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SPECIAL ISSUE

Biofuels

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Biofuels – the way forward?

Interest in biofuels is growing and the proposed EU target to increase the amount of biofuels used in transportation to 10 per cent is likely to drive further research and development in this field.

This thematic issue reports recent advances in biofuel research, focusing on research into the environmental and land use impacts of increases in biofuel crop production.

Biofuel crops vary considerably in their environmental impact and while they may offer advantages in terms of CO_2 emissions compared with fossil fuels, their wider environmental costs may be greater. Research exploring the potential of first generation crops, such as rapeseed, suggest that the benefits in terms of CO_2 emissions, energy dependency and urban pollution may be small compared with the impact on land and soil (see 'Negative impact of biodiesel greater than gains?').

Staple food crops which are also grown as biofuels, such as maize, present concerns about whether land should be used to grow food or fuel. Research reported here suggests that if growing biofuel crops causes new land to be converted for agricultural production, for example to meet food needs, then it may be associated with significantly more CO_2 emissions than previously thought (see 'Emissions 'payback' time too long for biofuel crops').

Perennial crops have fewer environmental impacts than first generation crops. Lower fertiliser input and less intensive farming practices mean these crops are associated with greater reductions in CO_2 emissions. If managed carefully, some perennial crops could have a positive effect on environmental quality and biodiversity, compared with intensively farmed agricultural land (see 'Bioenergy crops: balancing environmental impacts').

Biodiesel has been widely touted as a means of reducing urban air pollution. However, research reported in this issue highlights the need for stringent fuel production standards (see 'Biodiesel: how much pollution does it really product?').

Although already a viable renewable energy source, current biofuel technologies are not always as 'green' as they appear and policy makers need to think carefully about the impact of biofuel policies on agriculture, landscape and carbon emissions.

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How environmentally friendly are biofuels?

Biofuels could help reduce greenhouse gas emissions and dependency on fossil fuels. However, a new study which looked at the full life-cycle shows that, depending on the type and source of biofuel, the benefits and environmental impacts can vary considerably. The results highlight differences that could help inform policymakers considering tax-breaks for renewable fuels.

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"Governments must be selective about which biofuel crops they choose to support through subsidies, and tax breaks must promote the best production path."

Biofuels are currently the most important form of renewable energy in road transportation, but the debate over their environmental impact is ongoing. Some argue that when cultivation, including deforestation and soil acidification, is taken into account, biofuels consume more energy than they produce.

The researchers from the Swiss Federal Institute for Materials Science and Technology have provided, for the first time, a complete picture of the environmental costs and benefits of 26 different biofuels, which could help resolve this debate.

The study analysed the full life-cycle of each of the 26 fuels, from crop cultivation, to waste substance and consumption as fuel. It provides a detailed comparison of the environmental impacts of petrol, diesel and natural gas with different biofuels from a wide variety of crops.

The damaging effects of each biofuel were calculated using two different criteria: greenhouse-gas emissions relative to gasoline, and overall environmental impact (including natural resource depletion, damage to human health and ecosystems). The authors found that most (21 out of 26) biofuels reduce greenhouse emissions by 30 per cent compared with fossil fuels. However, nearly half of the biofuels have greater environmental costs than petrol.

The fuels which showed the greatest reductions in greenhouse gases (over 50 per cent) when compared with fossil fuels were biodiesel made from waste cooking oil and methanol and methane derived from wood. These fuels, plus bioethanol made from whey, also performed very well when taking into account their full environmental impact.

The least environmentally friendly biofuels were biodiesel made from Brazilian soy, and bioethanol made from potatoes, rye and soy. These all had low reductions in greenhouse gas emissions and high negative environmental impact.

The authors write that Governments must be selective about which biofuel crops they choose to support through subsidies, and tax breaks must promote the best production paths.

