to-end cycle. This framework can facilitate a good understanding of the dynamics of the system, ensuring that the assessment is properly comprehensive and 'integrated'.

A second approach is ***horizontal integration***, which entails broadening the study across disciplines within a single link of the causal chain. To take environmental pressures as an example, we can distinguish between different types of pressures from different activities and sectors. Thus nutrient loading in water bodies arises from a variety of sources (agriculture, industrial activities, sewage treatment plants). To properly assess their combined pressure, a combination of agronomic, engineering and environmental knowledge is required. Combining vertical and horizontal integration is the main challenge of IEA (Vos, 2001).

Life cycle assessment is also known as 'life cycle analysis', 'life cycle approach' or 'cradle to grave analysis'. It is a system orientated approach estimating pollution potential, energy and resource usage associated with a product or operation throughout its life cycle (EEA, 1996). In general, 'life cycle thinking' can be a useful spur to creative thought on the wider dimensions of a problem (EEA, 1997). Among the newer concepts in LCA is 'life cycle management' (LCM), which is an integrated approach to minimising environmental burdens throughout the life cycle of a product, system or service.

A typical LCA study consists of the following stages:

1. Goal and scope definition.
2. A detailed life cycle inventory (LCI) analysis, with compilation of data both about energy and resource use and on emissions to the environment, throughout the life cycle.
3. An assessment of the potential impacts associated with the identified forms of resource use and environmental emissions.
4. The interpretation of the results from the previous phases of the study in relation to the objectives of the study.

Impact categories are discussed in some detail in Appendix 4.2 of the EEA (1997) publication 'Life Cycle Assessment (LCA). A guide to approaches, experiences and information sources (Environmental Issues Series No 6)'.

A framework for evaluating the environmental impact of current biofuel use

The production and use of biomass has cross-sectoral effects, touching on transport, energy, trade and agriculture. Different stages in the production chain – cultivation, fuel manufacture, use of by-products, CHP technology, transport use – have very different sets of environmental impacts.

The cultivation of biomass for energy has various potential impacts on soil, water, air and biodiversity. These impacts can be listed as follows.

- Biodiversity (changes in the use of chemical inputs, changes in crop rotations, possible arable conversion of grassland, potential creation of landscape elements)
- Soil (organic matter content, soil structure, nutrient content)
- Quality of water and watersheds
- Air and atmosphere (ozone, acidification, particulate emissions, greenhouse gases)
- Energy efficiency
- Human health (pollution of air and water, allergenic pollen from crops)
- Amenity value.

Each of these impact types needs to be assessed for the biomass type in question, and for each stage in the processing and refinement of that biomass type.

