Renewable Fuels Agency

# The Gallagher Review of the indirect effects of biofuels production

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July 2008

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# Foreword by Ed Gallagher

UK Government policy on biofuels has always been based on making their production and use sustainable. The Renewable Transport Fuel Obligation, which the recently formed Renewable Fuels Agency administers, has at its heart a series of sustainability measures to achieve this goal.

However, recent research and rising food prices have highlighted the possible effects of other factors which are not monitored by the current mechanisms. These indirect effects, where displaced agricultural production causes land-use change, impact on both the greenhouse gas lifecycle emissions of biofuels and biodiversity.

The Secretary of State for Transport commissioned this review to investigate those effects. In the body of the review is an impressive list of those who have contributed to it in what, for a study of this kind, is a very short timescale. I gratefully acknowledge the value of all these contributions, which have come from every sector and viewpoint, and in particular the hard work and professionalism of the core Renewable Fuels Agency team of Greg Archer and Aaron Berry.

Our conclusions are set out in this document. Broadly, they are that at this stage more caution and discrimination are needed. With little sign of the developed countries losing their appetite for travel and millions of new motorists expected in rapidly developing countries such as India, China, Russia and elsewhere, better fuels are needed, along with other well documented measures. We cannot afford to abandon biofuels as part of a low carbon transport future.

Equally, we cannot continue producing biofuels which are ultimately more environmentally and socially damaging than the fossil fuels they seek to replace. However, we hope that those who care for the planet, but recognise that hard choices have to be made, and those who seek to build responsible renewable energy businesses in the twenty first century, will find this review helpful.

For its part, the Renewable Fuels Agency will continue to contribute to the developing debate about biofuels. In the short term, we will seek to rebuild the working consensus between Government, environmentalists and industry to lay out clear directions for the feedstocks, the production processes and the land usage that will enable alternative fuel production to proceed in a truly sustainable way.

**Ed Gallagher**
**Chair – The Renewable Fuels Agency**
**July 2008**

# Executive summary

Biofuels have been proposed as a solution to several pressing global concerns: energy security, climate change and rural development. This has led to generous subsidies in order to stimulate supply. In 2003, against a backdrop of grain mountains and payments to farmers for set-aside land, the European Union agreed the Biofuels Directive. Under this directive, member states agreed to set indicative targets for biofuels use and promote their uptake. Many environmental groups hailed a new revolution in green motoring.

Five years later, there is growing concern about the role of biofuels in rising food prices, accelerating deforestation and doubts about the climate benefits. This has led to serious questions about their sustainability and extensive campaigns against higher targets.

Concern was further raised among policy makers when the paper by Searchinger[1] asserted that US biofuels production on agricultural land displaced existing agricultural production, causing land-use change leading to increased net greenhouse gas (GHG) emissions.

## A slowdown in the growth of biofuels is needed

This review, by the independent UK Renewable Fuels Agency has been prepared for the UK Government in response to these concerns. The aim has been to examine the scale of the indirect effects of current biofuels production, and to propose solutions. The review has examined the sometimes inconsistent and limited evidence base. We have sought the views of leading experts in the field.

We have concluded that there is a future for a sustainable biofuels industry but that feedstock production *must* avoid agricultural land that would otherwise be used for food production. This is because the displacement of existing agricultural production, due to biofuel demand, is accelerating land-use change and, if left unchecked, will reduce biodiversity and may even cause greenhouse gas emissions rather than savings. The introduction of biofuels should be significantly slowed until adequate controls to address displacement effects are implemented and are demonstrated to be effective. A slowdown will also reduce the impact of biofuels on food commodity prices, notably oil seeds, which have a detrimental effect upon the poorest people.

## There is probably sufficient land for food, feed and biofuels

The review has examined both the likely levels of future demand for agricultural land and how much land might be available. There remains much uncertainty. At present, feedstock for biofuel occupies just 1% of cropland but the rising world population, changing diets and demand for biofuels are estimated to increase demand for cropland by between 17% and 44% by 2020. However, the balance of evidence indicates there will be sufficient appropriate land available to 2020 to meet this demand. Better datasets for land use will become available later in 2008 and should help further to inform this question. The review has not examined the situation beyond 2020 when current trends are anticipated to continue and climate change will affect land productivity. The long-term potential of bioenergy using land suited for agricultural production therefore requires further consideration.

1 Searchinger et al 2008

## Biofuels production must target idle and marginal land and use of wastes and residues

Although sufficient suitable land is probably available, current policies do not ensure that additional production occurs in these areas. Policies must therefore be focused upon ensuring that agricultural expansion to produce biofuel feedstock is directed towards suitable idle or marginal land or utilises appropriate wastes, residues or other non-crop feedstock. Although there are high levels of uncertainty in the data, the science and in the modelling of the indirect effects of biofuels, the balance of evidence shows a significant risk that current policies will lead to net greenhouse gas emissions and loss of biodiversity through habitat destruction. This includes effects arising from the conversion of grassland for cropland.

## Specific incentives must stimulate advanced technology

Advanced technologies have the potential to produce biofuels with higher greenhouse gas savings and have the benefit of being able to use a wider range of feedstocks. However, as with current technologies it is essential that feedstock production avoids the use of land that would otherwise be used for food production. Some feedstocks for advanced technologies require more land than current biofuel feedstocks, and consequently have the potential to induce more indirect land-use change. This is because current technologies use feedstocks that also result in the production of co-products that avoid land use (such as protein substitutes in animal feed that replace the need for soy cultivation). Advanced technologies are currently immature, expensive and will require specific incentives to accelerate their market penetration.

This review has proposed a specific EU-wide obligation to encourage these technologies to commence in 2015 rising to 1-2% by energy in 2020. Biofuels supplied to comply with this obligation would need to deliver high GHG savings from appropriate wastes, residues, crops grown on marginal land, or feedstock, such as algae, that do not require agricultural land.

## Biofuels contribute to rising food prices that adversely affect the poorest

The review has also found that increasing demand for biofuels contributes to rising prices for some commodities, notably for oil seeds, but that the scale of their effects is complex and uncertain to model. In the longer term higher prices will have a net small but detrimental effect on the poor that may be significant in specific locations. Shorter-term effects on the poor are likely to be significantly greater and require interventions by governments to alleviate effects upon the most vulnerable. There is some potential for the poor to benefit from biofuel production in some areas where land is available and the necessary infrastructural investment is forthcoming. Lower targets and shifting production for biofuels away from agricultural land used for food production should reduce price rises on affected food commodities.

## A genuinely sustainable industry is possible

This review concludes that it should be possible to establish a genuinely sustainable industry provided that robust, comprehensive and mandatory sustainability standards are developed and implemented. It further concludes that the risks of indirect effects can be significantly reduced by ensuring that the production of feedstock for biofuels takes place on idle and marginal land and by encouraging technologies that utilise appropriate wastes and residues. A framework for such policies is proposed, but significant challenges remain in the detailed design, implementation and enforcement. These challenges are complex and will take time to overcome.

The evidence gathered in this review does not provide assurance of the sustainability of any particular level of target and the creation of a sustainable biofuels industry cannot be assured. The RFA judgement, based upon the balance of evidence is that if all subsidies and other support for biofuels were removed entirely, this would reduce the capacity of the industry to respond to the challenges of transforming its supply chain and investing in advanced technologies. However, the rate of introduction of biofuels should be slowed until adequate controls are established.

## Lower targets and stronger controls are needed

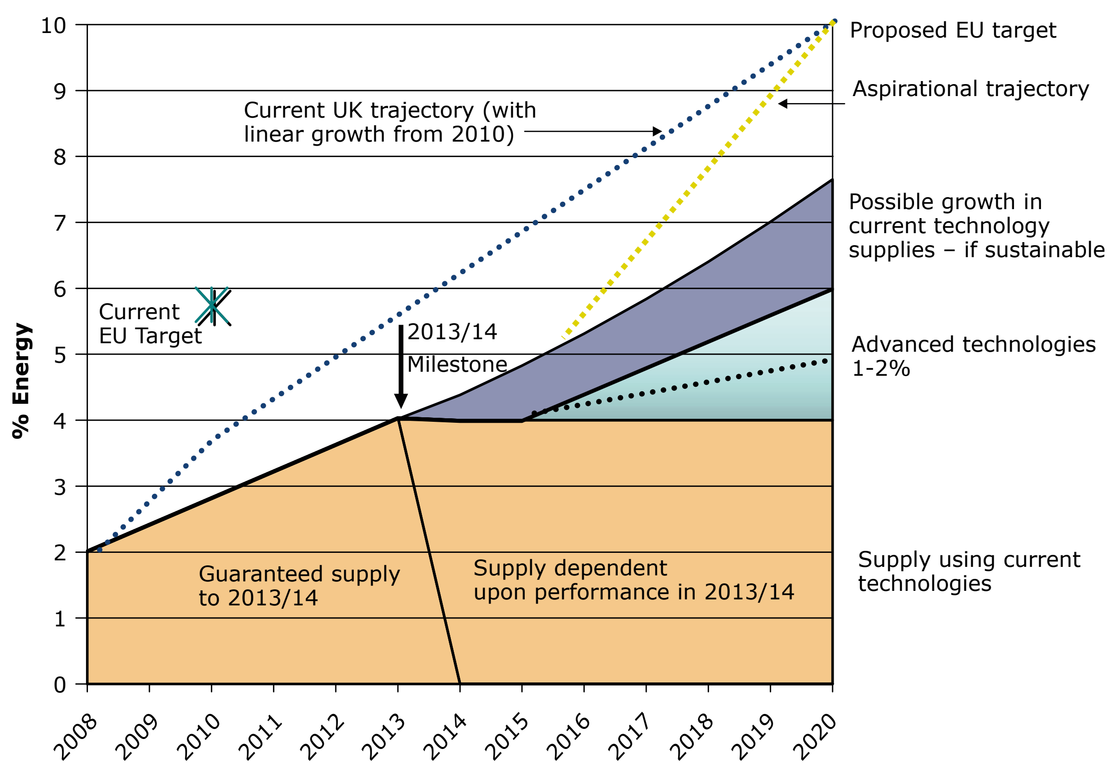
The RFA proposes that the current RTFO target for 2008/09 (2.5% by volume) should be retained, but the proposed rate of increase in biofuels be reduced to 0.5% (by volume) per annum rising to a maximum of 5% by volume by 2013/14. This compares with the RTFO's current target trajectory of 5% by 2010. We recommend that the RTFO is further reviewed in 2011/12 to complement and coincide with the 2011/12 EU review of member states' progress on biofuels targets. During the period to 2011/12, comprehensive, mandatory sustainability criteria within the EU Renewable Energy Directive should be implemented for biofuels and bio-energy, including requiring feedstock that avoids indirect land-use change.

Targets higher than 5% by volume (4% by energy) should only be implemented beyond 2013/14 if biofuels are shown to be demonstrably sustainable (including avoiding indirect land-use change). This milestone should be applied both at EU and UK level. If the industry fails to deliver demonstrably sustainable biofuels by 2013/14 the level of the target could also be reduced for subsequent years. A portion of growth beyond 2020 would arise from the proposed new obligation for feedstock to be used by advanced technologies. This would be implemented in 2015/16 and rise to 1-2% by 2020.

A sustainable level of target for the EU in 2020 will depend upon the availability of appropriate land and the success (or otherwise) of ensuring that only demonstrably sustainable feedstock is used. The penetration of biofuels utilising advanced technologies will also be important. Current evidence suggests that the proposed EU biofuels target for 2020 of 10% by energy is unlikely to be met sustainably and the introduction of biofuels should therefore be slowed while we improve our understanding of indirect land-use change and effective systems are implemented to manage risks. The immediate focus for policy should be on implementing the necessary controls and conditions that will enable the industry to develop sustainably.

Based on our judgement, we therefore propose targets for renewable transport fuels of between 5% and 8% (by energy) for the EU for 2020 (including 1-2% from advanced technologies). In the event that sufficient controls are enforced globally *and* new evidence provides further confidence, a higher aspirational trajectory starting in 2016 and rising to 10% by energy in 2020 could be possible. These targets and trajectories are illustrated graphically in the figure below. The proposed EU Fuel Quality Directive should not imply a higher level of biofuels, or faster rate of introduction, than that indicated by this review.

**Proposed trajectory of EU policy**




We recommend the replacement of volume or energy based targets with comparable greenhouse gas saving targets as soon as practicable to incentivise the supply of fuels with a lower carbon intensity. However, current greenhouse gas lifecycle analysis fails to take account of either indirect land change or avoided land use from co-products. Failing to include these factors may create perverse incentives which lead to higher greenhouse gas emissions by encouraging feedstocks that lead to higher net land use. These factors need to be better understood before the basis on which targets are calculated is changed.

## Stronger, enforced global policies are needed to prevent deforestation

Lower targets for biofuels, with slower increases in penetration and shifting production to idle and marginal land will reduce pressure for land change and reduce the pressure on food price increases. But biofuels are only part of the problem causing damaging land-use change and the measures that we propose here can therefore only form part of the solution. Stronger policies are needed to slow rates of deforestation particularly in South America, Africa and parts of South East Asia. This must form part of the next global climate agreement. Sustainability standards should also be extended beyond biofuels to all agricultural production. Finally, investment in agriculture and short-term assistance to the vulnerable is essential if the current food crisis is to be alleviated.

# Summary of conclusions and recommendations

1. **Biofuels can only contribute GHG savings from transport if significant emissions from land-use change are avoided and appropriate production technologies are employed.**
   - The Government should amend but not abandon its biofuel policy in recognition of the indirect effects to ensure its biofuels policy delivers net GHG benefits. Specifically:
   - At EU-level, targets within the Renewable Energy Directive and Fuel Quality Directive should recognise the need to avoid both direct and indirect land-use change that leads to significant loss of carbon stocks;
   - Biofuels support mechanisms should exclude feedstock grown on land where carbon losses arising from its cultivation lead to a payback of longer than 10 years by the biofuel produced
     - This could be achieved by conducting site specific assessments of anticipated payback times. These should be performed before any idle land that is permanent pasture is converted for biofuel production;
   - Biofuels support mechanisms should specifically exclude feedstock grown on land designated as of high conservation value;
   - Further work should be conducted concerning:
     - Indirect effects of EU policy;
     - Carbon losses associated with land change, especially for pastures;
     - The net benefits of growing biofuel feedstock on idle land;
     - The nitrogen cycle.
2. **Demand for food, animal feed and bioenergy is rising and creating additional pressure on land. Estimates of future demand and the amount and suitability of land potentially available are highly uncertain. The balance of evidence indicates there is sufficient land available to satisfy demand to 2020, but this needs to be confirmed before global supply of bioenergy increases significantly. Current policies do not ensure that additional production moves exclusively to suitable areas. Attempts to direct agricultural expansion to particular areas face significant implementation and enforcement challenges.**
   - Biofuels policies need to require the utilisation of feedstock that does not cause a net additional pressure on current agricultural land. This includes use of appropriately defined idle agricultural land, marginal lands, wastes and residues and intensification of current production.
   - Further work is needed to develop definitions for idle and marginal lands. Assessment tools must also be developed and procedures implemented to confirm the suitability of specific locations before any land change occurs. This should take into account:
     - The land's existing use;
     - The land's productive potential;
     - The net carbon impact of using the land for biofuels;

  - The land's existing environmental value; and
  - Social implications of its use for biofuels.
- Only a proportion of available idle land should be used for bioenergy production to manage the risk of indirect land-use change;
- The EU should reassess the amount of appropriate 'idle' land available within the EU to 2020, taking into account forecasts on increased demand for food and animal feed.

3. **Advanced technologies have significant potential, but may only produce biofuels with higher GHG savings if feedstock production avoids use of existing agricultural land that leads to indirect land-use change. This can be achieved using feedstock grown on marginal land or that does not use land, such as wastes and residues (although this may compete with other uses of these materials). Advanced technologies are immature, currently expensive and require specific incentives to achieve significant market penetration before 2020.**

- There should be a specific obligation on transport fuel suppliers to supply biofuels achieving a high level of GHG saving (possibly greater than 75%) from:
  - Appropriate wastes and residues;
  - Feedstock grown on marginal land; and
  - Other technologies and feedstocks that avoid indirect land change (for example algae).
- The EU needs to determine how increasing targets for heat, power and renewable transport fuels compete for wastes and residues and how this competition should be managed;
- Further work should be undertaken to assess how a specific obligation, and constraints on feedstock, will affect the development of the market for advanced biofuels. This should be used to refine a target range for 2020;
- Current evidence indicates an achievable target range for 2020 to be of the order of 1-2% by energy of road transport fuels;
- The European Commission should propose a technology-neutral approach within the EU Renewable Energy Directive to incentives for advanced technologies, focusing on feedstock type and type of land on which it has been produced.