Source: R Zah, H Boni, M Gauch *et al.* (2007). Empa report. Life cycle assessment of energy products: environmental assessment of biofuels. Executive summary available from: http://www.bfe.admin.ch/themen/00490/00496/index.html?lang=de&dossier_id=01273.

Additional sources: Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen (in German) can be downloaded from http://www.news-service.admin.ch/NSBSubscriber/message/attachments/8514.pdf.

Additional information: Biodiesel made from specially selected waste vegetable oil fuelled a quarter of buses in Valencia, Spain, under the project ECOBUS. ECOBUS is co-financed by the European Union under its LIFE programme. For more information see www.ecobus.net

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Environmental protection needed as Europe increases bioenergy crops

According to a new report, Europe has the space to increase the amount of crops grown as bioenergy sources. However, managing the increase in land used to grow crops for bioenergy requires measures and safeguards to protect environmental quality. Such measures should not only directly tackle the growth of biomass crops, but also wider farming practices.

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"The report warns that action needs to be taken to protect biodiversity, waters and soils."

Increasing demand for biofuels raises concerns about additional pressure on Europe's environment and farmland biodiversity. The European Environment Agency has released a new report that explores the environmental impact of increases in the production of biomass for use in energy production. The report warns that action needs to be taken to protect biodiversity, waters and soils. It concludes that action is needed in five key areas:

- At least 30 per cent of agricultural land area should be devoted to 'environmentally oriented' farming. A large number of Member States are already on track to achieve the minimum share by combining organic farming and high nature value farmland (farmland rich in biodiversity), particularly in Southern and Eastern Europe.
- At least 3 per cent of intensively cultivated land should be set aside as ecological compensation areas. This measure could halt the loss of bird populations by providing non-cropped habitats and maintain links between zones covered by European ecological networks such as Natura 2000.
- Certain types of farming, such as permanent grassland, dehesas and traditional olive groves, should not be converted to arable energy crops.
- Crops and crop mixes should be chosen for optimum environmental benefits. In future, the EEA report sees a higher share of biomass coming from perennial sources, including grassland and short rotation coppice such as willow, and specialised cropping systems such as double cropping, whereby the same or similar crop is produced twice in the same year.
- Improvements are required in the technology used to convert biomass to energy. This will be driven by short term targets for biofuels for use in the transport sector and the development of gasification and second generation biofuel technologies, such as fermentation using 'cellulosic' biomass, which will shift demand away from annual arable crops, such as oil crops, to perennial crops.

The report highlights some general approaches that are needed to minimise the impact of biomass production on Europe's environment. These include recommendations that biomass crops should not require irrigation or intensive use of pesticides or fertilisers. Crops should also be planted to increase farmland diversity and avoid monoculture. Specific policy mechanisms that could be used to encourage environmentally sound farming practices are also reviewed in the report.

Source: EEA Technical report No 12/2007. Report available from: http://reports.eea.europa.eu/technical_report_2007_12/en

Bioenergy crops: balancing the environmental impacts

Environmental issues, such as the availability of land to grow the crops, their impact on the appearance of the landscape and soil and water supplies, must be considered before they are grown on a large scale. A new study has concluded that, with the right planning measures, their use could provide a number of environmental benefits.

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"Short rotation coppice (SRC) crops for biofuels, such as willow and poplar, have the potential to increase biodiversity, although they are less beneficial to ecosystems than natural woodland or grassland."

While biofuels reduce our reliance on fossil fuels and some biofuel crops can be carbon neutral (i.e. they absorb as much CO_2 during growth as is generated during processing and use), the environmental impacts of biofuels are still debated.

In an attempt to draw together available data on the environmental impacts of biofuel crops, researchers have compared the available scientific evidence and devised a set of recommendations on the growth of bioenergy crops in the UK. The study focused on 'second generation' bioenergy crops, which are crops grown exclusively as biofuels, such as *Miscanthus*, a bulky variety of grass, and short rotation coppice (SRC), which includes trees such as willow and poplar. These were compared with traditional 'first generation' biofuel crops, such as wheat and oilseed rape, which compete with food crops for agricultural land.