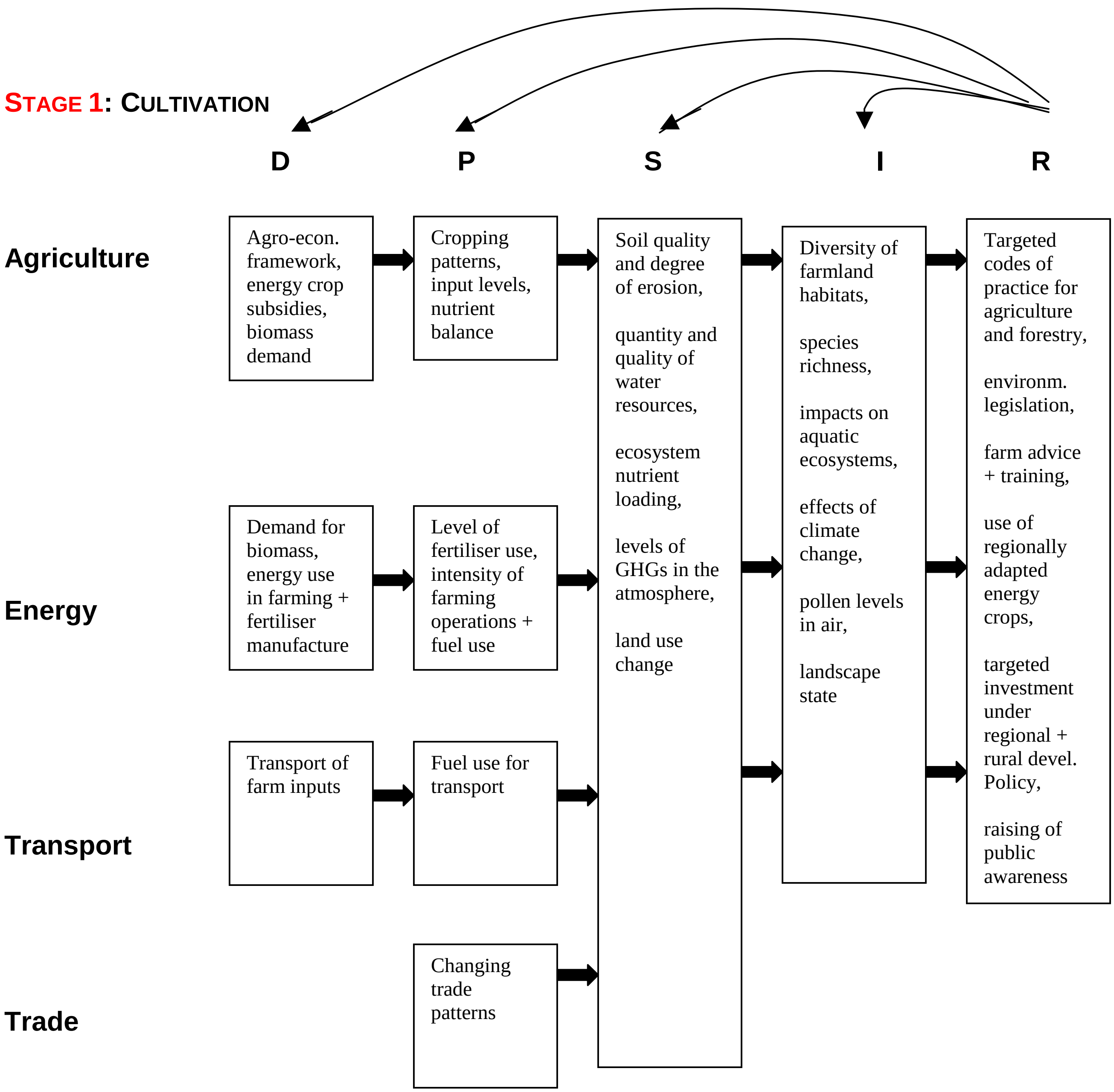
In developing an integrated framework for assessing the environmental impact of biofuel production and use, both horizontal and vertical integration are necessary to achieve effective evaluation. Stages of the production process should be considered one by one, and looked at from the point of view of parameters that affect the environmental outcomes: agriculture and land use, energy, transport and trade. Economic assessment – including cost-benefit analysis – is also important, but is beyond the scope of this paper.

At each stage of this multi-sectoral life-cycle assessment, the DPSIR cycle is kept in mind. This maintains a useful causal continuity throughout the framework. Instead of a list of factors, the framework retains a sense of the underlying reasons for, and possible responses to, each factor.

The evaluation framework is illustrated in Table 2.

Table 2

Framework for integrated evaluation of environmental impact of biomass production and use. The product life cycle is divided into three stages: cultivation, processing and end-product consumption. Individual factors may have negative or positive effects.