4. **Current lifecycle analyses of GHG-effects fail to take account of indirect land-use change and avoided land use from co-products. As a consequence:**

- **GHG-based targets may result in a greater land requirement, and land-use change, than a volume or energy-based target; and**
- **Second generation biofuels using feedstock grown on existing agricultural land may cause greater net land-use change than first generation biofuels that also produce co-products that avoid land use.**

**Quantification of GHG emissions from indirect land-use change requires subjective assumptions and contains considerable uncertainty. The role of co-products in avoiding land-use change requires further examination.**

- Basing incentives and targets for biofuels on their GHG savings remains the optimum policy approach but should only proceed once the implications of indirect effects and avoided land use from co-products have been fully explored and adequately incorporated into calculation methodologies.

- Urgent further work is needed to enable incentives and targets for biofuels to be based upon lifecycle greenhouse gas emissions that include:
  - Indirect land-use change;
  - Avoided land use from co-products;
  - Effects of competition for limited wastes and residues; and
  - Potential additional carbon sequestration from utilising marginal land.
- The European Commission should specifically consider the findings with respect to avoided land use from co-products as part of the on-going design of the Fuel Quality Directive and the mandatory threshold for GHG savings proposed in the Renewable Energy Directive.

5. **Lower targets for biofuels and shifting production to idle and marginal land will reduce pressure for land-use change. Stronger policies are needed to slow rates of deforestation particularly in South America, Africa and parts of South-East Asia.**
   - Mechanisms for crediting foregone land-use change need to be incorporated into the next global climate agreement to discourage countries from deforesting areas of land;
   - Carbon and sustainability certification used for biofuels should be extended to all agricultural activities over time;
   - Significant increases in the use of land for bioenergy, and biofuels specifically, should only be contemplated once effective controls are implemented at a global level. This is to avoid indirect land-use change causing significant GHG emissions or destruction of high value conservation areas; and
   - Sustainability standards should also be extended beyond biofuels to all agricultural production.
6. **Increasing demand for biofuels contributes to rising prices for some commodities, notably for oil seeds. In the longer term this has a net small but detrimental effect on the poor that may be significant in specific locations. Shorter-term effects are likely to be significantly greater. Lower biofuel targets and directing production onto idle land reduces these negative impacts. There is some potential for the poor to benefit from biofuel production in some areas where the land is available and where the necessary infrastructural investment is forthcoming. This might be accelerated by policy directing sustainable production on to suitable idle and marginal land.**
   - Biofuels targets and policies should be constructed to ensure long-term impacts on food prices do not significantly disadvantage the poor. For example, this could be achieved by focusing production away from existing agricultural land except where this is made possible by intensification;
   - International, short-term, targeted assistance should be provided to reduce the effects of the current spike in food commodity prices on the poorest;
   - Social criteria, including land rights, should be incorporated within biofuels sustainability requirements; and
   - Targeted support to develop biofuel feedstock production should be directed to Southern Africa, Latin America and parts of South-East Asia where the existence of underused arable land offers considerable potential for biofuels to realise economic benefits.

7. **Mechanisms do not yet exist to accurately measure, or to avoid, the effects of indirect land-use change from biofuels. Consequently, the net GHG emissions from current biofuel targets cannot be assessed with certainty, and there is a risk that any biofuel target could lead to a net increase in GHG emissions. The assessments underpinning the EU 2020 10% target and RTFO did not adequately address indirect land-use change. A framework to prevent biofuels causing land-use change has been proposed but is challenging and will take time to develop. The practical details, implementation and enforcement regime, need to be defined and will determine the overall effectiveness of the approach. In the meantime the rate of introduction of biofuels should be slowed.**

    - The current RTFO target for 2008/09 should be retained but the RTFO Order amended to require a lower rate of increase of 0.5% pa rising to a maximum of 5% by volume by 2013;
    - The C&S reporting should be revised to include idle and marginal land and increasing targets set for companies for the proportion of feedstock that demonstrably does not cause indirect land-use change. These targets should be made mandatory (along with other sustainability criteria) as soon as possible;
    - Mandatory sustainability criteria within the EU Renewable Energy Directive should be strengthened and consistently implemented for biofuels for transport and heat and power. This should include requirements for biofuel feedstock to avoid indirect land-use change;
    - To complement and coincide with the 2011/12 EU review of member states' progress on biofuels targets, it is recommended that progress on sustainability is reviewed in 2011/12;
    - Until biofuels are demonstrably sustainable, including addressing indirect land-use change, the European Commission should not allow Member States to supply more than 5.75% (by energy) of biofuels; and allow more cautious Member States to supply biofuels to 4% (by energy);
    - Progress to higher targets for current technologies should only be implemented beyond 2014 if biofuels are demonstrably sustainable, including avoiding indirect land-use change;
    - A second obligation to produce feedstock from appropriate wastes, residues and production on marginal land should commence in 2015. A target of 1-2% by 2020 is proposed but should be subject to further detailed consideration along with the buy-out price;
    - A lower EU 2020 target is proposed in recognition of the risk of indirect land-use change and absence of adequate control measures. A target range of 5-8% (including 1-2% from advanced technologies) is suggested with the higher target triggered only if milestones in 2013/14 are met. Higher targets, up to 10% (by energy) might be possible if sufficient controls are enforced globally on land-use change and new evidence provides further confidence that the effects upon food prices are manageable. An accelerated rate of biofuel introduction should not be introduced before around 2016;
    - Biofuel targets should not be mandates but obligations with an appropriate "buy-out" price set; and
    - The Fuel Quality Directive should not imply a higher level of biofuels than suggested for the Renewable Energy Directive.

**8. Large areas of uncertainty remain in the overall impacts and benefits of biofuels. International action is needed to improve data, models and controls to understand and to manage effects.**

- There should be an urgent meeting of international experts to consider the findings of the study along with other recently published research and take forward the suggestions for further work given here. This workshop should focus upon the areas of uncertainty highlighted by the review;
- The Government should seek to take forward, or encourage others to initiate, the further work indicated in the table in chapter 9.

# 1. Introduction

This review examines evidence of the indirect effects of increasing demand for biofuels and makes recommendations that provide a direction for policy to deliver sustainable biofuels into the UK and EU transport fuels market. The review has been undertaken by the Renewable Fuels Agency (RFA)[2] at the request of the UK Government.

The RFA is an independent non-departmental public body with the aim *to help the UK to achieve its renewable transport fuel targets sustainably by administering the Renewable Transport Fuel Obligation effectively and efficiently and by reporting to the Secretary of State on its effects*. The views expressed in this document are solely those of the RFA.

## 1.1 The policy context

Renewable transport fuels, predominantly biofuels, have received substantial support from governments globally over the past 5 years. This is due to their:

- Potential greenhouse gas (GHG) savings in relation to fossil fuels;
- Capacity to diversify the supply of transport fuels and provide additional fuel security benefits; and
- Ability to create new agricultural markets and rural development opportunities.

Countries prioritise these objectives differently, which, in turn, influences the design of policies that encourage the supply of biofuels. The UK has consistently emphasised that its support for biofuels is based on their potential GHG savings. This review focuses, therefore, on the way in which indirect land-use change may influence the potential GHG benefits of biofuels whilst also considering the wider effects on food security.

Since 2000, global bioethanol supply has doubled to over 40 billion litres in 2007[3] and is projected to grow by a further 20% in 2008.[4] Global bioethanol production is dominated by Brazilian sugar cane and US maize. Biodiesel production is significantly lower but has expanded in the last 4 years to around 10 billion litres in 2007. Biodiesel use is centred in the EU. In the future, notable increases in demand for biofuels are anticipated from the USA, Brazil, EU, China and India amongst others.

In the UK, supply of biofuels is encouraged through a duty derogation and the Renewable Transport Fuels Obligation[5] (RTFO). The RTFO requires 2.5% (by volume) of transport fuel to be delivered from renewable sources by 2008/09 rising to 5% by 2010/11. Fuel suppliers that fail to achieve their obligation (either through supplying renewable transport fuels, or buying certificates from other companies with surplus supply) must pay a buy-out penalty. The Government estimates the RTFO will reduce GHG emissions from road transport by approximately 0.7 – 0.8 MtC by 2010 (although this figure does not currently include potential emissions arising from land-use change).

2 www.renewablefuelsagency.org

3 Renewables 2007

4 F.O. Lichts 2008

5 www.dft.gov.uk/pgr/roads/environment/rtfo

The RTFO was introduced to assist the UK in meeting its obligations under the EU Renewable Fuels Directive which proposes that 5.75% (by energy – about 7% by volume) of transport fuels should be from renewable sources by 2010. The UK does not expect to achieve the EU target because 5% by volume is the highest biofuel content allowed by European fuel quality specifications for petrol or diesel. Recently the European Commission proposed to increase the EU target for renewable transport fuels to 10% (by energy) by 2020. A further EU proposal to reduce the carbon intensity of transport fuels within the Fuel Quality Directive has the potential to bring even greater volumes of biofuels into the road transport market. This could be more than 15% (by energy) depending on the final target and extent to which approaches other than biofuels contribute to a lowering of the carbon intensity of fuel.

## 1.2 Direct effects

The rapid expansion in demand for biofuels has raised concerns that feedstock production is causing a range of negative effects. These include:

- Habitat destruction (particularly in Amazonia for soy and South-East Asia for palm oil);
- Local environmental impacts upon air, water and soil quality and exacerbation of local water supply concerns; and
- A range of social issues including poor working conditions for labourers and reported loss of land rights for indigenous peoples where new plantations for feedstock are established.

Managing these direct consequences of increased biofuel feedstock production is potentially within the control of the oil and biofuel industries and their supply chains. A range of policies and mechanisms to address the direct effects of biofuels, and encourage good practice, have been or are in the process of being developed. For example, the EU has proposed mandatory environmental criteria to prevent feedstock being supplied from areas of high biodiversity value and to deliver minimum levels of GHG savings.

As part of the RTFO, the UK has introduced the world's first carbon and sustainability (C&S) reporting scheme. This includes targets for the proportion of feedstock that meets acceptable levels of environmental performance and average GHG savings. By 2011/12 the UK has also indicated it will introduce mandatory criteria, subject to EU and World Trade Organisation (WTO) agreement. Through the UK carbon and sustainability reporting scheme, the RFA will monitor fuel supplier performance and name, praise and shame suppliers as appropriate. The assessment of the sustainability of feedstock supplied to meet the first three months of the UK's RTFO will be published in September 2008. The RFA nevertheless welcomes plans for stronger measures that will *require* rather than *encourage* companies to source biofuels responsibly.

Some progress has also been made in developing voluntary biofuels certification schemes such as the Roundtable on Sustainable Palm Oil. The success and credibility of such schemes is important to the future of the biofuels industry, given its reliance on government, and thus public, support. It is, therefore, essential that biofuel certification schemes address the full scope of sustainability concerns and are extended to all feedstocks, sourcing countries and companies, and implemented robustly. Current biofuel feedstock certification schemes are, as yet, unproven. Past experience indicates it will be some time before certification schemes achieve widespread take-up. Their effectiveness in improving the sustainability of biofuels remains to be demonstrated.

Policies to manage the direct effects of biofuels are immature and unproven but progress in their development and implementation is being made. A range of previous studies, including extensive work in the development of carbon and sustainability reporting as part of the RTFO, has examined policy options and practical solutions. This review focuses upon the indirect effects of biofuels.

## 1.3 Indirect effects

There are a range of indirect effects of biofuels but this review is focused upon:

- Rising food commodity prices and the effect upon food security for the poor; and
- The displacement of agricultural production onto uncultivated areas with impacts on biodiversity, GHG savings and local land rights as a result of biofuel production.

Environmental organisations have highlighted to the RFA a number of examples of the indirect effects of biofuels. These include the expansion of sugar cane production in Brazil, in part for biofuels, leading to displacement of cattle ranching and accelerated deforestation in Amazonia. The expansion of soy production in South and Latin America has also been highlighted as a consequence of US farmers increasing production of maize (and reducing production of soy) to meet US bioethanol targets. Increased demand and prices for oil seed rape (OSR) for biodiesel in the EU has been linked to the expansion of palm oil production in South-East Asia.

The reason why the displacement of agricultural activity is significant from a GHG perspective is that many forms of land-use change result in significant releases of carbon to the atmosphere. A recent modelling study by Searchinger, described further in chapter 5, evaluated the effects of indirect land-use change on the net GHG savings of biofuels. This concluded that the GHG emissions from indirect land-use change negate any benefits (compared to petrol) from maize bioethanol for 167 years. The complexity of agricultural commodity markets makes modelling and monitoring the indirect effects of rising demand for biofuel feedstock complex and highly uncertain. It is nevertheless clear that the indirect effects of biofuels cannot be ignored if biofuels are to provide a genuinely sustainable part of the suite of measures required to reduce GHG emissions from transport.

## 1.4 The Gallagher Review

UK support for biofuels is based on the premise that biofuels deliver considerable net reductions in GHG emissions compared to fossil fuels. As a secondary benefit, it was hoped a growing biofuels market would create economic opportunities for farmers both in the UK and elsewhere, including the developing world. This review has been commissioned by the UK Government to specifically examine the emerging evidence of the indirect effects of biofuels, which potentially calls these benefits into question. The terms of reference for the study are contained in Annex A.

The review has sought to address six key questions:

1. What are the key drivers of land-use change and food insecurity to date and to what extent is increasing demand for biofuels significant?
2. To what extent may global demand for biofuels contribute to land-use change and food insecurity to 2020 given known current and proposed targets and anticipated future commodity prices?
3. How are GHG savings from biofuels affected by displaced agricultural activity and resulting land-use change taking into account the introduction of possible new technologies and other changes in land productivity and cultivation and production methods?
4. What are the sustainability risks associated with different levels and forms of biofuel targets to 2020 for a range of supply scenarios?
5. What policies can mitigate the potential negative indirect effects of biofuels on land-use change and food security?
6. What further work would help to monitor and evaluate displacement effects of biofuels?

The conclusions have been reached through a critical evaluation of evidence gathered from experts globally. The review has drawn upon a number of studies that have recently been, or will imminently be, published examining the sustainability of biofuels or the effects of rising food prices. For example; AEA (2008) have published a study for Defra examining the environmental sustainability of international biofuels production and use.

Further evidence for the review was assembled through a general call for evidence which received over 70 substantive responses from academics, industry and non-governmental organisations. Submissions (where these were not provided in confidence) are available on request from the RFA along with the main supporting evidence that were inputs to the review. Additional evidence was collected and discussed during a series of international expert seminars at:

- SenterNovem in Utrecht, Netherlands;
- Department for Transport, London, UK;
- University of Illinois at Urbana-Champaign, Illinois, USA;
- British Consulate, Sao Paulo, Brazil;
- Food and Agriculture Organisation of the UN, Rome, Italy.

The RFA also commissioned a series of consultancy studies designed to:

- Evaluate the drivers of land-use change;
- Review future demand and supply of biofuels to 2020 and their impact on GHG-emissions;
- Assess the possible economic benefits and food insecurity impacts of increasing demand for biofuels.

There is a table of the studies that were commissioned in Annex B. Summary findings of these studies were presented to a stakeholder workshop and to a group of energy and science counsellors from the embassies of several countries at the Foreign and Commonwealth Office. These workshops provided an opportunity for a wide range of views to be heard.

To ensure the scientific robustness of the study it was overseen by an expert advisory group (see Annex C) including representatives from a wide range of perspectives. Where possible, the studies that provided inputs to the review were also peer reviewed by selected experts before being submitted to the RFA. In addition, an independent peer review of the draft report was performed by a team led by the Government Chief Scientific Advisor, Professor John Beddington. This considered the scientific and economic evidence that the RFA used to draw its conclusions. The RFA has made amendments to the text of the review in the light of these helpful and informed comments.