Land already set aside for energy production in the UK will not be sufficient for crops to contribute significantly to meeting the UK's targets for renewable energy production and more arable land will need to be converted for biofuel crops. Since *Miscanthus* grass grows up to 6 metres tall, its visual impact will need to be considered when planning the scale and location of plantations.

Water demand from many biofuel crops is also higher than traditional crops, so plantations would need to be kept away from vulnerable habitats such as wetlands. However, crops such as willow will grow on land which is too wet for other types of agriculture.

The review highlighted many potential benefits of second generation crops. Woody SRC crops have deep roots and there is less need to dig or plough soil, so these crops, should reduce nitrate leakage into water supplies – a common problem for agricultural land treated with nitrogen-based fertiliser. They were also shown to improve soil quality, increase the amount of carbon sequestered in the soil, and reduce soil erosion.

SRC crops also have the potential to increase biodiversity, although they are less beneficial to ecosystems than natural habitats such as woodlands and natural grassland and intense management of such crops can interfere with wildlife. However, measures such as carefully planned planting density and location, and the introduction of crop types that are preferred by nesting birds, could help to maximise the benefits and provide greater biodiversity than is found on traditional arable land.

Source: R.L. Rowe, N Street, G Taylor (2007). Identifying potential environmental impacts of large-scale deployment of dedicated bioenergy crops in the UK. *Renewable and Sustainable Energy Reviews.* DOI: 10.1016/j.rser.2007.07.008

Negative impact of biodiesel greater than gains?

A new study suggests that it may not be worth investing in biodiesel. Using Italy as a case-study, the author argues that in terms of cutting CO_2 emissions, energy dependency and urban pollution, the gains would be small, and the impacts on the land and soil would be of concern. First generation crops, such as wheat and rye, have particularly high environmental impacts.

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"As there is little abandoned and set-aside land in Italy, the consequence of large-scale oil seed production would be a large increase in imports of biodiesel (or of food, if the energy crops were grown in Italy)."

High prices for crude oil and Europe's drive to increase its energy self-sufficiency are pushing the case for biofuels. The latest European Commission proposal for a Directive on the use of renewable energy, announced in January 2008, set the target for sustainable biofuel use in transport at 10 per cent by 2020[1]. The stringent targets set by the Kyoto Protocol strengthen the case for alternative forms of energy, and biofuels are thought to reduce greenhouse-gas emissions, though this has been questioned recently when the full life-cycle is considered (see the 'Emissions 'payback' time too long for biofuel crops' article, also in this issue).

Research from the Universitat Autònoma de Barcelona highlights the impact on agriculture of meeting the EU biofuel targets using first generation crops, such as oilseed rape. Taking Italy as a case study, the research showed that about one third of current agricultural land would be needed to meet the 5.75 per cent target set by the European Directive in 2003[2]. As there is little abandoned and set-aside land in Italy, the consequence of large-scale oil seed production would be a large increase in imports of biodiesel (or of food, if the energy crops were grown in Italy). This could also transfer the environmental impacts of European biodiesel demands to tropical countries, were most of the production would likely be located.

The research also suggests that cultivating large areas of land with first generation biofuel crops would have negative environmental impacts. Oilseed rape, for example, is typically cultivated using intensive agricultural practices, which would increase the use of fertilisers and pesticides.

The author also recommends other means of curbing urban pollution, such as adopting policies that favour the use of other readily-available, less polluting fuels, for example Compressed Natural Gas. In relation to the introduction of second generation crops, such as grasses used to produce ethanol, government policies must ensure that the required raw materials are produced with high environmental standards. Similarly, there may be a case for niche products, such as recycling used cooking oil for the production of biodiesel, but these approaches are unlikely to have a large-scale impact on biofuel production.