STAGE 2: PROCESSING

	D	P	S	I	R
Transport	Spatial distribution of processing plants and biomass crops	Transport of raw materials + processed fuel	Change in particulate levels in air; levels of GHGs in the atmosphere	Pollution impacts on health and ecosystems, effects of climate change	Domestic production of raw materials, siting of facilities close to source
Energy and Industry	Biofuel type, demand + support for CHP, efficiency of production	Emissions from processing facilities, by- products			Use of BAT / BATNEEC Support for technol. research

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE

Transport	Develop-ment of fuel distribution network, demand for biofuels, pure or blended	Distribution infrastruc-ture	**Lower emission levels of GHGs,** diversified fuel sources	Pollution impacts on health and ecosystems, (reduced) effects of climate change	Engine modification support for biofuel use, distribution network
Energy	Investment in CHP facilities and infrastruc-ture	new CHP + heat pipeline infrastruc-ture			Measures to encourage development of CHP

Application of the framework

In order to test the framework, it will be applied to two different types of biomass use: biodiesel (FAME, fatty acid methyl ether) production from oilseed rape, and woody biomass use for CHP. These 'test runs' of the framework are not intended to be comprehensive: rather, they are intended to assess its usefulness, and to highlight key features of these two biomass use types. The examples chosen represent on the one hand a fairly well-developed approach to biofuel production for transport, and on the other hand a less well-developed approach for bio-energy generation. The first option can be easily integrated in current crop rotations, whereas the second option entails the introduction of new, long-term crops.

Biodiesel production from oilseed rape

Biodiesel can be produced from several raw materials: oilseed rape, sunflowers, soya, other oil crops, and non-agricultural sources of oil such as used cooking oil. In the EU, oilseed rape is the main agricultural raw material for biodiesel.

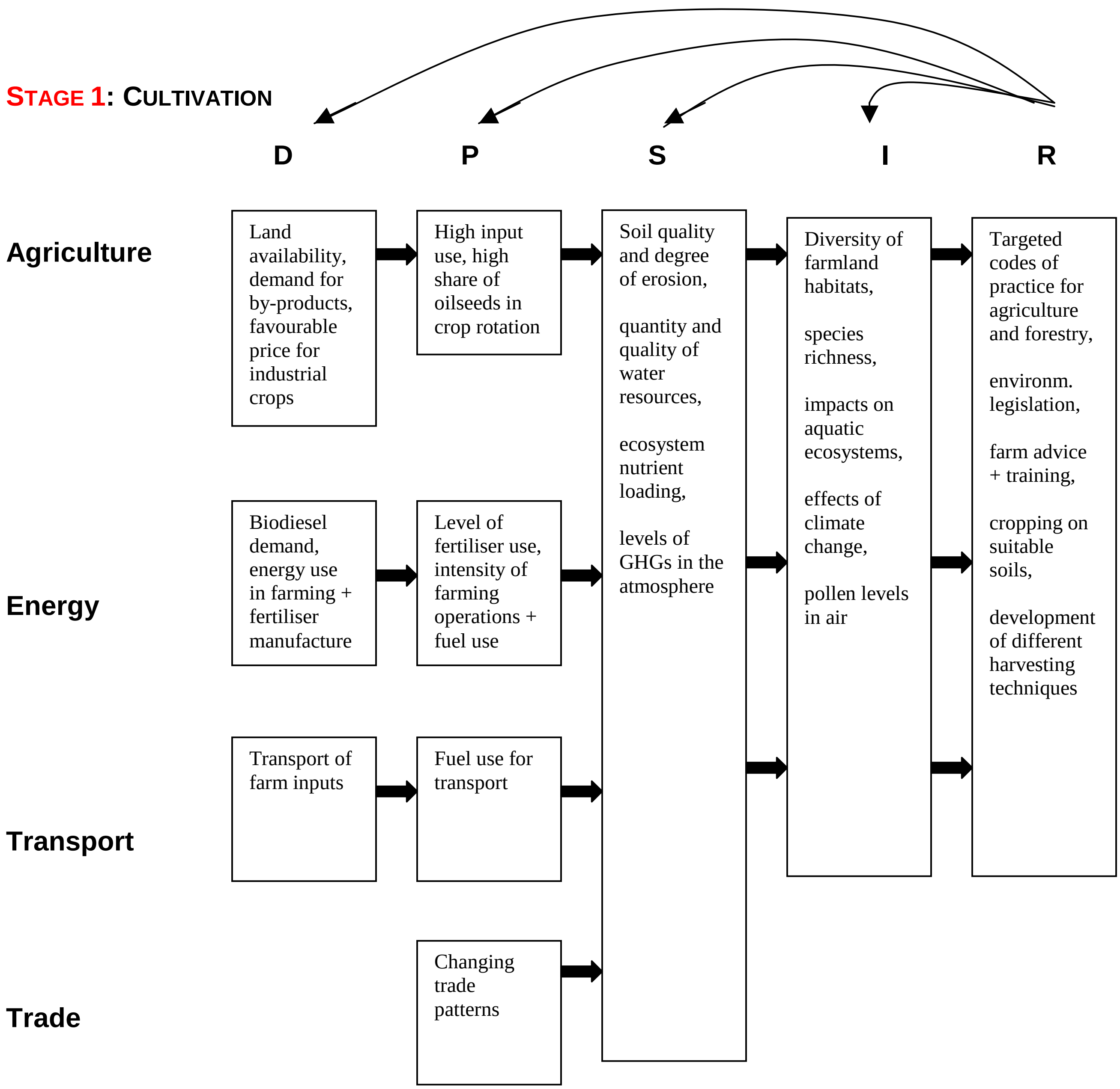
Oilseed rape is the agricultural crop that is most widely used for fuel production at present. Industrial oilseed rape was grown on approximately 2,900,000 ha in the EU-15 in 2002. Compared to bioethanol yield from starch crops, the biodiesel yield from oilseed rape is relatively low: one hectare of oilseed rape produces between 0.5 and 1.5 T/ha.