This review has been performed quickly to enable its outcomes to inform ongoing EU negotiations on future biofuels policy.

The current evidence and the limited time available for this review have not made it possible to produce a definitive assessment of the indirect effects of biofuels. The RFA has, therefore, endeavoured to critically evaluate key evidence and literature and added to this through the studies it has commissioned. From these, we have been able to draw broad conclusions on the scale of the indirect effects and propose a potential pathway to a genuinely sustainable biofuels market and make suggestions as to the policies that might facilitate this. This report focuses upon the policy conclusions and evidence supporting these. More detailed information is available in the commissioned studies, consolidated within the reports to the RFA by AEA Energy and Environment (2008) and by the Overseas Development Institute (2008).

The terms of reference for the review specifically focused upon examining the indirect effects. The review does not therefore consider, in detail, any of the wider benefits of biofuels such as development in the EU or increasing security and diversification of supply. Policy decisions on biofuels could take these into account. The review has also not been able to consider in any depth:

- The direct effects of biofuels or policies to address these (which have been considered in depth as part of the development of the RTFO and EU Renewable Energy Directive);
- The cost-benefit of biofuels policy compared to other carbon mitigation approaches;
- Further specific modelling of the indirect effects of biofuels on land-use change and the subsequent GHG-emissions;
- Opportunity costs of biofuels versus other options for use of land, investment in technologies and uses of wastes and residues;
- Economic analysis of alternative biofuel targets;
- The marginal effects of UK and EU biofuels policy on global agricultural supply.

The available evidence is incomplete and in some areas highly uncertain and the conclusions of the review are therefore based upon an impartial expert judgement supported by evidence. Whilst the uncertainty in the evidence is reflected in the overall findings, the potentially large scale of the negative indirect effects of biofuels and the direction of policy required to address this remains clear. Specific details and implementation pathways require further consideration and consultation.

# 2. The effect of land-use change on GHG savings from biofuels

**Biofuels can only contribute GHG savings from transport if significant emissions from land-use change are avoided and appropriate production technologies are employed.**

## 2.1 The potential GHG benefits of biofuels

Avoiding "dangerous climate change"[6] requires GHG emissions to be stabilised in the next decade and reduced by 60-80% by 2050[7]. This imperative requires a wide range of GHG mitigation strategies to be adopted in all sectors. Transport is a particularly challenging and relatively expensive sector from which to make GHG savings. Road transport currently represents about a quarter of the UK's GHG-emissions and that proportion is increasing. By 2020 road transport emissions are estimated to be about 33 Mt $C_{eq}$ – effectively unchanged from 1990 levels.

By 2020, and with the caveat that emissions arising from land-use change are avoided, biofuels have the potential to deliver annual global GHG savings of approximately 338 – 371 million tonnes $CO_2$e compared to a "without biofuels" scenario (E4Tech 2008c). This assumes current global targets for 2020 are met and there is a penetration of advanced technology.[8] The EU contribution to this target is estimated to be approximately 54 – 68 million tonnes $CO_2$e applying the same assumptions, including that the 10% target by energy is met.

The Stern Review (2006), highlighted the economic need to mitigate climate change and highlighted the benefits of solutions that deliver emissions reductions now. Biofuels offer one of a limited range of options to reduce GHG emissions from current vehicles if they can be produced sustainably, including without causing land-use change.

Identifying the appropriate role of biofuels in reducing road transport GHG-emissions requires a more thorough examination of their opportunity costs and cost effectiveness that goes beyond the scope of this review. It is clear, however, that achieving significant reductions in road transport GHG-emissions requires an integrated approach including:

- More efficient vehicles;
- Low carbon fuels;
- Increasing use of public transport;
- Walking and cycling;
- Aids to enable more efficient driving;
- Efficient use of infrastructure; and
- Demand management.

6 A serious risk of large scale, irreversible system disruption – typically associated with increases in global average temperature of about 2°C above pre-industrialised levels

7 IPCC 2007

8 E4tech 2008b

Support for biofuels as a means of GHG reduction is justified only if the policy can be constructed in a manner that avoids significant emissions arising from land-use change.

## 2.2 Biofuel lifecycle GHG-emissions

Lifecycle analyses demonstrate that most current (1st generation) and advanced (2nd generation) biofuel technologies deliver GHG savings from road transport *if land-use change (direct or indirect) causing significant losses of carbon stocks is avoided*. The issue of how and whether land-use change can be avoided is dealt with elsewhere in the review. The results here indicate the potential biofuels can offer.

A range of studies has shown that where feedstock is produced without land-use change (either direct or indirect) most biofuels achieve net GHG savings. Current biodiesel technologies generally achieve a 40 – 50% saving compared to that of conventional diesel. The range of savings from current bioethanol technologies is much wider, from –20% to 80% depending upon: feedstock, rates of fertiliser application; type of other energy source (coal, gas or biomass); heat and power source (simple boiler, CHP or advanced turbine) and the specific use of co-products. Figure 2.1[9] illustrates factors that can reduce the carbon intensity of biofuels, using the conversion of wheat to bioethanol as an example (ignoring land-use change).

**Figure 2.1: GHG savings arising from production of wheat to ethanol using different production processes**

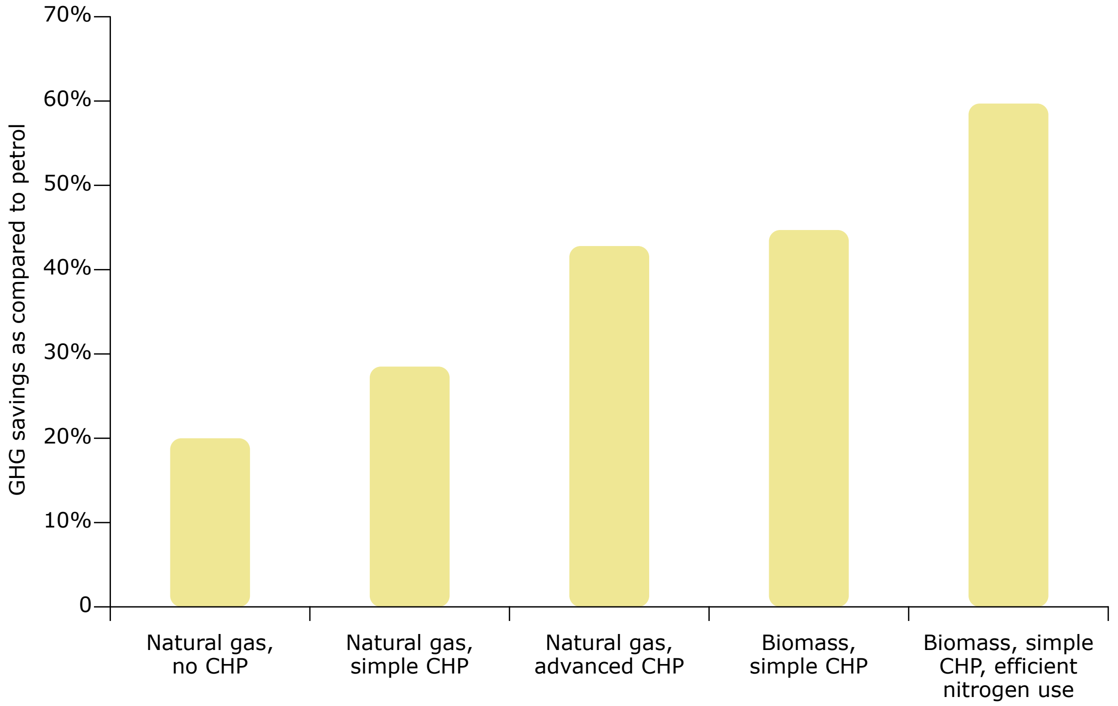
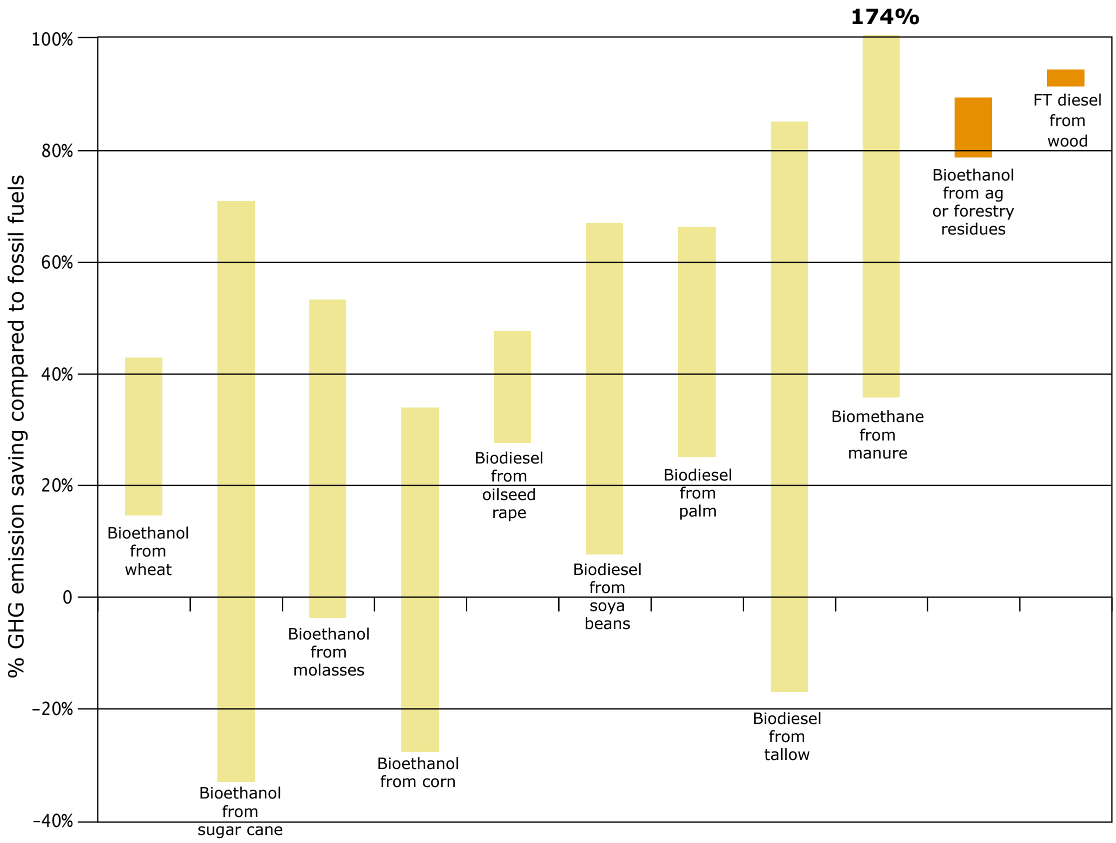



Figure 2.2 illustrates the range of GHG savings delivered by different biofuels compared to petrol or diesel (assuming no land-use change is incurred in supplying the biofuel feedstock). The best and worst GHG savings from bioethanol are presently achieved from sugar cane. Excellent GHG savings are achieved in Brazil where there are high yields and use of bagasse for heat and power. An example

9 E4tech 2008c

of efficient production is from some Brazilian mills which export electricity to the grid. An example of a production method which is less efficient is a South African plant which uses an electric boiler with grid electricity predominately using coal. Biomethane produced from manure has the highest savings overall – 174% of diesel emissions.

**Figure 2.2: Estimated GHG savings of current biofuels**




Note: current technologies are shown in yellow, advanced technologies in orange

GHG savings for advanced technologies are more uncertain, but have been estimated to be 80-90% where residues are used as feedstock. For syndiesel production via gasification with Fischer-Tropsch processing, the credits from the surplus renewable electricity that is produced led to net GHG savings approaching 100% of the diesel equivalent, with other studies showing higher savings.

There are a range of uncertainties in the lifecycle emissions estimates for biofuels, including how to account for co-product credits and nitrous oxide emissions from soil arising from the application of nitrogen fertiliser. Studies inputting to this review included a critical examination of frequently cited research by Crutzen et al (2007) who concluded that the International Panel on Climate Change (IPCC) emissions factor for nitrous oxide underestimates emissions by a factor of 3 to 5 and that, as a result, most biofuels would not generate net GHG savings. An examination of the Crutzen methodology[11] (Box 2.1) concluded the findings are not reliable, but acknowledge the IPCC Tier 1 factor can, *in some instances*, underestimate emissions from oil seed rape (OSR) biodiesel and wheat ethanol by 40-50% (and other feedstock by 14 to 20%). In some instances, this will result in feedstock not achieving GHG savings compared to fossil fuels.

10 E4tech 2008b

11 North Energy 2008

## Box 2.1: Review of the findings of Crutzen et al, 2007

The paper by Crutzen at al is frequently cited as evidence against the use of biofuels as an effective means of mitigating global climate change. It is therefore important to assess the basis upon which its conclusions are reached.

The paper examines the $N_2O$ flux through the atmosphere in an attempt to determine the amount of nitrous oxide that can be attributed to the global cultivation of soils. This is then compared with the global estimate of nitrogen (N) fertiliser applied to cultivated soils to derive a relationship between soil $N_2O$ emissions and nitrogen fertiliser application. The resulting relationship is contrasted with that provided from relevant work by the Inter-governmental Panel on Climate Change (IPCC 2006) and a significant discrepancy is identified.

Prominent life cycle assessment (LCA) studies of biofuels use data from the IPCC (2006) to estimate soil nitrous oxide emissions. From this, Crutzen et al imply such studies underestimate the contribution of soil nitrous oxide emissions by a factor of 3 to 5. This conclusion is then applied to an evaluation of certain biofuels to demonstrate that most do not generate net GHG savings relative to conventional fossil fuels.

Key issues with the methodology are:

1. The attribution of nitrous oxide emissions from cultivated soils uses a "remainder calculation" that is highly sensitive to the assumed values of individual "non-cultivated soil" fluxes;
2. The comparison with the IPCC estimate is inappropriate since this compares *total* soil emissions with *direct* emissions in the IPCC estimate. The IPCC *total* soil emissions range actually has a slight overlap with the range of values derived by Crutzen et al.;
3. The comparison with the GHG-savings of biofuels only considers a limited and selective list of biofuels that is not representative of all current biofuels;
4. The paper assumes that a fixed nitrogen content of the biomass from which biofuels are produced can be used as an accurate proxy. This also requires an assumption of a 40% uptake efficiency of nitrogen fertiliser by all crops that is not appropriate;
5. The analysis ignores co-product allocation which is assumed to partially compensate for the GHG emissions of all the other stages of biofuel production – although no evidence is offered to support this questionable assumption.

The paper applies an uncertain approach, questionable assumptions and inappropriate, selective comparisons to reach its conclusions. The review by North Energy concludes that *"Whilst the paper by Crutzen et al does seek to address an important matter, namely the magnitude of soil $N_2O$ emissions from the cultivation of crops for the production of biofuels, it cannot be regarded as resolving the problems and assisting the objective evaluation of biofuels"*

It is not possible, based upon currently available evidence, to evaluate the frequency with which the IPCC tier 1 factor will underestimate emissions. To some extent, criteria for minimum GHG savings, as proposed in the EU Renewable Energy Directive, should help to ensure that uncertainties in the absolute level of nitrous oxide emissions should not lead to biofuels that cause net-GHG emission increases (assuming there are no land-use changes). Nevertheless, improved methodologies to account for uncertainties in nitrous oxide emissions are needed and discussed further in chapter 9. Improved methodologies to calculate nitrous oxide emissions will require significant additional data compilation and analysis. This is possible on farms within agri-environmental assurance schemes. However, this will not be available for all feedstock for which nitrous oxide emissions estimates will continue to rely upon average fertiliser application rates and Tier 1 default values.

## 2.3 GHG-emissions from land-use change

Biofuel lifecycle analyses traditionally assume that no land-use change has occurred. Where analyses have been extended to consider the impacts of land-use change, for example to convert forests or grasslands to agricultural land for biofuel production, the results indicate a significant release of carbon stocks that usually eliminates any GHG savings that would otherwise be derived from the biofuel.[12] This has led to policy proposals to restrict the conversion of certain land types for biofuel feedstocks, such as the proposed EU Renewable Energy Directive. To date, policy proposals have not been extended to policies to restrict indirect land-use change.