The author points out that although she has taken Italy as a case study, the conclusions can be generalised to other densely populated European countries. She stresses that the role of policy-makers is crucial, since the amount of biodiesel to be produced is a political decision.

[1] See http://www.ec.europa.eu/energy/climate_actions/index_en.htm for more details.

[2] See http://europa.eu/scadplus/leg/en/lvb/l21061.htm for more details.

Source: Russi, D (2008). An integrated assessment of a large-scale biodiesel production in Italy: Killing several birds with one stone? *Energy Policy*. 36 (3): 1169-1180.

Emissions 'payback' time too long for biofuel crops

Most lifecycle studies suggest that replacing fossil fuels with biofuels can substantially reduce greenhouse gas (GHG) emissions if sugarcane or cellulose are used as a fuel source, but these studies don't adequately account for the effect of land use change. New research has taken account of the carbon emissions that occur when farmers world wide respond to higher crop prices by converting forest and grassland to new cropland.

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"For bioethanol derived from maize, the researchers calculated that it would take 167 years to offset these GHG emissions."

Growing biofuel crops removes CO_2 from the atmosphere which means that in theory biofuels can reduce GHG emissions relative to fossil fuels. However, most previous studies have focused on the benefits in terms of carbon uptake associated with biofuels without considering the effects of land use change on the carbon equation.

Researchers explored the consequences of increasing US production of bioethanol from maize by 56 billion litres, taking into account the likely effects of land use change. Increasing use of maize for bioethanol production would increase global prices for maize and could encourage farmers world wide to convert previously natural land (forest or grassland) to arable crop production. This conversion is associated with both short-term and long-term carbon emissions. Short term emissions arise from loss of carbon in soils and from the plants removed from the land, while deep ploughing is becoming a major concern. Long term emissions continue when growing forest land is converted to agricultural production because the forest no longer sequesters carbon. In this case, the loss of carbon sequestration is counted as an 'emission' because it contributes to increases in atmospheric CO_2.

The study found that the average GHG emissions are 351 MT per converted hectare. For bioethanol derived from maize, the researchers calculated that it would take 167 years to offset these GHG emissions. Essentially, that means greenhouse gasses would effectively increase for 167 years. Although focused on ethanol produced from maize, which is not particularly efficient in terms of energy yield, the analysis has implications for other biofuel crops. For example, if US maize fields were converted to switchgrass, a perennial biomass crop, there would still be a world wide need to replace the lost maize because there is an overall demand for food and animal feed. The authors estimate that it would take 52 years to offset GHG emissions from the resulting land use change.

Brazilian sugarcane offers the best alternative. It leads to the greatest reductions in GHG excluding those associated with land use change (approximately 86 per cent compared with 20 per cent for maize). If only tropical grazing land were converted to sugarcane the upfront carbon emissions could be recouped in just 4 years. However, if displaced farmers converted rainforest into grazing land it could take 45 years for the carbon emissions to be recouped.

Source: T Searchinger, R Heimlich, RA Houghton *et al.* (2008). Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change. *Science.* Doi 10.1126/science.ll51861.

Additional information: The Clean Environment Management Centre at the University of Teeside, UK is working on the conversion of 'brownfield' sites into agricultural land for growing biofuel crops. The work is supported by the European Union under its LIFE programme. For further information, see **http://www.tees.ac.uk/clemance/**

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Biodiesel: how much pollution does it really produce?

Biodiesel, made from partially renewable sources of oil such as soy, rapeseed or waste cooking oil, has been heralded as an environmentally-friendly alternative to petroleum-derived diesel. However, new research has shown that the quality of the biodiesel used as fuel has a significant impact on emissions. The researchers call for more stringent testing of biofuels and stress the importance of using good quality fuel.

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"The introduction of new biofuels will not necessarily translate into air quality benefits while fuel standards remain poor and compliance to fuel quality standards is not strictly enforced."