There are three main stages to the production process. Cultivation of the crop is followed by harvesting and pressing to obtain the oil. The high-protein cake that remains is a valuable animal feed. The oil is then esterified and purified to produce biodiesel. It may be blended with fossil diesel for use in unmodified engines – most current blends contain 5% biodiesel – or distributed in pure form for use in suitably adapted engines. Finally, the fuel needs to be transported to distribution points. In Germany over 900 filling stations offer pure biodiesel to supply a growing market that has been fostered by favourable taxation.

In accordance with the proposed framework, key features of this process are listed in Table 3.

Table 3

Assessing the environmental effects of biodiesel production from oilseed rape.



STAGE 2: PROCESSING

	D	P	S	I	R
Transport	Location of processing plants versus main rapeseed areas	Transport of raw materials + processed fuel	Change in particulate levels in air; Levels of GHGs in atmosphere	Pollution impacts on health and ecosystems, effects of climate change	Domestic production of raw materials, siting of facilities close to source
Energy and Industry	Societal demand for biodiesel, efficiency of production	Emissions from processing facilities, by-products			Use of BAT / BATNEEC Support for technol. research

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE

Transport	Developmt. of fuel distribution network, biofuel tax exemption, pure or blended use	distribution infrastruc-ture	**Lower emission levels,** diversified fuel sources	Pollution impacts on health and ecosystems, (reduced) effects of climate change	Engine modification support for biofuel use, distribution network, raising of public awareness

STAGE 1: CULTIVATION (Land availability, input intensity and greenhouse gas balance)
At the cultivation stage, two aspects of particular importance are the high **fertiliser requirements** of oilseed rape, and the relatively low yield of biodiesel (FAME) per hectare (0.5-1.5 T Ha^{-1}). It is an intensive crop that is best cultivated in areas already dominated by high-input arable cropping, in order to avoid negative impacts in more extensive areas. The yield of biodiesel per hectare means that very large areas of land are required to produce significant quantities of fuel, substantially more than are required to produce some types of bioethanol (for petrol replacement). In countries that do not have a high proportion of arable area, **land availability** could therefore become a particularly important criterion in selecting approaches for biofuel production. Use of waste oil as a feedstock can help to boost the availability of feedstock materials for biodiesel production (Eibenstiner and Danner, 2000).