GHG-emissions from land-use change vary widely between biomes and specific locations but generally stem from:

- The loss of most of the above ground carbon (in vegetation and litter) in forests, savannas and wetlands; and
- Below ground carbon retained in the soil and roots of temperate grasslands.

Conversion of peatland leads to the highest carbon losses. Typical payback times for replacement of lost carbon where land-use change results from increased demand for biofuel feedstock is shown in Table 2.1.

**Table 2.1: Illustrative GHG savings and payback times for biofuel feedstock causing land change[13]**

| Fuel chain | Assumed country of origin | GHG saving excluding the impacts of land-use change | Carbon payback (years) | |
|---|---|---|---|---|
| | | % | Grassland | Forest |
| Palm to biodiesel | Malaysia | 46% | 0 – 11 | 18 – 38 |
| Soya to biodiesel | USA | 33% | 14 – 96 | 179 – 481 |
| Sugarcane to bioethanol | Brazil | 71% | 3 – 10 | 15 – 39 |
| Wheat to bioethanol | UK | 28% | 20 – 34 | 80 – 140 |

12 North Energy 2008

13 E4Tech 2008c

Where biofuels lead to land-use change, there are generally significant net GHG-emissions – although there may be specific areas where conversion of pasture for biofuels will deliver feedstock providing good GHG savings, providing indirect land-use change does not occur. This is notably the case for Brazilian sugar cane planted on some permanent pasture.

## 2.4 GHG-emissions from use of idle land

Idle land, such as set-aside, accumulates carbon in the soil over time and, over a long period, may begin to have significant vegetation and above ground carbon stocks. This carbon is generally released when the land is brought back into agricultural production by ploughing. Analysis, undertaken by North Energy, indicates that the additional emissions associated with bringing set-aside land back into production reduces by approximately half the savings for OSR biodiesel and wheat bioethanol compared to feedstock grown on existing agricultural land. GHG savings will therefore be better where biofuels are grown on rotational rather than permanent set aside or fallow land.

There is emerging evidence that some agricultural practices can preserve soil carbon, for instance through avoiding excessive tillage. Techniques such as these may enable some pasture to be converted for biofuel feedstock without causing significant GHG emissions, assuming no indirect land-use change occurs, and *if the biofuel concerned is already recognised, under established GHG calculation methodologies, to deliver high GHG savings*.

Where certain lands have been judged to have a low soil carbon content, for example – where it has been in use recently or where it has not been fallow for very long, there are opportunities for particularly good GHG savings through the cultivation of biofuel feedstock using perennial plants such as palm, sugar cane or woody biomass. In these cases, it is likely that net GHG savings and relatively short payback periods would be achieved.

A cautionary approach would indicate establishing policies that disincentivise or prevent the production of biofuels on permanent pasture except where specific assessments indicate that there are worthwhile net GHG benefits. This may include pasture converted for palm oil, sugar cane or other perennial energy crops; but not generally for wheat or OSR.

## 2.5 Estimating GHG-emissions from indirect land-use change

Recent studies, most notably by Searchinger, have analysed the GHG implications of using agricultural land to grow biofuels. They have focused particularly on emissions arising from land-use change caused by displacement of agricultural production, commonly referred to as an 'indirect impact' of biofuel production. Further consideration of this issue is included within Chapter 5.

## 2.6 Recommendations

- The Government should amend but not abandon its biofuel policy in recognition of the indirect effects to ensure its biofuels policy delivers net GHG-benefits. Specifically:
  - At EU-level targets within the Renewable Energy Directive and Fuel Quality Directive should recognise the need to avoid both direct and indirect land-use change that leads to significant loss of carbon stocks;

- Biofuels support mechanisms should exclude feedstock grown on land where carbon losses arising from its cultivation lead to a payback of longer than 10 years by the biofuel produced
  - This could be achieved by conducting site specific assessments of anticipated payback times. These should be performed before any idle land that is permanent pasture is converted for biofuel production;
- Biofuels support mechanisms should specifically exclude feedstock grown on land designated as of high conservation value[14];
- Further work should be conducted concerning:
  - Indirect effects of EU policy;
  - Carbon losses associated with land change, especially for pastures;
  - The net benefits of growing biofuel feedstock on idle land;
  - The nitrogen cycle.

14 High conservation value resource network http://hcvnetwork.org/

# 3. Land availability and the drivers of land-use change

**Demand for food, animal feed and bioenergy is rising and creating additional pressure on land. Estimates of future demand and the amount and suitability of land potentially available are highly uncertain. The balance of evidence indicates there is sufficient land available to satisfy demand to 2020, but this needs to be confirmed before global supply of bioenergy increases significantly. Current policies do not ensure that additional production moves exclusively to suitable areas. Attempts to direct agricultural expansion to particular areas face significant implementation and enforcement challenges.**

## 3.1 Land demand for food and animal feed

A major question for this review has been to compare likely demand scenarios for biofuel feedstock, food, animal feed and other demands with estimates of globally available land that is judged suitable for agriculture. There is a very high degree of uncertainty in all such forecasts, so precise numbers need to be treated with considerable caution, but broad trends may be discerned.

Global land demand for food and animal feed is anticipated to rise and increasing demand for biofuels adds to this pressure. One study commissioned by the RFA[15] estimates an additional land demand of 200-500 million hectares to 2020, even taking into account anticipated improvements in yield (one of the most significant factors in reducing demand for land). This compares with current estimated land use for cropland of around 1500 million hectares. The forecast for an overall increase in demand for agricultural land is consistent with UN Food and Agriculture Organisation (FAO) forecasts. According to their estimations, in 2030 about 20 percent of extra food production is the result of expansion of arable land, 70 percent of increasing yields and the rest of increasing cropping intensity.[16]

### Box 3.1: Will potential yield improvements be realised?

Yield improvements offer the prospect of reducing pressure on the overall amount of land required for agriculture around the globe. The combined analysis commissioned for this review indicates that high and low yield improvement scenarios result in approximately ±10% influence on total land demand for biofuels.[16] Yield improvements for agriculture can generally reduce the amount of land required for a given output.

There are a variety of reasons why yield trends may have been dampened in recent years, including:

- Collapse of Eastern European centralised economies in the early 1990's;
- McSharry reforms of the EU's CAP in 1993, reducing price supports which reduced a focus on maximising yields; and
- Greater climatic instability, particularly evident through increased frequency of droughts, e.g. in Australia.

15 CE Delft 2008

16 ADAS 2008

### Box 3.1: Will potential yield improvements be realised? *(continued)*

The review concludes that there are realistic prospects for substantial improvements in yields for the future, but that such advances are critically dependent on a combination of three drivers:

1. Public investment in research and infrastructure;
2. Supportive legislative and trade agreements; and
3. Private investment supported by profitability of production – hence product prices.

Biofuels provide a mechanism to encourage investment in agriculture to increase yields. Significant growth in biofuels supply will also, in part, depend upon the need to realise these yield improvements.

## 3.2 Demand for land under current global biofuel target expectations

Currently, land use from biofuels is estimated at around 13.8 million hectares in the USA, EU, Brazil and China combined,[17] or around 1% of the total 1500 million hectares currently estimated to be in use for cropland globally.

Further land will be required to meet the estimated overall level of biofuel targets set globally. The analysis in the study estimated that the total requirement for land for biofuels, if all major countries and regions were to attain their stated targets to 2020, would be between 56 and 166 million hectares.[18] The lower figure takes into account the avoided land use benefits of co-products, 2nd generation technologies from wastes and residues and assumes significant improvements in yield. The higher estimate is a gross figure, for the low yield scenario, not taking into account the anticipated benefits of co-products and without a positive contribution from 2nd generation technologies.

Although the proportion of global land use for current biofuel production is small, biofuels appear to represent a substantial share of the additional land demand to 2020. The evidence indicates that they may represent between 11% and 83% of the additional global agricultural land requirement forecast.

The review has analysed a range of scenarios of global land demand for biofuels to meet:

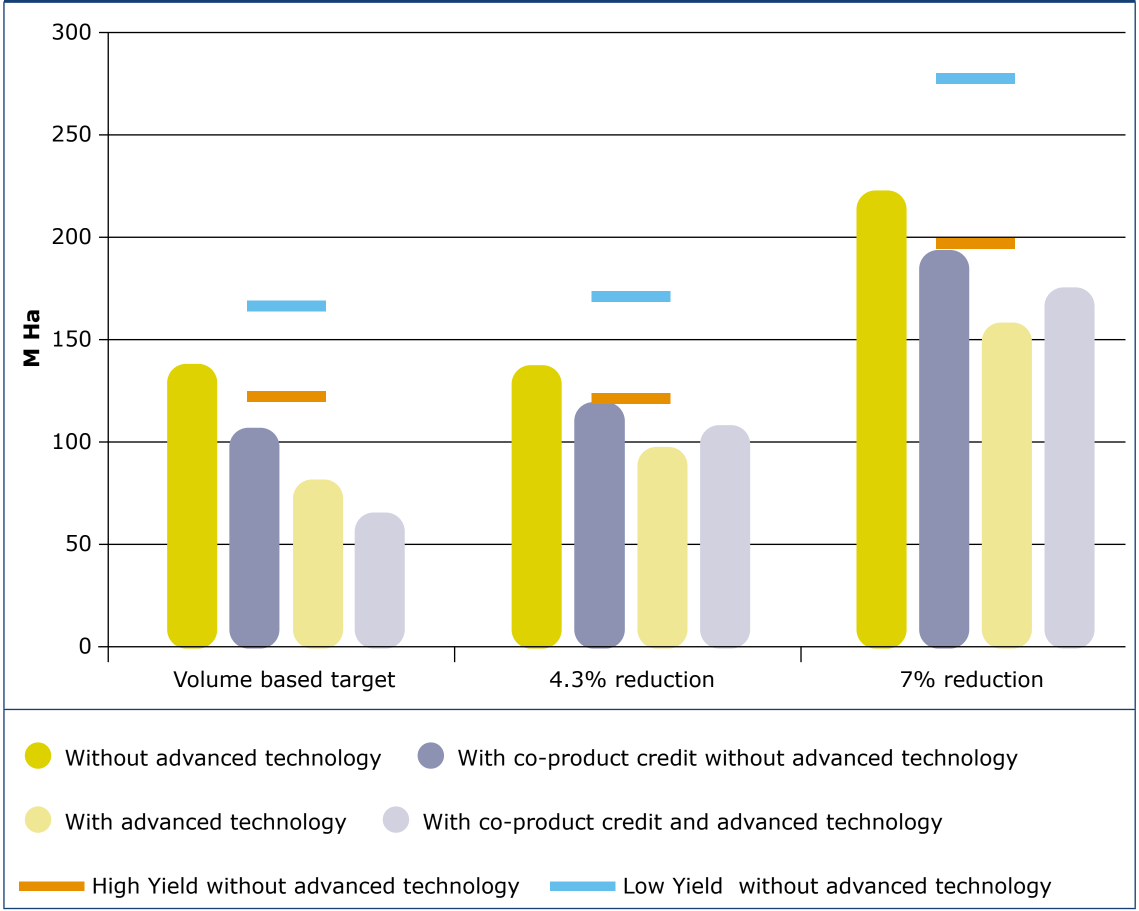
- Current volume or energy based targets (as already specified);
- A 7% GHG saving from road transport (to try and predict the implications if countries adopted GHG targets as the EU is preparing to do in the draft EU Fuel Quality Directive);
- A 4.3% GHG-based target (that requires the same volume of biofuel as current volume or energy-based targets) but with a focus on GHG-saving.

17 CE Delft 2008. Figures are for 2006
18 E4Tech 2008 & ADAS 2008

The analysis indicates that a 7% GHG-saving target leads to an increase in demand for land of up to 276 million hectares globally, substantially higher than current volume based targets.[19] The 4.3% GHG target also results in a higher volume of *net* land demand than the current volume targets. This is because the GHG target was forecast to result in a higher use of feedstocks that generally give higher greenhouse gas savings, but also produce fewer co-products that can reduce land demand. The impact of co-products on land demand is a relatively new area of study and further research is required before firm conclusions are drawn. It is important to note that the effect of possible feedstock switching which may increase overall land demand only arises because current lifecycle methodologies fail to take into account indirect land-use change, both negative and positive. For the future, it may be possible to develop GHG lifecycle methodologies to include such factors, though this presents serious challenges.

Figure 3.1 below illustrates the varying level of land demand requirements for global targets to 2020, depending on the level and type of targets set and different assumptions around the technologies employed.

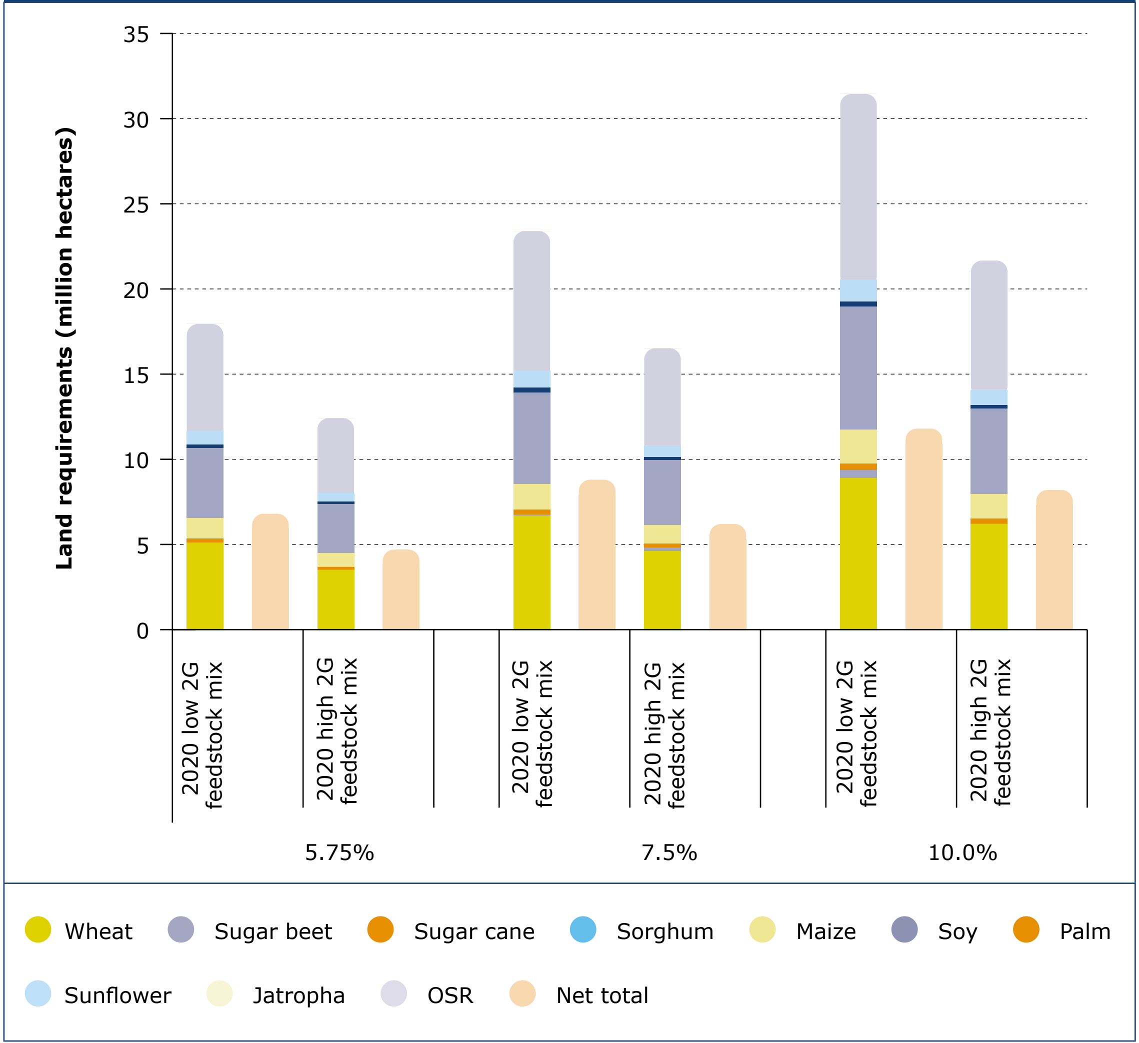
**Figure 3.1: Global 2020 biofuel land demand scenarios**




19 ADAS 2008, Ecofys 2008b and E4Tech (2008b). This is a gross figure, with the low yield scenario and no 2nd Generation contribution.