Petroleum diesel engines are heavily polluting. They emit nitrogen oxides and particulate matter that are harmful to human health. There are serious concerns especially over children exposed to exhaust pollutants. Previous studies of engines fuelled by biodiesel, on the other hand, suggest biodiesel is less polluting than petroleum-derived diesel. It produces less carbon monoxide, hydrocarbons and particulate matter. Furthermore, biodiesel can be used in diesel engines without any engine modification.

Studies that show an advantage for biofuels, however, do not simulate real driving conditions. The tests are generally performed in the controlled environments of laboratories, run on single engines with high quality fuel and in unrealistic conditions.

The researchers monitored 200 school buses in the winter of 2004. They measured both gas and particulate matter emissions close to where the school bus depot was located. During the first phase of the experiment conducted in January, the buses ran on petroleum diesel. The emissions were measured again in March when the vehicles switched to a 20 per cent biodiesel blend.

The real-world conditions yielded unexpected results. After the switch from petroleum to biodiesel, bus exhaust particulate emissions jumped by a factor of 1.8. Carbon monoxide and hydrocarbon emissions from the vehicles were also higher.

However, the authors point out that the buses were running on poor quality biofuel which did not comply with official US standards. They found high concentrations of free glycerine in the fuel, a sign of poor quality arising from improper production procedures.

These findings stress the importance of stringent quality testing in biofuel production. Additionally, the introduction of new biofuels will not necessarily translate into air quality benefits while fuel standards remain poor and compliance to fuel quality standards is not strictly enforced.

Source: C Mazzoleni, HD Kuhns. H Moosmülleret *et al.* (2007). A case study of real-world tailpipe emissions for school buses using a 20% biodiesel blend. *Science of the Total Environment*. 385 (1-3): 146-159.

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A selection of recent articles on Biofuels from the *Science for Environment Policy* News Alert

Perennial grass crops – a carbon neutral biofuel? (21/2/08)

Perennial crops, such as grasses, are attracting increasing interest as potential biofuel crops. Perennial crops have significant advantages over many annual crops because they require less energy input during growth than annual crops which not only need to be planted each year, but typically require more fertiliser, herbicide and pesticide input. Research on farm-scale cultivation of the perennial grass, switchgrass (*Panicum virgatum* L.), has shown that it can produce five times more energy per hectare than is needed to grow, harvest and process it into ethanol.

Biofuels: Bad news for water quality? (17/1/08)

Demand for ethanol-based biofuels in the US has led to a boom in corn crops which could have detrimental effects on water quality and supply, warns a new report by the US National Research Council (NRC).

Wood smoke major source of pollution in winter (17/1/08)

Over half of organic air pollution in Europe during winter comes not from fossil fuel burning, but from home fires, and burning of agricultural and garden waste products, according to new results published by the EU-funded CARBOSOL project. Restricting these sources of human-made emissions could cut pollution significantly, with immediate benefits to public health and a positive impact on climate change.

Is a full Transition to Biofuels possible in the Transport Sector? (13/12/07)

Swedish researchers have analysed the potential for a full transition to domestically produced biofuels in the transport sector in Stockholm by 2030. Considering the particular case of Sweden, the results demonstrate the importance of making studies of energy efficiency potentials in all energy sectors before making an assessment of distributions of bioenergy between sectors. Furthermore, this study highlights the importance of considering both demand and supply-side policies in order to reduce energy use in the transport sector.

Human Activities significantly decrease the Earth's Biological Productivity (31/10/07)

How much of the biosphere's productivity can we appropriate before planetary systems begin to break down? Austrian researchers have recently quantified and mapped the impacts of human land use and biomass harvest on the biosphere. The results suggest that humans consume approximately 24% of the organic matter contained in vegetation globally. This amount reduces energy available to other species, having a marked impact on biodiversity, flows of carbon, water and energy. Croplands and pastures now rival forests as the largest ecosystems on the planet, occupying 35 % of the ice-free land surface.

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