N_2O (nitrous oxide) is 300 times more potent as a greenhouse gas than CO_2, and it is released in significant quantities from cultivated fields, particularly with intensive fertiliser use. Oilseed rape has high fertiliser requirements, and is therefore associated with higher N_2O emissions. Projections for emissions from soils use the IPCC (Intergovernmental Panel on Climate Change) methodology which assumes that 1.25% of the nitrogen contained in mineral fertilisers is released directly as N_2O, with further quantities arising from volatisation and subsequent deposition of NH_3 and NOx from fertiliser application (EEA, 2002b), totalling approximately 10% of the N contained in the fertiliser (Wilson, pers. comm.). Excluding N_2O emissions data, FAME produces a greenhouse gas saving of 53%, but taking N_2O emissions (calculated using IPCC methods) into account the saving drops to approximately 10% for FAME (Concawe, 1995) (Table 1).

STAGE 2: PROCESSING (Use of by-products)
At the processing part of the production cycle, sale of **by-products** is particularly important to the economic balance of biodiesel. In fact, the high-protein animal feed produced from oilseed rape is more important than a by-product, because its importance as feed product has been boosted in the wake of the BSE crisis. Glycerine is also a by-product of biodiesel production. In the event of a large increase in production, there is a possibility of market-damaging overproduction of glycerine.

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE (Diesel market and introduction of biofuels)
Regarding use of and demand for end-products, diesel compression ignited (CI) engines are 15-20% more efficient than gasoline spark ignited (SI) engines, and so there is a strong demand for diesel in the EU market. Most diesel is produced from straightforward distillation, and a second fraction is obtained by cracking heavier hydrocarbons, a process which is much more expensive both in energy and economic terms. There is great interest in diesel substitutes, making the biodiesel market a promising one (albeit dependent on continuing government subsidies). If an increase in biodiesel were to incur a reduction of this second fraction, clear energy-saving gains would result.

The use of **pure biodiesel** avoids the environmentally damaging effects of the fossil diesel in biodiesel/diesel blends. However, it requires engine modifications and a separate distribution network, which are more easily achieved for captive fleets. Examples include buses in the German district of Heinsberg and in Kuala Lumpur, Malaysia (where biodiesel is manufactured from white palm oil), and garbage trucks, snow ploughs and refrigerator truck fleets in the US. In Germany over 900 filling stations offer pure biodiesel to supply a growing market that has been fostered by tax exemption for pure biodiesel.