The implications of the EU targets are outlined in figure 3.2 below. The EU 10% target contributes a gross land requirement of between 22 million hectares and 31.5 million hectares.[20] The lower and higher estimates relate to assumptions about yield and 2nd generation fuels. These are reduced to a net land requirement of between 8 and 12 million hectares when the potential avoided land use benefits of co-products are taken into account.

**Figure 3.2: EU 2020 biofuel land demand scenarios**



### Box 3.2: How do co-products affect land demand?

Current biofuels production from wheat, maize and rapeseed produce valuable co-products such as rape meal and dried distillers grains and solubles(DDGS). These products have a high protein content and are suitable for displacing animal fodder. Using DDGS in this way potentially allows for fewer crops to be grown specifically for animal feed, particularly protein rich sources such as soy. This is particularly valuable because protein rich crops generally require a relatively large amount of land for a given output compared with cereal crops. The overall effect is that these kinds of co-products can reduce the land required to produce high protein crops specifically for animal feed.

Analysis for this review (CE Delft, 2008) indicates that for rapeseed, soy, wheat and maize, the effect of displacing protein rich crops is to reduce the net land requirements per tonne of biofuel by 60-81%.

Biofuels produced from tropical feedstocks such as sugarcane, where nearly all of the product is used to produce the biofuel, do not have these useful co-products that avoid land use. Consequently whilst the greenhouse gas emissions savings associated with sugarcane are very high, the net land requirements may also be higher.

2nd Generation biofuels are also likely to have co-products, but it currently appears that most of these will be further petro-chemical type products. These could further reduce greenhouse gas emissions but are unlikely to have the avoided land-use change benefits that co-products of current technologies offer.

## 3.3 Land availability

The concept of land 'potentially available' for agriculture and in particular for expanded bioenergy production is hugely complex. Various studies have made assessments, and the outcomes vary significantly depending on the assumptions made about what constitutes suitable land, yield improvements, demand levels and so on. Analysis is also hampered by varying uses of terminology in the absence of agreed definitions. For clarity, we set out the following broad definitions in this paper, though it is important to note that these terms have not necessarily been used, or used in the same way, in the studies supporting this review and underlying evidence:

**Idle land:**

- Former or current agricultural land that will not otherwise be used for food production; and
- Land that is potentially suitable for agricultural production.

**Marginal or degraded land:**

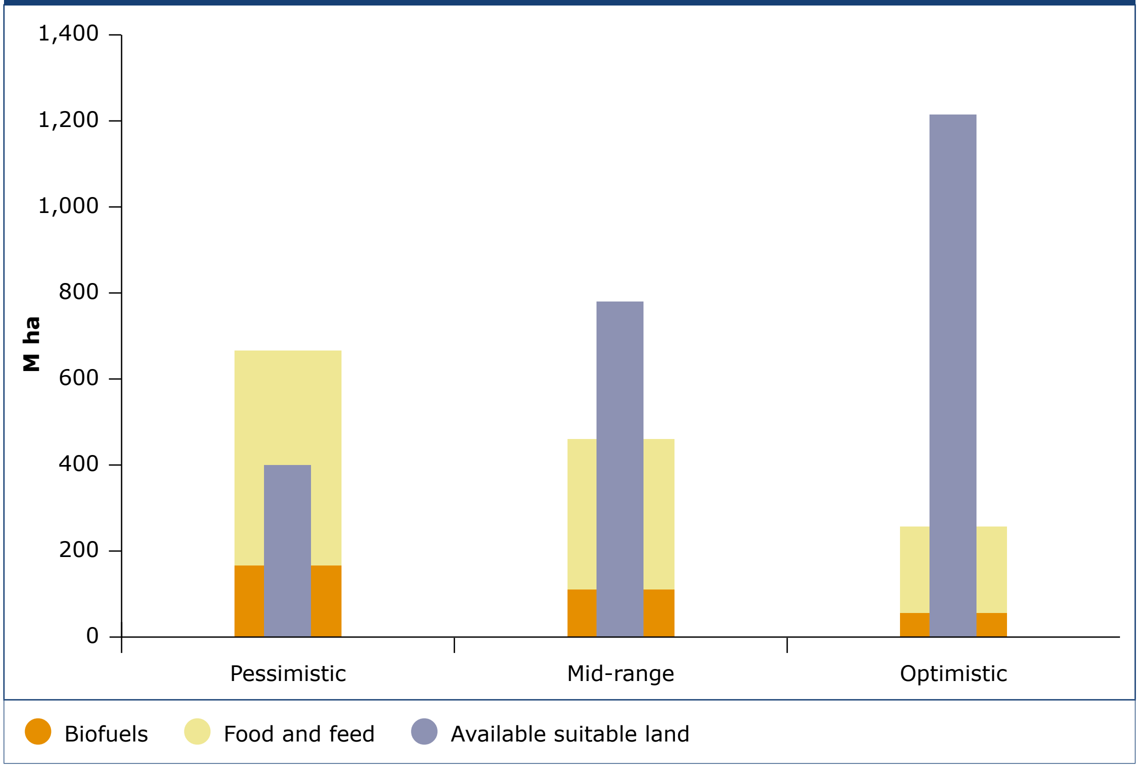
- Land unsuited for food production, e.g. with poor soils or harsh weather environments; and
- Areas that have been degraded, e.g. through deforestation.

The studies commissioned for this review (CE Delft 2008 and various regional case studies) indicate that there are potentially large areas of land which could be deemed suitable for expanded agricultural production, though there is enormous uncertainty around these estimates. Modelling by the International Institute for Applied Systems Analysis (IIASA), partially based on FAO data, used global satellite mapping tools and remote sensing to identify potential suitable land. The tools removed those areas of land which demonstrated high biodiversity value, forest cover and other indicators that would deem them unsuitable for agricultural expansion. The models also took into account water availability as a requisite for agricultural expansion. The modelling indicated that between 790 million hectares (GLC[21]) and 1,215 million hectares (MODIS[22]) of suitable land was potentially available globally.[23]

The European Environment Agency (EEA) has significantly lower estimates of land suitable for agricultural expansion ranging from less than 50 million hectares to approximately 400 million hectares depending on whether natural grassland was used.

Figure 3.3 contrasts the varying assessments of demand for food, animal feed and the varying biofuels forecasts using current global targets for 2020 with potential land availability.[24] The IIASA modelling indicates that there is enough land even for high biofuel and feed demand set against their 'low' availability scenario. In contrast, the lower EEA estimate indicates that there is not enough land for even the low biofuel demand scenarios.

**Figure 3.3: Global land availability and requirements**




21 Global Land Cover 2000 database

22 MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites

23 IIASA presentation to RFA expert land seminar, (May 2008), www.renewablefuelsagency.org

24 The pessimistic scenario for biofuels assumes low yield, and no co-products or 2nd Generation, the optimisic the reverse of this.

The demand considered above includes food, animal feed and biofuels. There might also be additional land demand for wood and for bioenergy although estimates here appear even less certain. Using FAO data, CE Delft (2008) indicate a possible expansion of forest plantations to meet growing wood demand. According to FAO (2003) data, the area of forest plantations could maintain its current (2000) level of approximately 190 million or increase to as much as 310 million hectares in 2020.[25] If demand for forestry land were added to the figures above, it would potentially limit the amount of land available further. However, this possible increase in plantations is set against an expectation that global forest area will shrink.[26]

The regional case studies also indicate that there are large areas of land potentially available for increasing agricultural production. For example, the Southern Africa study found that in Mozambique only 10% of arable land is currently under cultivation, indicating over 30 million hectares of additional land.[27] Tanzania is estimated to have a further 55 million hectares of land suitable for crop production but currently not in agricultural use. CE Delft (2008) quote an FAO assessment that 13 million hectares of idle land in the former Soviet Union could be returned to use with little environmental impact (out of a total of 26 million hectares that has fallen out of production).

The studies also point to significant regional variation in availability. Much of southern and eastern Asia and North Africa is land constrained, whilst there appear to be significant opportunities for areas including Eastern Europe, South America and sub Saharan Africa (even taking forests, water constraints and conservation areas into account).

## 3.4 Global shifts in agricultural production

Whilst agricultural land demand is rising at the macro level, in some regional areas agriculture decreased through the 1990's, for example in Europe and the former Soviet Union.[28] This is significant as such agricultural land may be used for biofuel production without competing with food use, or causing displacement and indirect land-use change, even against a global backdrop of increased demand.

CE Delft note that the global statistics on fallow and former agricultural land are incomplete, but might account for around 1% of current agricultural land (around 150 million hectares). They note that this is insufficient to meet their estimates of additional demand for food and animal feed (200-500 million hectares), let alone additional bioenergy demand. They conclude that 'biofuels demand increase will require additional agricultural land, *and thus will cause land-use change in various regions of the world*.' However, this latter conclusion ignores what appears to be a global dynamic in which agricultural production is shifting to other parts of the world as agricultural markets are increasingly liberalised. This will indeed cause land-use change. However, the effect of this dynamic is that agricultural land may be left idle in some regions even where demand at the global level is increasing. Biofuels policy, particularly in the EU, was developed partly in response to this dynamic in which there was anticipated to be a *reduced* demand for agricultural land within the EU.

25 CE Delft 2008

26 AEA 2008

27 Diaz-Chavez, R and Jamieson, C, 2008

28 ADAS critique of Searchinger 2008

## 3.5 Idle land availability in the EU

The EU impact assessment of the 2020 10% target took into account long term market trends in the EU 27. These indicated that a trend of limited EU competitiveness on world markets would be an important factor in allowing further area for biofuel production by 2020.[29] This indicated that, in the absence of a biofuels policy in the EU, arable land use was expected to fall by about 7 million hectares between 2000 and 2020. Combined with current[30] EU compulsory set aside of 3.8 million hectares this provides a total of 10.8 million hectares of idle arable land in the EU.[31] This compares to the land demand estimates for meeting the EU 10% target of between 22 million hectares and 31.5 million hectares (gross) and 8 and 12 million hectares (net) when the potential avoided land use benefits of co-products are taken into account.

## 3.6 Land-use change caused by the EU 10% target

The extent to which the EU target would be met by EU production given the global nature of markets is an important question. The EU analysis set out in the Biofuels Progress Report estimated between 22% and 54% would be met by imports. It further estimated that 37% of the land use for biofuels in the EU would come from export diversion or diversion of domestic use:

- "Export diversion" where products were previously used for exports but are retained within the EU for domestic biofuels production, which must then be replaced by production elsewhere; and
- "Diversion of domestic use" where products that were previously used for other domestic purposes such as food and feed are diverted to biofuels, ultimately resulting in additional imports to meet EU food and feed demands.

Each of these effects is likely to lead to indirect land-use change elsewhere. On the basis of analysis of the EU impact assessments, Ecofys (2008b) estimate that the net result of meeting a 7% by energy target in the EU would be 4.9 million hectares of land-use change outside of the EU, or 10 million hectares to meet a 14% by energy target. This could be mitigated if increased demand for biofuels resulted in higher yield increases; increased efficiencies resulted in less waste; or, there was a decline in demand in other sectors. However, there is little evidence that these possibilities are likely to offset much, if any, of the land-use change. Ecofys (2008) conclude that the EU impact assessments did not recognise or analyse the land use effects as a result of EU imports or displaced demand for production outside of the EU, and that "the conclusion made in the (EU) roadmap that the GHG emissions savings from biofuels will be positive is premature as it does not include GHG emissions from land-use change."

29 European Commission 2007

30 The EU announced in 2007 that compulsory set aside would be set to zero for the autumn 2007 spring 2008 growing season. It is not yet clear whether this is simply a short term response to a spike in demand due to events such as successive droughts in Australia, or whether earlier forecasts of fall in demand for EU agricultural land remain valid.

31 EU Biofuels Progress Report. The paper indicates that this scenario was developed by research organisation IIASA.

## 3.7 Use of marginal land and intensification of agriculture

Whilst there appears to be good quality land that may be suitable for conventional biofuel feedstocks at a global level, there may also be opportunities to use alternative biofuel crops on land that is generally seen as unsuitable for food production. For example, the use of the oilseed crop jatropha is being explored in countries such as India where marginal land is being targeted.[32] Perennial biofuels could even play a useful role in regenerating poor quality land through the addition of carbon to soils, resulting in carbon sequestration.[33]

The potential for use of marginal land should not be overstated since whilst crops can grow in difficult conditions, the yield performance may be poor. For example; the commercial viability of jatropha on such land has been questioned.[34] It is also important that the crops are not supported independently of the land on which they are grown. This is because, outside of an appropriately designed and well enforced regulatory environment, there may be nothing to prevent biofuel producers cultivating such crops on high quality arable land. Such an outcome would fail to exploit the potential of such crops as well as exacerbating the negative impacts of land-use change.

Intensification of the use of land can also free-up potentially large areas of land. For example, the Brazilian case study points to opportunities to release pasture land for cropland by intensifying the currently very low density of cattle heads per hectare.[35] This cites estimates that 50-70 million hectares of pasture land would be made available in Brazil if the Sao Paulo productivity rate were extended to the rest of the country. Woods and Black (2008), also note the potential for increases in Sub-Saharan Africa and Latin America through improving current agricultural practices.

## 3.8 Will agricultural production expand into 'appropriate' areas?

In the absence of policies that direct agricultural expansion to specific areas, or effectively encourage greater productivity, commercial production of traditional crops, possibly targeting high quality lands, will continue to dominate the biofuels feedstock mix.[36] The case studies highlight a number of areas where expansion into sensitive land might be anticipated. In Indonesia, for example, government plans for increased palm production for both food and biofuels through an expansion of current agricultural land. There is a high likelihood that this expansion will involve the clearance of tropical rain forest and the drainage of peat land. Both of these release significant amounts of carbon into the atmosphere with resultant negative impacts on the emissions savings from biofuels.[37] CE Delft (2008) anticipates that arable land may expand at the expense of forests, especially in sub-Saharan Africa and in Latin America.

32 Woods and Black 2008
33 AEA 2008
34 ODI 2008
35 Volpi 2008
36 IEEP 2007
37 Themba 2008

The case studies point to a range of issues that would need to be addressed in order to successfully exploit opportunities to use land deemed appropriate for agricultural expansion. For example, the case study for southern Africa indicates a lack of infrastructure in some regions that can stall development.[38] It is also notable that half of the potentially available land is in just seven nations, many of which are suffering from conflict with little or no control internally over much of their land.[39] Such obstacles are perhaps to be expected given that the land is apparently not being utilised for agriculture already. This also suggests that future agricultural expansion may not gravitate to these areas in the absence of targeted policies.

## 3.9 Issues with exploiting marginal and idle land

Evidence considered in the course of this review has referred to various types of land 'potentially suitable' for bioenergy production. However, the way in which different studies have defined suitability varies making comparisons uncertain. Terms such as 'idle' and 'marginal' lands do not have internationally agreed definitions, though they are generally used to refer to the quality of land used and its suitability for agriculture. Idle land is sometimes used to refer to underutilized agricultural land, such as EU set aside land, but might also be used to refer to potential good quality land that has not been used previously. The carbon stock and sustainability value of such land may therefore vary considerably. Marginal or degraded land indicates land of lower quality with more challenging growing conditions.

Given the large degree of uncertainty on the level, availability and characteristics of land that is available for expanded agricultural production, the appropriateness of using idle or marginal land would need to be investigated on a case by case, site specific basis using agreed criteria together with consideration of potential conflicts with its current use. For example, in many developing countries waste lands are used for subsistence agriculture, or perform important ecosystem functions. With this in mind Woods and Black (2008) suggest criteria would need to consider whether the land is:

- Of low carbon stock;
- Of low biodiversity value;
- Of low value (cost);
- Capable of high productivity;
- In need of rehabilitation; and
- In an area where investment will support food production and wealth growth for local inhabitants.