Woody biomass used for CHP

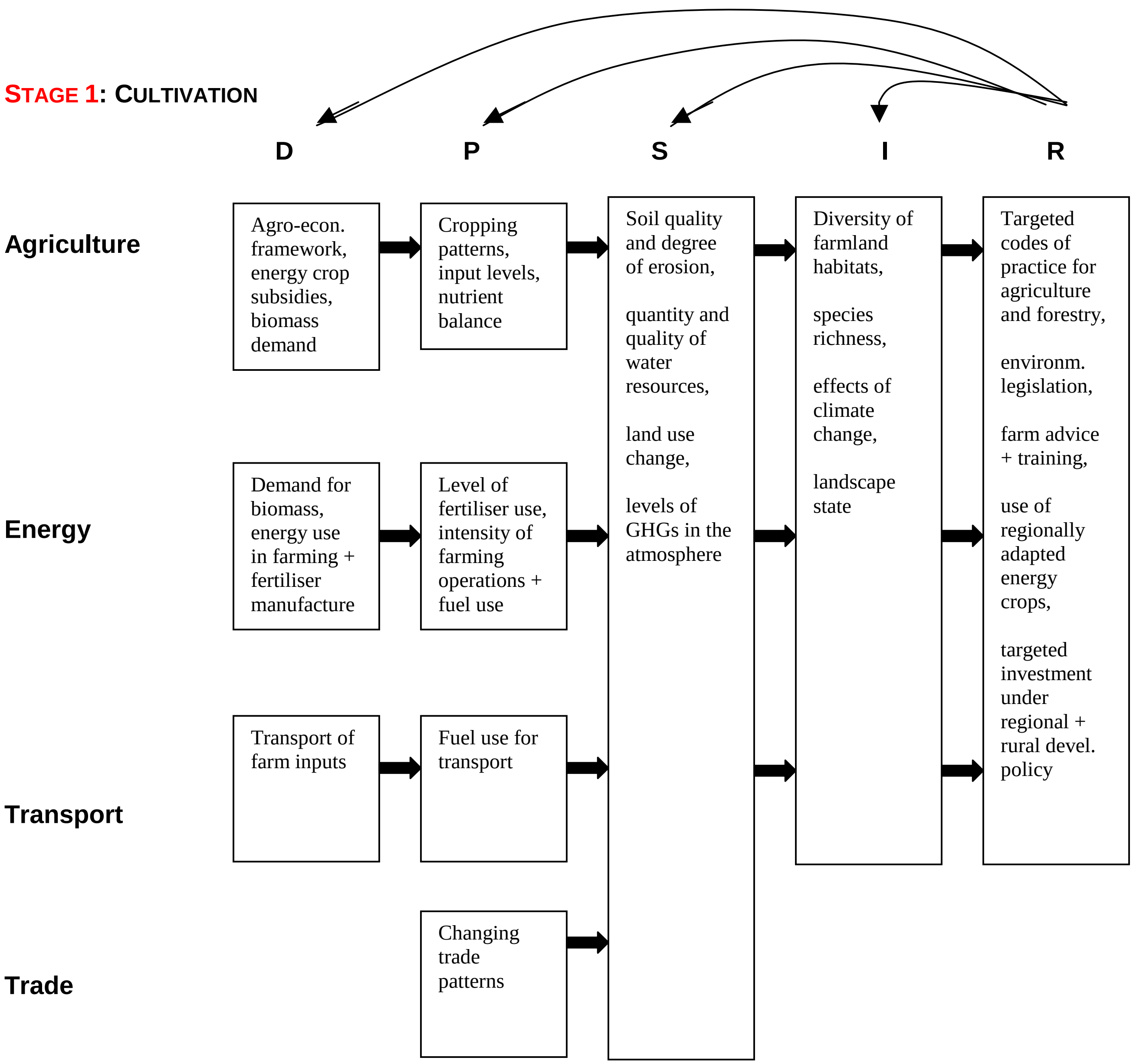
CHP (combined heat and power) or cogeneration is a highly efficient use of biomass that could contribute significantly to the economic viability of electricity from biomass. It is a particularly efficient form of energy generation: electricity is generated from steam or gas turbines fuelled by the biomass, and the 'waste' heat is used to heat water which is piped to households to provide heating. The use of woody biomass for CHP is a more straightforward process than the production of biodiesel. Feedstocks include woody biomass from SRC (short-rotation coppicing) of a variety of species including willow and poplar, wood from managed forests, forestry thinnings, sawmill waste and various agricultural wastes. In this paper dedicated short-rotation willow plantations on agricultural land will be considered. The main stages in the process are the cultivation of the trees, harvesting, transportation to the power plant, combustion and harnessing of the energy released.

Woody biomass production or SRC (short rotation coppicing) is particularly low in input requirements and has potential wildlife and amenity benefits. Because biomass is an ideal renewable fuel for energy and heat generation, these products have several outlets: CHP and liquid biofuel production when technology is further developed, together with several useful by-products.

In accordance with the proposed framework, key features of this process are listed in Table 4.

Table 4

Assessing the environmental effects of combined heat and energy production (CHP) using willow biomass.