The previous section demonstrates that the conversion of land to an agricultural use will very often result in a net increase in carbon emissions. There is therefore a tension between seeking to avoid indirect land-use change on the one hand, and the direct greenhouse gas impacts of actively directing production onto 'idle' and 'marginal' lands. This is a significant point and indicates that, for annual crops in particular, the opportunities to achieve greenhouse gas savings may be rather more limited than previously understood. Perennial crops, including palm for example, have the advantage that they will sequester carbon whilst they are growing as well as providing oil to produce fuel.

38 One example involves the potential development of biofuels in Mozambique, which is being stalled by infrastructure problems such as the need to build a bridge across a river. This construction would take time and make the project financially unattractive (Craig Jamieson, pers comm. 2008).

39 Themba 2008.

## 3.10 Encouraging production onto 'appropriate' land?

Searchinger and others have identified that using current agricultural land for biofuel production is likely to result in the existing demand being displaced, possibly causing land-use change with serious negative environmental consequences. If biofuels policies were to be redirected to deliberately target idle and marginal land and opportunities for appropriate intensification were taken up, the risk of indirect land-use change would be dramatically reduced. Significantly, such an approach would also give Governments and policy makers greater control over what form of land-use change occurs.

However, implementing and enforcing policies to target 'appropriate' land represents a significant policy challenge and would take considerable time and effort. In the first instance, a definition of appropriate land would need to be developed and agreed. In the course of developing the Renewable Transport Fuel Obligation sustainability guidelines, the concept of idle land was explored (Box 3.3)[40]

### Box 3.3: Current RTFO definition of idle land

"For the purpose of the RTFO, idle land is land which meets the following criteria:

- Compliance with all criteria of the RTFO Sustainable Biofuel Meta-Standard on carbon storage (criterion 1.1), i.e. no destruction of large carbon stocks may have taken place;
- Compliance with all criteria of the RTFO Sustainable Biofuel Meta-Standard on biodiversity (criteria 2.1/2.3), i.e. no conversion in or near areas with one or more High Conservation Values;
- Compliance with all criteria of the RTFO Sustainable Biofuel Meta-Standard on land rights and community relations (criteria 7.1/7.2), i.e. no violation of local people's rights; and
- On 30-11-2005, the land was not used for any other significant productive function, unless a viable alternative for this function existed and has been applied which does not cause land-use change which is in violation with any of the criteria for 'idle land'."

This may provide a suitable starting point for further work on agreeing a suitable definition for idle land. One of the many challenges will be in incorporating the temporal aspect into the concept, as what is idle today may not be tomorrow in a world in which demand for agricultural land for food is growing (and in an EU context in particular, what is in agricultural production for food today, may fall out of production tomorrow).

40 Ecofys (2008) "Sustainability reporting within the RTFO: framework report"

Ensuring that such land is utililized is very challenging. A global agreement on land use planning as part of a global climate agreement is the optimum solution, if strongly enforced. However, in the absence of such an agreement, extending the range of criteria within sustainability assurance schemes provides a possible mechanism, particularly if the criteria are mandatory as proposed in the Renewable Energy Directive. This is considered further in chapter 8.

## 3.11 Recommendations

- Biofuels policies need to require the utilisation of feedstock that does not cause a net additional pressure on current agricultural land. This includes use of appropriately defined idle agricultural land, marginal lands, wastes and residues and intensification of current production.
- Further work is needed to develop definitions for idle and marginal lands. Assessment tools must also be developed and procedures implemented to confirm the suitability of specific locations before any land change occurs. This should take into account:
  - The land's existing use;
  - The land's productive potential;
  - The net carbon impact of using the land for biofuels;
  - The land's existing environmental value; and
  - Social implications of its use for biofuels;
- Only a proportion of available idle land should be used for bioenergy production to manage the risk of indirect land change;
- The EU should reassess the amount of appropriate 'idle' land available within the EU to 2020, taking into account forecasts on increased demand for food and animal feed.

# 4. Advanced technologies

**Advanced technologies have significant potential, but may only produce biofuels with higher GHG savings if feedstock production avoids use of existing agricultural land that leads to indirect land-use change. This can be achieved using feedstock grown on marginal land or that does not use land, such as wastes and residues (although this may compete with other uses of these materials). Advanced technologies are immature, currently expensive and require specific incentives to achieve significant market penetration before 2020.**

Second generation or advanced biofuels (that do not use food crops to produce bioethanol through fermentation from starch or sugar crops; or biodiesel from oil crops) offer the prospect of enhanced greenhouse gas benefits from a wide variety of non-food feedstock. Because of this better GHG performance, assuming no emissions from land-use change and avoidance of direct competition with food crops, they have generally been regarded as superior to first generation technologies.

In general, GHG savings from advanced technologies producing ethanol are about 90% compared to petrol whilst syndiesel can generate savings in excess of 100% through co-generation of renewable energy (excluding emissions from land-use change). By avoiding direct competition with feedstock for food, feedstock for advanced technologies avoids direct food price increases. Although promising, advanced technologies can have similar limitations to current technologies. Specifically:

- If feedstock is grown on existing agricultural land it will still cause indirect land change and potentially increase food commodity prices;
- Since the whole plant tends to be used for biofuel production the co-products produced from advanced technologies tend not to avoid land use in the same way DDGS and other co-products do for current technologies;[41]
- The biofuels produced are expected to be, initially at least, more expensive than existing technologies.

To address these limitations, policies are needed to specifically encourage the supply of advanced biofuels that do not cause indirect land-use change. Specifically, incentives are needed for utilising feedstock that occupies land that is not required for other agricultural uses, such as marginal land; or uses wastes and residues. Table 4.1 summarises the key advanced technologies in terms of their development status, estimated GHG savings and the issues and challenges associated with commercial deployment.

41 It is important to emphasise advanced technologies may produce a range of valuable co-products such as other synthetic hydrocarbons or renewable electricity. However, these will not tend to offset much land use

**Table 4.1: Advanced Biofuel Technologies Overview**

| | Description of process | GHG savings | Development status | Issues and challenges | Deployment prospects |
|---|---|---|---|---|---|
| Lignocellulosic ethanol | Hydrolysis of lignocellulosic plant matter to fermentable sugars, followed by fermentation to ethanol | 76-81% reduction compared with gasoline[42]. Will vary depending on feedstock and technology. | Component processes at different stages of development. Steam explosion, acid/alkaline hydrolysis for pre-treatment well developed. Enzymatic hydrolysis and C5 sugar fermentation at the R&D-early demo stages. | Low cost enzyme production. Development of robust microbes. Demonstration of processes at scale, process control, plant design. Potential for integration of process with production of other fuels and fuel additives. | First commercial plants currently being built. Success with these likely to lead to construction of further plants before 2020. Continued financial support likely to be needed to 2020 as cost unlikely to fall enough to make the route cost competitive in this time period. |
| Syndiesel (BTL) | Gasification of biomass to a syngas consisting mainly of CO and H2. The syngas is reacted in a catalytic (FT) process at specified temperature and pressure to produce a range of liquid and gaseous transport fuels. | 93-96% reduction compared with diesel. Savings will vary depending on feedstock used (e.g. residues or energy crops). | Gasification technologies commercially available. Syngas conversion technologies (mainly from natural gas or coal) demonstrated at commercial scale. Little commercial experience of integrating biomass gasification with FT process. | Key issues relate to gasifier design, syngas quality, product selectivity in chemical synthesis, process integration and scale. Further R&D needed to determine plant configurations that will be technically and economically viable using biomass. Sourcing enough biomass to supply demands of plants at viable scale may be a challenge. | Demonstration plants already under construction, with significant amounts of private capital being invested. First full scale plants could be built before 2020 in Europe. |
| Hydrogenation | Hydrogenation of vegetable oils to produce a fuel product similar to diesel. | Savings similar to those from conventional biodiesel production | Early commercial – several companies use this process, e.g. Neste Oil. | This process is currently limited by the need for food based feedstocks and the fact that the GHG emissions savings are not any greater than for conventional 1G biodiesel. For economic reasons the route will probably need to be coupled to a refinery process. | Attractive as it produces a superior product that can be blended at higher levels at similar cost. However, this process still uses vegetable oils as feedstock making it less attractive than 2G biofuels which can be produced from wastes and residues. |

42 Calculated using JRC/EUCAR/Concawe (2007) http://ies.jrc.ec.europa.eu/wtw.html

**Table 4.1: Advanced Biofuel Technologies Overview *(continued)***

| | Description of process | GHG savings | Development status | Issues and challenges | Deployment prospects |
|---|---|---|---|---|---|
| Pyrolysis to transport fuels | Rapid heating of biomass in the absence of oxygen to produce a char, gas and organic vapours. Cooled gas forms an oil which can be upgraded and integrated into a conventional oil refinery. | Not possible to estimate as no agreed upon process by which transport fuels would be produced. GHG intensity will depend on feedstock and whether hydrotreating is part of the chosen process. | Biomass pyrolysis at the early commercial stage with relatively few small scale commercial plants in operation. The production of transport fuels through a pyrolysis process is still at the R&D stage. | Key issues include reactor design, oil quality improvement (reducing suspended chars, alkali metals, water and viscosity, increasing pH and improving oil yield), and optimisation of process relative to feedstock used. | Given this process is still at R&D stage with significant improvements and developments still needed, it is not expected that this route would have significant penetration in the global fuel mix by 2020. There may be some demo/early commercial plants under development by this stage. |
| Butanol | Fermentation of sugars from biomass to butanol. 30% higher energy content than ethanol. | GHG savings likely to be similar to ethanol. | Several companies working on this route, although unclear how close to a commercial process these companies are. | Key challenges relate to optimising the butanol yield, concentration and rate of process and the separation and purification process. | Those currently developing routes from sugar and starch feedstocks used in 1G plants anticipate their processes should be ready in 2010. |
| Algae | Culture of oil containing micro-algae, followed by harvesting of the oil and esterification to biodiesel. | GHG are unknown as there is no single agreed upon route; process is still very much at the R&D stage. | Route still at R&D stage. Although many companies claim they are nearing commercialisation there is little evidence of this so far. | Key challenges relate to developing micro-algae with high oil yields and economically culturing algae at large scales. | Given that micro-algal biofuels are still very much at the early R&D stage, it is not anticipated that this route will be commercial before 2020. |
| Non food 1G feedstocks | E.g. Jatropha | Emissions from route assumed to be similar to palm oil. | In the past the crop has been used for soap, candles and medicine. | Jatropha has not been grown on a large scale and it is not known yet whether the high yields quoted can be achieved. | India plans to convert >11Mha of wasteland to grow jatropha. Other likely regions are Southern Africa, SE Asia and Latin America. |

Commercial scale plants are unlikely before 2018 and market penetration rates are highly uncertain but could be increased by specifically focusing policy on encouraging investment in these technologies. Without specific incentives to encourage these technologies into the market, the rate of penetration is likely to be slow due to the higher costs associated with developing advanced technologies.

EU proposals within the Renewable Energy Directive propose to provide double incentives for specific technologies, such as lignocellulosic production techniques. To minimise the impact upon land-use change and avoid technology-prescriptive solutions it would be preferable to direct support mechanisms towards waste and residues and feedstock produced on marginal land rather than incentivise specific forms of technology.

A specific obligation on transport fuel suppliers to supply fuels produced from wastes, residues and feedstock grown on marginal land will encourage investment in these technologies and provide a mechanism to encourage production on marginal land.

Wastes and residues are particularly attractive feedstocks but will compete with other sectors, including heat and power generation. Analysis by Ecofys (2008b) highlighted that availability of EU wastes and residues is insufficient to meet proposed targets for electricity generation and heat. Whilst residue feedstock can be imported into the EU, this will raise costs and contribute to transport emissions. The use of agricultural or forest residues as biofuel feedstock will also have an opportunity cost since, in some instances, the GHG savings for heat and power may be better than for biofuels. A similar issue was recently identified in the use of tallow for biodiesel in an AEAT report[43] for the Department for Transport. This highlighted that the use of a limited feedstock, in this case tallow, for biodiesel production can lead, indirectly, to higher emissions in another sector (in this case, the oleochemical and meat rendering industries).

For advanced technologies to make a significant contribution to future supply of transport fuels, feedstock will need to avoid indirect land-use change through the use of waste products, sustainably produced residues or cultivation of energy crops on marginal land. The industry will need to develop both cost-effective processing technologies and sustainable, but relatively cheap, feedstock supply chains.

Strong market support, with carefully designed incentives, will encourage second generation technologies that can utilise appropriate feedstock with genuine environmental benefits. Learning lessons from the introduction of current generation biofuels would indicate that a steady increase in second generation production is desirable in order that the effects can be monitored and managed.

The EU has suggested that by 2020 advanced fuels could make a contribution of up to 30% towards the proposed 10% target. Given the current stage of development of technologies this appears optimistic. Furthermore, a rapid expansion in production of advanced technologies has risks and opportunity costs given questions about the most appropriate way to use wastes and residues. A further detailed assessment of the possible market penetration by 2020 is needed to evaluate how constraints on feedstock will affect the development of the market and the proposed specific obligation will stimulate investment. Based upon current evidence a market share of 1-2% by energy of transport fuels by 2020 seems feasible. A higher target market penetration may be possible but will require technology to develop, and new feedstock supplies to be identified, more rapidly than currently envisaged. Further detailed work is needed before firm targets should be set.

43 AEA 2008c

## 4.1 Recommendations

- There should be a specific obligation on transport fuel suppliers to supply biofuels achieving a high level of GHG saving (possibly greater than 75%) from:
  - Appropriate wastes and residues;
  - Feedstock grown on marginal land; and
  - Other technologies and feedstocks that avoid indirect land change (for example algae).
- The EU needs to determine how increasing targets for heat, power and renewable transport fuels compete for wastes and residues and how this competition should be managed;
- Further work should be undertaken to assess how a specific obligation, and constraints on feedstock, will affect the development of the market for advanced biofuels. This should be used to refine a target range for 2020;
- Current evidence indicates an achievable target range for 2020 to be of the order of 1-2% by energy of road transport fuels;
- The European Commission should propose a technology-neutral approach within the EU Renewable Energy Directive to incentives for advanced technologies, focusing on feedstock type and type of land on which it has been produced.

# 5. Quantifying greenhouse gas emissions from indirect land-use change

**Current lifecycle analyses of GHG-effects fail to take account of indirect land-use change and avoided land use from co-products. As a consequence:**

- **GHG-based targets may result in a greater land requirement, and land-use change, than a volume or energy-based target; and**
- **Second generation biofuels using feedstock grown on existing agricultural land may cause greater net land-use change than first generation biofuels that also produce co-products that avoid land use.**

**Quantification of GHG emissions from indirect land-use change requires subjective assumptions and contains considerable uncertainty. The role of co-products in avoiding land-use change requires further examination.**

## 5.1 Uncertainties in quantifying indirect land-use changes

To date, most analysis of the GHG effects of biofuels has focused upon deriving the carbon intensity of the fuel on a field to forecourt basis. More recently, some assessments, such as those required by the RFA as part of carbon and sustainability reporting linked to the UK RTFO have taken into account direct land-use changes from conversion of pasture or forest. Few analyses to date have sought to quantify indirect land changes. This chapter examines the current state of the art and limitations of these approaches.

There is considerable uncertainty regarding the type, scale and timing of indirect land changes and, therefore, how we measure and account for these changes in assessments of the GHG savings that biofuels may offer. These uncertainties arise from the:

- Complex global nature of agricultural markets and uncertainties in predicting the effect of increased production for biofuels;
- Potential for feedstock switching (i.e. where a biofuel can be produced from a variety of feedstocks, there is potential for producers to switch their feedstock crops more frequently than would otherwise be the case). This potentially leads to increased land-use change and is a feature of the oil seed market;
- Production of co-products; and
- Commodity price changes.

To quantify GHG-emissions arising from land-use change, the following must be determined:

- The type of crop that has been displaced;
- The type of land-use change that occurs as a consequence of the displaced crop; and
- The amount of carbon released arising from land-use change.

This range of factors creates high levels of uncertainty in the calculation of the GHG-emissions for biofuels.

## 5.2 Partial equilibrium modelling

Searchinger has arguably undertaken the most sophisticated analysis to date of the GHG implications of using existing agricultural land to grow biofuels. This applied a model of agricultural markets and linked the outputs to estimates of GHG emissions arising from land-use change. An outline of the approach is described in Box 5.1.

### Box 5.1: Searchinger et al 2008

The analysis by Searchinger used a partial equilibrium model of agricultural markets (CARD) to quantify the increased demand for land arising from US corn ethanol targets. Modelled changes in maize and other commodity prices were used to calculate changes in demand. Assuming constant land productivity, additional demand for land was calculated that was allocated between uncultivated land in the US and primarily Brazil, India and China. The type of land conversion in each country was derived based upon historic data and GHG emissions from land conversion estimated using the GREET model.

Searchinger's analysis concluded that when indirect land-use change emissions were quantified and taken into account, the emissions for US maize had a payback period of 167 years (that it would take 167 years for the GHG benefits of biofuels derived from US maize to be realised when the emissions from indirect land-use change were taken into account). The study has been invaluable in highlighting the risks and potential impact of indirect land-use change. There has, however, been considerable expert debate concerning the validity of the findings. Notable identified limitations include:

- The capacity of the partial equilibrium models to predict, with sufficient precision, global future feedstock demand and locations of supply;
- Future land productivity including price-induced yield increases;
- The credit that should be attributed to certain biofuels where their production process creates useful co-products (that might avoid land-use change);
- The extent to which policy on land-use change might influence the rate of land-use change in the future; and
- Insufficient recognition of the uncertainties in the amount of GHG emissions that occur following land-use change.

More recently, Plevin et al. (2008) have examined the uncertainty in the Searchinger et al findings and assumptions. This found that, including indirect land-use change, the estimated GHG emissions of maize ethanol at a 95% confidence interval (with emissions amortised over 30 years) were 73 – 150g $CO_2$/MJ and the average value 107g $CO_2$/MJ was still worse than emissions from petrol (c90g $CO_2$/MJ).

The Plevin et al. analysis also shows 96% of the emissions occur in 5 regions: Latin America (30%), United States (23%) South East Asia (21%), China/India/Pakistan (13%) and Africa (9%). A sensitivity analysis indicates 42% of the variance (uncertainty in the calculation) arises from uncertainties in the area changes estimated in the economic modelling and 43% from estimates of the carbon content of the vegetation.

The Plevin et al. analysis has not been able to take account of all the uncertainties in the Searchinger approach. Notably, the discussion acknowledges that the model of market mediated land-use change emissions is incomplete and that the influence of price-induced yield increases and anticipated yields for feedstock grown on marginal land are not adequately taken into account. The paper also notes it is not possible to include in the assessment the effect of trade policies. This review has been unable to definitively assess the accuracy of the Searchinger calculation for the GHG emissions arising from US maize ethanol. The evidence however indicates that US-maize ethanol does lead to net GHG emissions compared to petrol and indirect land-use change effects can be significant.

Attempting to translate Searchinger findings to other biofuel feedstocks adds further layers of uncertainty. For example; there are notable differences between US and EU biofuels policies and feedstock including:

- Different objectives for supporting biofuels – US-policy is focused on addressing security of supply; EU policy aims for a combination of GHG saving, security of supply and rural development;
- Feedstock and biofuel types – US production is predominately maize-ethanol; EU is predominately rape seed biodiesel; and
- Fiscal policy – US-fiscal policy for biofuels is more generous than that in most EU-member states.

It is, therefore, difficult to draw definitive conclusions on the precise impact of indirect land-use change on EU feedstocks or targets. This is because of the complexity of the relationship between a huge number of variables and the extent of scientific and statistical uncertainty.

Whilst the scale of the effects of indirect land-use change is too uncertain to model accurately, the effect certainly reduces, and may in some cases eliminate, the GHG benefits of biofuels. For some feedstocks, the effects can also potentially lead to a significant net increase in emissions. These effects cannot be ignored in either calculations of the carbon intensity of biofuels or the construction of biofuels policy.

## 5.3 The iLUC[44] Factor Approach

In contrast to econometric and analytical approaches to determine indirect land-use change risks, a deterministic approach has been developed by the Oeko-Institut. The approach has been proposed to enable potential GHG emissions from indirect land-use change to be incorporated into regulatory policy.[45] Originally known as the "risk adder"[46] the approach has recently been renamed to the "iLUC factor"[47] to reflect its applicability for both providing credits and debits for GHG savings for different feedstocks (Box 5.2).

44 Indirect Land-Use Change

45 Fritsche 2008 Personal Communication

46 Fritsche 2007; Fehrenbach, Fritsche and Giegrich 2008

47 Fritsche 2008

## Box 5.2: The iLUC factor

The approach of the Oeko-Institut considers that *all* arable land used for *additional* (incremental) biomass feedstock production will induce indirect land-use change risks due to displacement, but that the risk is small and can be ignored for feedstock produced from wastes and on degraded land and also on set-aside and idle land, as well as biomass feedstocks derived from intensified land use (higher yields). This is entirely consistent with approaches proposed in this review.

The iLUC factor is derived by considering the *potential* release of GHG from land-use change caused by displacement to be a function of the land used to produce agro products *for export purpose* on the basis that only trade flows will be affected by displacement. The approach assumes countries increase feedstock production in response to global supply and demand. The additional land demand is estimated in a *deterministic* approach.

Assumptions are made about the likely type of land-use change and emissions calculated using the regional land-use shares for agro commodities. From this, an average $CO_2$ emission factor per hectare of displaced land can be derived, and discounted over a time horizon of 20 years. A "full" iLUC factor would have to be applied if the risk of displacement is 100%. The authors suggest that in practice the risk will be lower for feedstock produced on idle land, through intensification of existing cultivation schemes and use of marginal land, etc. An *indicative* order of magnitude for the iLUC factor is given below,with a "minimum" assuming 25% of all non-zero risk biofuels are subject to the iLUC factor, "medium" meaning a 50% share of non-zero risk feedstocks, and "maximum" for the 75% level of the iLUC factor.

### Life-Cycle GHG Emissions of Biofuels and Impacts from Indirect Land-Use Change

| | kg $CO_{2eq}$/GJ with iLuc factor | | | relative to fossil diesel/gasoline | | |
|---|---|---|---|---|---|---|
| | including conversion/ by-products, without direct LUC | | | including conversion/by-products | | |
| biofuel route, life-cycle | max | med | min | max | med | min |
| Rapeseed to FAME. EU | 260 | 188 | 117 | 201% | 118% | 35% |
| palmoil to FAME, Indonesia | 84 | 64 | 45 | −3% | −25% | −48% |
| soyoil to FAME, Brazil | 101 | 76 | 51 | 17% | −12% | −41% |
| sugarcane to EtOH, Brazil | 48 | 42 | 36 | −44% | −52% | −59% |
| maize to EtOH, USA | 129 | 101 | 72 | 50% | 17% | −16% |
| wheat to EtOH, EU | 144 | 110 | 77 | 67% | 28% | −11% |
| SRC/SG to BtL, EU | 109 | 75 | 42 | 26% | −13% | −51% |
| SRC/SG to BtL, Brazil, tropical | 34 | 25 | 17 | −61% | −71% | −80% |
| SRC/SG to BtL, Brazil, savannah | 59 | 42 | 25 | −32% | −51% | −71% |

**Source: Fritsche (2008)**

The iLUC factor approach suggests no net savings for biodiesel from rapeseed oil, and only small savings for ethanol from maize and wheat for the "minimum" iLUC factor. With a medium level of 50% risk to induce indirect land-use change, rapeseed, wheat and maize will not be reducing GHG emissions. For a high level of the iLUC factor, only ethanol from sugarcane, and 2nd generation BtL would still allow a GHG reduction.

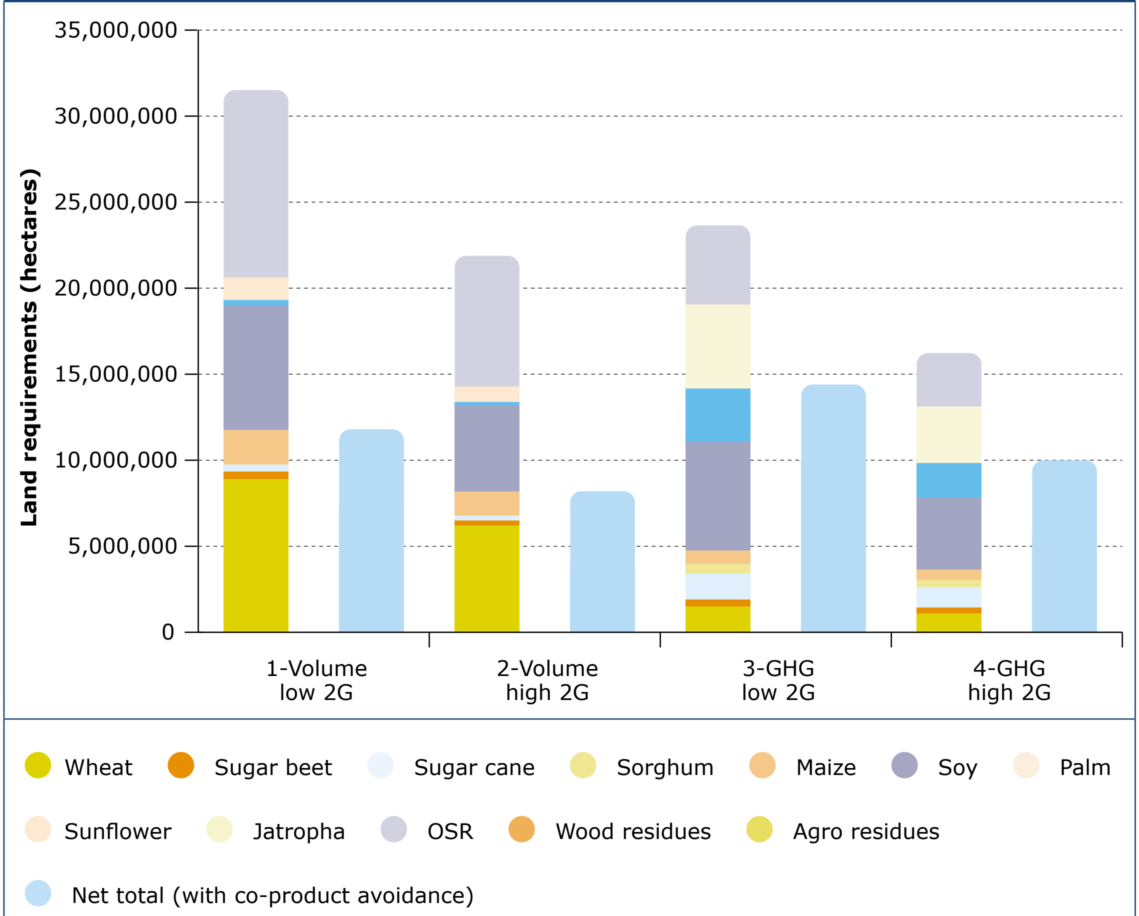
The iLUC factor is derived by considering the *potential* release of GHG from land-use change caused by displacement. These are derived using a function of the land used to produce agricultural products *for export purpose* on the basis that only trade flows will be affected by displacement. This key assumption ignores the extent to which biofuels drive higher commodity prices that potentially stimulate indirect land-use change.

The authors acknowledge that the iLUC factor approach is still being discussed and is under development, and could be refined further to reflect more specific situations than global averages. It provides further evidence of the likely scale of the indirect effects but at this stage requires further refinement and development before it could be used as a regulatory tool.

## 5.4 The effect of co-products on land use requirements

Analysis by Ecofys 2008b conducted for this review illustrates the gross and net land requirements of meeting the EU 10% 2020 target with and without a high penetration of advanced technology (Figure 5.1).

**Figure 5.1: Land requirement for different EU biofuel scenarios**




*The scenarios shown are to deliver the 10% target with no and 3% advanced technologies. The GHG target is a direct comparison requiring the same amount a feedstock but with a policy oriented towards GHG saving.*

This illustrates that a volume-based target, with no advanced technology, results in the highest land demand (31.5 million hectares) if avoided land-use is excluded from the analysis. This is largely for oil seed rape (OSR), soy and wheat. If the avoided land demand that is realised through the use of co-products is included, the total land requirements are significantly reduced to 11.9 million hectares. A high contribution from second generation biofuels, (produced from wastes and residues) results in a 30% reduction in land required to meet the volume-based target. If feedstock for advanced technologies was produced on agricultural land, the net GHG benefits would be smaller due to emissions arising from cultivation and net land demand greater – increasing the indirect land-use change.

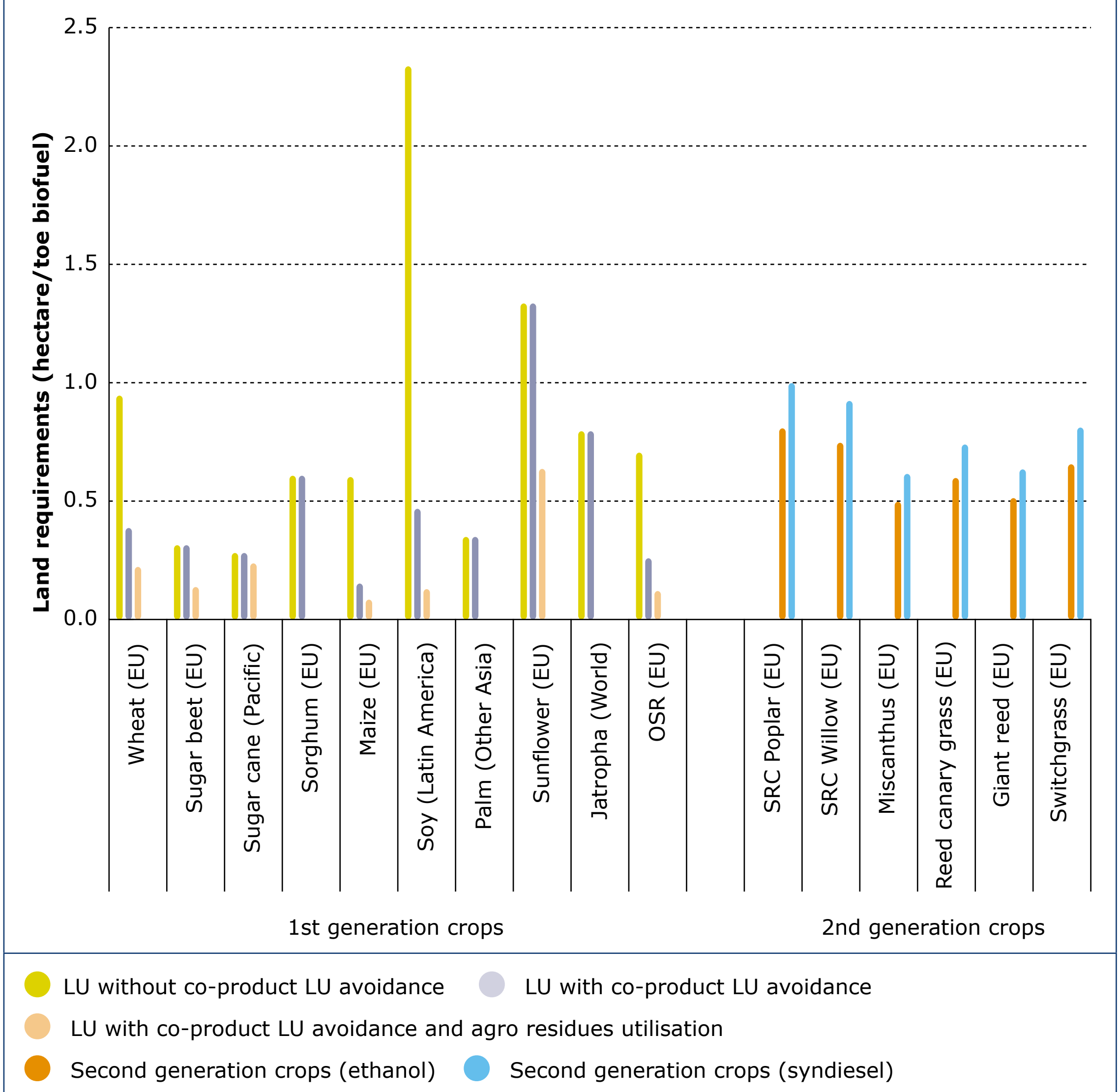
The GHG reduction scenarios assume the same total supply of feedstock and result in a 25% lower *gross* land requirement (c34Mha) than the equivalent volume based target. However, the *net* land requirements of the GHG based scenarios are higher than that of the volume based scenarios (12 and 14 Mha respectively). This is mainly caused by the higher shares of wheat, maize and oil seed rape (ODR) in the volume based scenarios. These crops produce more co-products than sugar cane, oil palm and jatropha, which are potentially important feedstocks in the GHG-reduction scenarios.