STAGE 2: PROCESSING

	D	P	S	I	R
Transport	Location of processing plants versus SRC plantations	Transport of raw material	Change in particulate levels in air, levels of GHGs in the atmosphere	Pollution impacts on health and ecosystems, effects of climate change	Domestic production of raw materials, siting of facilities close to source
Energy and Industry	Demand + support for CHP, efficiency of production	Emissions from CHP plants, by- products			Use of BAT / BATNEEC Support for technol. research

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE

Energy	Investment in CHP facilities and infrastruc-ture	new CHP + heat pipeline infrastruc-ture **change in GHG emissions** **ash toxicity and disposal**	**Lower emission levels**, diversified energy sources	Pollution impacts on health and ecosystems, (reduced) effects of climate change	Measures to encourage development of CHP

STAGE 1: CULTIVATION (Effects on landscape, habitats and environmental resources)
The following recommendations for the planning and cultivation of short-rotation willow plantations illustrate key factors for the assessment of this stage (Perttu, 1999).

1. Plantations should be planned to suit the local landscape, preserving existing sensitive habitats. Small 'islands' around features such as open ditches, cairns etc. should be retained.
2. The coppice should be located close to existing forests to enlarge the continuous available habitat.
3. Variation in the landscape can be increased by planting several small stands which can be harvested in different years, rather than one large stand.
4. Several species and clones should be planted. This reduces the risk of damage from fungi, insects and frosts.
5. A higher proportion of male clones will favour early spring pollinators.
6. Weed control should be adjusted to need without overapplication of herbicides. In most cases, weed control is necessary during the establishment phase but can usually be avoided in a full-grown stand.
7. Fertiliser application should be adjusted to stand development, and minimised accordingly.

Willow has a pronounced capacity to take up nutrients and heavy metals, including cadmium; and willow stands have been shown to be adaptable as vegetation filters in order to purify water and soils. The purification efficiency of willow vegetation filters has been demonstrated in several countries, such as Sweden, Poland, Denmark and Estonia.

STAGE 2: PROCESSING (Technological aspects)
In the processing stages, use of BAT (best available technology or techniques) is particularly important in achieving the best environmental outcomes. Combustion technologies and co-firing with coal are commercial technologies on which the current bioelectricity industry is based. Gasification technologies are commercial in niche markets, and for specific feedstocks. Gasification could lead to more efficient and cleaner use of biomass for electricity production. Its demonstration and commercialisation using a wide range of biomass feedstocks could be very important for economically viable and environmentally sustainable bioelectricity production. Furthermore, biomass gasification can lead to future biomass facilities being integrated with advanced conversion technologies such as fuel cells and co-production of additional outputs, such as transport fuels (Bauen *et al*., in print).

STAGE 3: END PRODUCTS: CONSUMPTION AND WASTE (Policy responses and support)
As bioelectricity expands, the market pull for energy crops will need to come from the energy sector, but agricultural and forestry policy needs to provide the conditions for biomass feedstock to be delivered in an efficient and environmentally sound way.

An existing biomass industry base and a readily available biomass feedstock are strong factors behind the relatively more developed bioelectricity sector in some countries. Usually, however, the development of bioelectricity has also been a result of regulations favouring the input of bioelectricity into the electricity grid and policies supporting the price of bioelectricity, or due to taxes on the use of conventional fuels on environmental grounds. Therefore, a significant increase in bioelectricity use will require strong policy commitment and needs to be accompanied by regulations and guidelines that ensure its environmental sustainability.

For example in Austria, the Housing Promotion Act in the provincial governments provides financial support for renewable energies, particularly solar technologies and biomass boilers. Besides the Housing Promotion Act, special support for biomass, solar and heat pump systems are offered to the consumers by the provincial governments in the order of up to 20% of the investment costs.

Conclusions: Evaluation of assessment framework and biofuel options

Evaluating the framework

Existing environmental assessments of biomass and biofuels generally restrict themselves to partial evaluations of the effects of production and use of the fuels concerned. Agricultural and land use implications are often neglected, particularly in assessments of transport biofuel production where the focus is usually on the fuels themselves and comparisons with their fossil counterparts. The framework proposed in this paper addresses these gaps, pointing to the need for an integrated environmental assessment of each stage in the biomass product life cycle, while keeping a causal continuity throughout by bringing in the DPSIR approach. The framework is flexible: it does not have to be exhaustively completed, but it does provide a structure that facilitates a comprehensive analysis of the important elements of these complex product life histories. Other types of impact can be added to it as appropriate. In clarifying potential environmental impacts it helps to show trade-offs between different benefits and disadvantages of biofuel options. However, by itself it does not resolve the often difficult decisions that policy makers face in this context, including other important issues such as cost-effectiveness.

The two case studies show how aspects of the framework can be applied as part of a comprehensive approach to assessing the environmental impact of the fuels concerned. However, it should be said that applying the framework does require a more detailed quantitative approach than is provided here. Without such a real-life test its usefulness can ultimately not be judged. Further work needs to be done to compile relevant data and information and test the framework on that basis at regional or country level.

Comparison of biofuel options

If a given area of land is used to produce transport biofuels, the net greenhouse gas reduction would be much less than if that same area of land was used to grow biomass for energy generation such as CHP. This is because the production of transport biofuels involves energy-expensive processing to produce a high-specification product, and because most biofuel crops require high levels of nitrogen fertiliser, which is very energy-expensive to produce. Biomass crops for energy generation on the other hand do not need as much fertiliser, nor do they do not need much processing. It is a considerably more efficient production chain: after harvesting, the raw materials can be burned, or put through thermochemical conversion (charcoal-making) process. However, renewable options in the transport sector alone are limited. The many benefits of CHP do not address the very large – and rising – greenhouse gas output of this sector, and therein lies the justification for developing biofuels for transport.

There is a land-use trade-off between crops for transport biofuel manufacture, and crops for energy generation. The Biofuels Directive recognises this cross-sectoral trade-off: if a country sets targets for transportation biofuels that are lower than the indicative levels of 2% by 2005 and 5.75% by 2010, it can justify the shortfall by showing its progress in developing biomass for energy generation. Both biofuel options require significant public support for large-scale production and use although the necessary price subsidisation of CHP energy compared to fossil fuel alternatives appears to be smaller than in the case of biodiesel (FAME).

The potential impact of short rotation coppice (mainly used for CHP at present) on agricultural landscapes and habitats appears more favourable than that of rapeseed production. This is due to the increase in landscape diversity and breeding habitats that such plantations provide in comparison to oilseed rape, which is already a widely grown crop. However, introduction of the latter in cereal-dominated crop rotations could also provide benefits for seed-eating birds (Anderson *et al*., 2003).

The overall effect of biofuel crops on farmland habitats and diversity depends on the present intensity of agricultural land use and cropping patterns as well as the specific characteristics of the individual crops for biomass production. These aspects are of particular interest to the EEA in the further development of environmental assessment frameworks for biofuel production.

Acronym Glossary

BAT:	Best available technology. Defined in the IPCC Directive as best available techniques, which is a broader definition including management practices
BATNEEC:	Best available technology not entailing excessive costs
CHP:	Combined heat and power
DPSIR cycle:	The causal cycle of driving forces, pressures, states, impacts, responses
GHG:	Greenhouse gas
IEA:	Integrated environmental assessment. Working definition of IEA used at the EEA: '*The interdisciplinary process of identification, analysis and appraisal of all the relevant natural and human processes and their interactions which determine both the current and future state of environmental quality, and resources, on appropriate spatial and temporal scales, thus facilitating the framing and implementation of policies and strategies*' (Thomas, 1995).
IPCC:	Intergovernmental panel on climate change
LCA:	Life cycle assessment/analysis
LCI:	Life cycle inventory
LCM:	Life cycle management
FAME:	Fatty acid methyl ether
SRC:	Short rotation coppicing

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