Figure 5.2 (Ecofys 2008b) illustrates the number of hectares required to produce one tonne oil equivalent of biofuel from different feedstocks for three cases:

- Without avoided land use from co-products;
- With avoided land use from co-products; and
- With avoided land use from co-products and use of agricultural residues.

This figure illustrates the importance of incorporating avoided land use from co-products into the assessment and value of using agricultural residues. For example, the land requirements of soy biodiesel are lowered from about 2.3 ha/toe to around 0.1 ha/toe because soy yields much more meal than oil for biofuel. Wheat also shows a large decline in land requirements due to land-use avoidance made possible by the use of distillers dried grains solubles (DDGS).

**Figure 5.2: Hectares required to produce one tonne of oil equivalent of biofuel from different feedstocks**




*For each feedstock the left bar indicates the hectares required if co-products are not taken into account. The middle bar indicates the hectares required if co-products are taken into account. The third columns shows the hectares required if also the straw is used to produce ethanol, which further reduces the land requirements.*

The figure shows that most first generation crops outperform the second generation energy crops, if co-products and straw utilisation are considered. For second generation energy crops, no co-products are anticipated *which would offset significant land demand*. These crops will produce a range of other valuable co-products including those which allow significant renewable electricity production. These are not captured within an assessment of land use but could be within a carbon intensity calculation, although their carbon offsetting effect is smaller than for land use.

The analysis indicates that co-products have a significant impact on land use requirements for biofuels. The scale of the effects will depend upon the substitutions adopted in the co-product analysis, which are detailed in the study by CE Delft (2008). Further sensitivity analysis to determine whether the effects remain as pronounced if alternative substitutions are adopted are needed to confirm the findings.

## 5.5 Overall findings

Figure 5.2 emphasises the importance of using feedstock for advanced technologies that does not lead to indirect land-use change. This is because the scale of indirect land-use change is potentially larger for second generation crops (compared to first generation crops) – if they are grown on existing agricultural land. Further work is necessary on a range of co-products and substitutions to confirm this preliminary finding.

A lifecycle analysis of a biofuel that fails to take account of indirect land-use change and avoided land use from co-products may lead to feedstock switching, in particular in favour of palm oil and sugar cane. This switching would cause additional demand for land and potentially increased land-use change and higher emissions. The boundary of lifecycle GHG calculations for biofuels will therefore need to be extended to include:

- The well to tank GHG emissions of the biofuel;
- Emissions arising with direct land-use change;
- Emissions arising from indirect land-use change (including effects arising from substitution of waste or residue feedstock used in other applications – such as tallow); and
- Avoided indirect emissions from the use of co-products.

This is a significantly more complex calculation than is currently used but is necessary to reflect a realistic view of the overall lifecycle GHG-emissions of biofuels.

Two methodologies are presented in this review; one using partial equilibrium modelling and the other a deterministic approach to derive quantitative estimates of indirect land-use change. Both approaches contain significant uncertainties and rely upon a range of assumptions. The review concludes that, at the present time, neither approach is suitable for use as a regulatory tool to incentivise biofuels – although both provide a valuable insight into the scale and nature of indirect effects and both support the evidence that indirect effects are significant. In the absence of adequate tools to quantify indirect effects, the review concludes a way forward is to seek to minimise the risks of indirect land-use change through directing biofuel production onto idle and marginal land or using non crop-based feedstock. Further work is urgently needed to continue to develop quantitative assessment tools that provide the optimum solution to ensuring only biofuels with a good GHG saving are produced. In the meantime, more prescriptive approaches constitute an appropriate risk management measure.

## 5.6 Recommendations

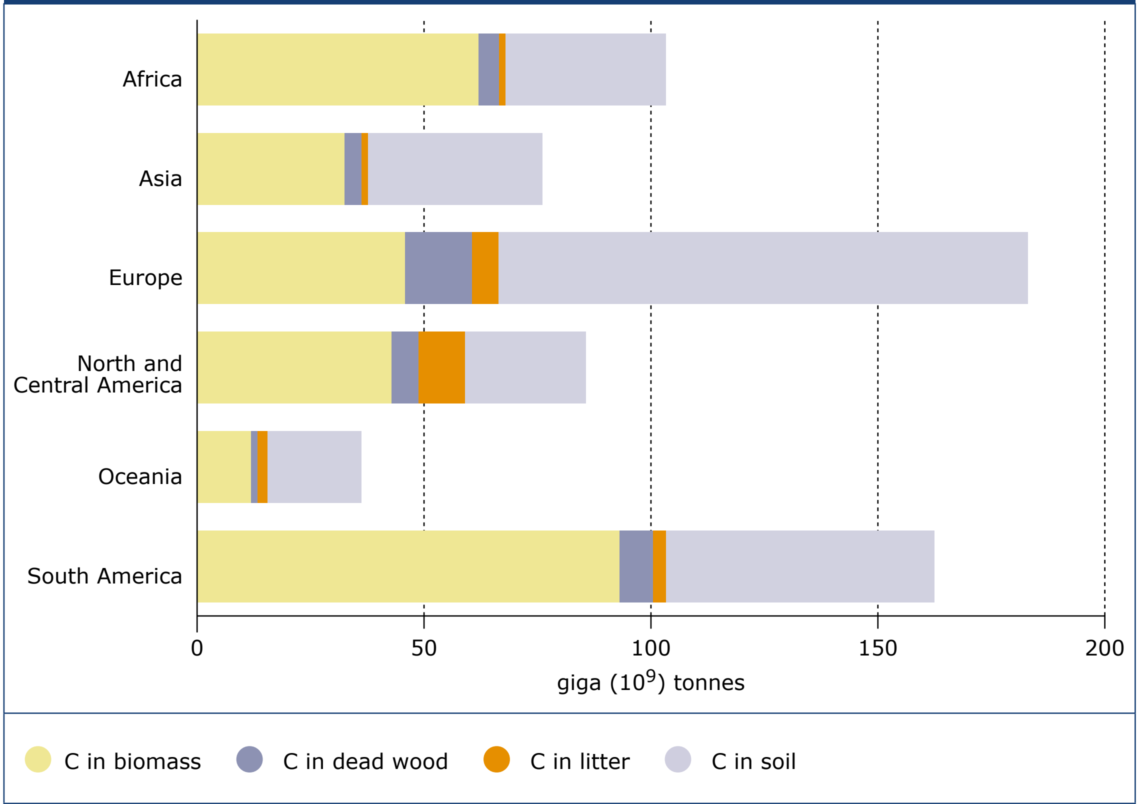
- Basing incentives and targets for biofuels on their GHG savings remains the optimum policy approach but should only proceed once the implications of indirect effects and avoided land use from co-products have been fully explored and adequately incorporated into calculation methodologies.
- Urgent further work is needed to enable incentives and targets for biofuels to be based upon lifecycle greenhouse gas emissions that include:
  - Indirect land-use change;
  - Avoided land use from co-products;
  - Effects of competition for limited wastes and residues; and
  - Potential additional carbon sequestration from utilising marginal land.
- The European Commission should specifically consider the findings with respect to avoided land use from co-products as part of the on-going design of the Fuel Quality Directive and the mandatory threshold for GHG savings proposed in the Renewable Energy Directive.

# 6. Reducing pressure for land-use change, particularly in forested areas

**Lower targets for biofuels and shifting production to idle and marginal land will reduce pressure for land-use change. Stronger policies are needed to slow rates of deforestation particularly in South America, Africa and parts of South-East Asia.**

Forests provide a wide range of environmental and ecological benefits. For example, they are crucial natural habitats; they conserve soil and water; supply wood and non-wood products; can have key social functions and are a huge carbon sink. Carbon stored in forests is estimated to be 638 GtC[48] (divided fairly evenly between biomass and soils and litter). This is of a similar magnitude to that in the atmosphere. Figure 6.1 (FAO 2005) shows the total carbon stock in forests by region.

**Figure 6.1: Total carbon stock in forests by region 2005**

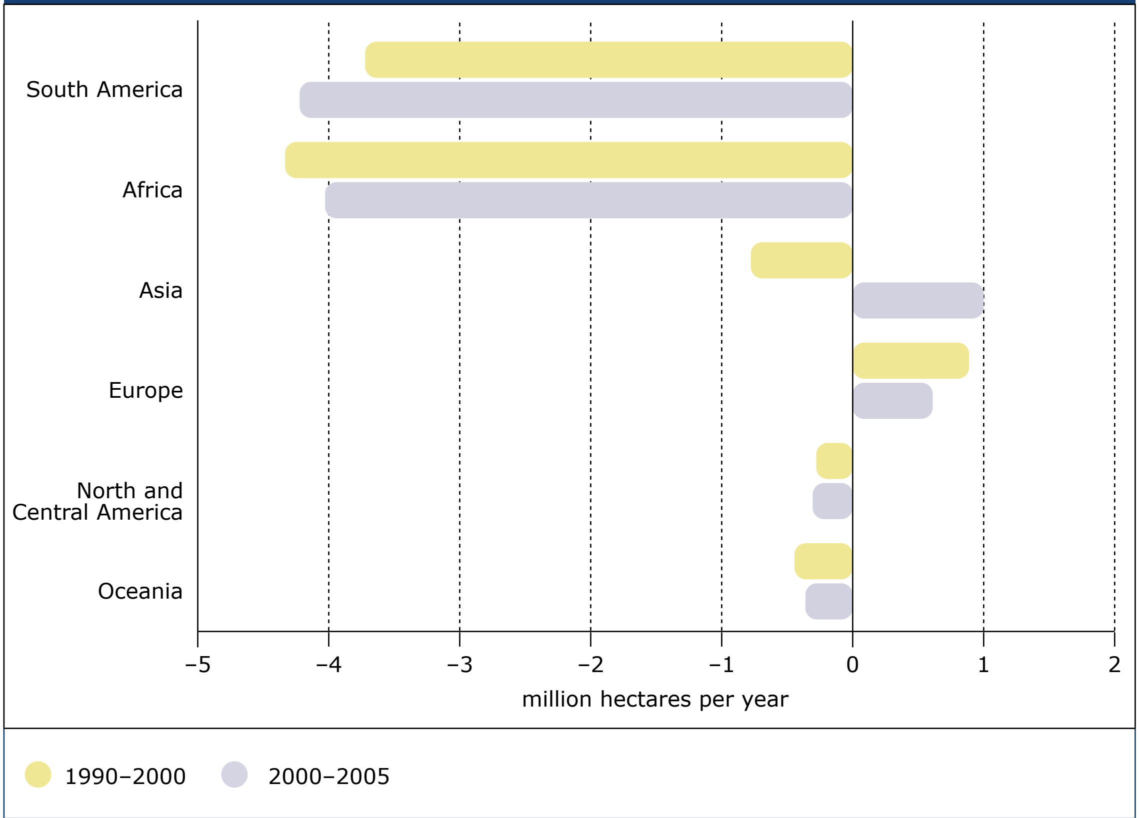



Protecting and, where possible, expanding forest (particularly in degraded and marginal areas that will not lead to indirect effects) is a key element of climate stabilisation. The 10 countries with two-thirds of global forest area are key to preserving existing forest. Global rates of deforestation slowed from 2000 to 2005 but are still over 4 million hectares per annum in Africa and South America. Brazil and Indonesia were jointly responsible for two-thirds of the global net loss in forest from 2000 to 2005.

48 FAO 2005, Global Forest Resources Assessment 2005

The FAO estimate about 13 million hectares of the world's forests are lost annually due to deforestation, but the rate of net forest loss is reducing due to new planting and natural expansion of existing forests[49]. Between 2000 and 2005 the annual net loss of forest area was 7.3 million hectares per annum (about the area of Panama) down from 8.9 million hectares between 1990 and 2000. This represents a net loss of 0.18% of the world's forests annually. The greatest losses are in South America (4.3 million hectares per annum) followed by Africa (4 million hectares per annum). Reforestation in China led to a net gain of 1 million hectares per annum in Asia as a whole although losses in South-East Asia remain rapid. Brazil and Indonesia were responsible for 42% and 26% respectively of the net loss of global forest (Figure 6.2).[49]

**Figure 6.2: Annual net change in forest area by region 1990-2005**




There are significant uncertainties in emissions arising from deforestation, but the IPCC estimate that deforestation contributes about 8 gigatonnes of carbon dioxide equivalent. This equates to about 18% of total global carbon emissions in 2004. Emissions from deforestation have risen since 1990 and bringing these under control is an essential element of climate stabilisation.

There are a range of drivers of deforestation but demand for agricultural land is one of the most significant. On a global basis increased demand for land for food and feed (200-500 million hectares by 2020) will continue to cause a greater proportion of land-use change than the additional land demand for biofuels. This demand is estimated to be between 56-166 million hectares (section 2). Although biofuels use only about 1% of current arable land, their marginal effects may be more important, particularly in specific high risk locations such as where there are huge releases of soil carbon from peat soils or loss of high value conservation areas. A sustainable biofuels policy is important but will only contribute to reducing the land pressures that lead to deforestation. To be more effective, the issue of land-use change must be appropriately integrated in the next global climate agreement. In

49 FAO 2005, Global Forest Resources Assessment 2005

addition, specific incentives to reward countries preserving forests and an extension of sustainability assurances schemes to all agricultural production are needed. These issues are being specifically considered by the Eliasch Review[50] (Box 6.1) and are, therefore, outside the scope of the Gallagher Review.

### Box 6.1: The Eliasch Review

The independent Eliasch Review is due to report to the Prime Minister in Summer 2008 on the role of international finance mechanisms to preserve global forests in tackling climate change. It will specifically consider:

- What would be the mitigation costs of reducing deforestation and associated policies to reduce carbon emissions significantly, and how could the carbon market and/or public funding meet these costs?
- If forests were included in a carbon market, how would it operate to ensure that carbon emissions were reduced?
- How are multilateral funds currently used to address deforestation, and how could they be made more effective?
- How can forest carbon be efficiently and accurately measured and monitored? Can carbon be used as a proxy for other ecosystem services?
- What capacity-building is needed in developing countries to access international finance, and how can that finance best ensure that poverty reduction goals are met?

The challenge of obtaining global agreements to preserve forest and other high value carbon or conservation areas must not be underestimated. Systems to effectively implement and enforce the agreements will prove equally challenging. It is, nevertheless, clear that significant growth in the bioenergy sector and in biofuels specifically can only be contemplated once these controls to manage the risks of indirect land-use change are demonstrated to be effective.

## 6.1 Recommendations

- Mechanisms for crediting foregone land-use change need to be incorporated into the next global climate agreement to discourage countries from deforesting areas of land;
- Carbon and sustainability certification used for biofuels should be extended to all agricultural activities over time;
- Significant increases in the use of land for bioenergy, and biofuels specifically, should only be contemplated once effective controls are implemented at a global level. This is to avoid indirect land-use change causing significant GHG-emissions or destruction of high value conservation areas; and
- Sustainability standards should also be extended beyond biofuels to all agricultural production.

50 http://www.occ.gov.uk/activities/eliasch.htm

# 7. Commodity prices, food security and economic impacts

**Increasing demand for biofuels contributes to rising prices for some commodities, notably for oil seeds. In the longer term this has a net small but detrimental effect on the poor that may be significant in specific locations. Shorter-term effects are likely to be significantly greater. Lower biofuel targets and directing production onto idle land reduces these negative impacts. There is some potential for the poor to benefit from biofuel production in some areas where the land is available and where the necessary infrastructural investment is forthcoming. This might be accelerated by policy directing sustainable production onto suitable idle and marginal land.**

## 7.1 Effects of biofuels on global prices

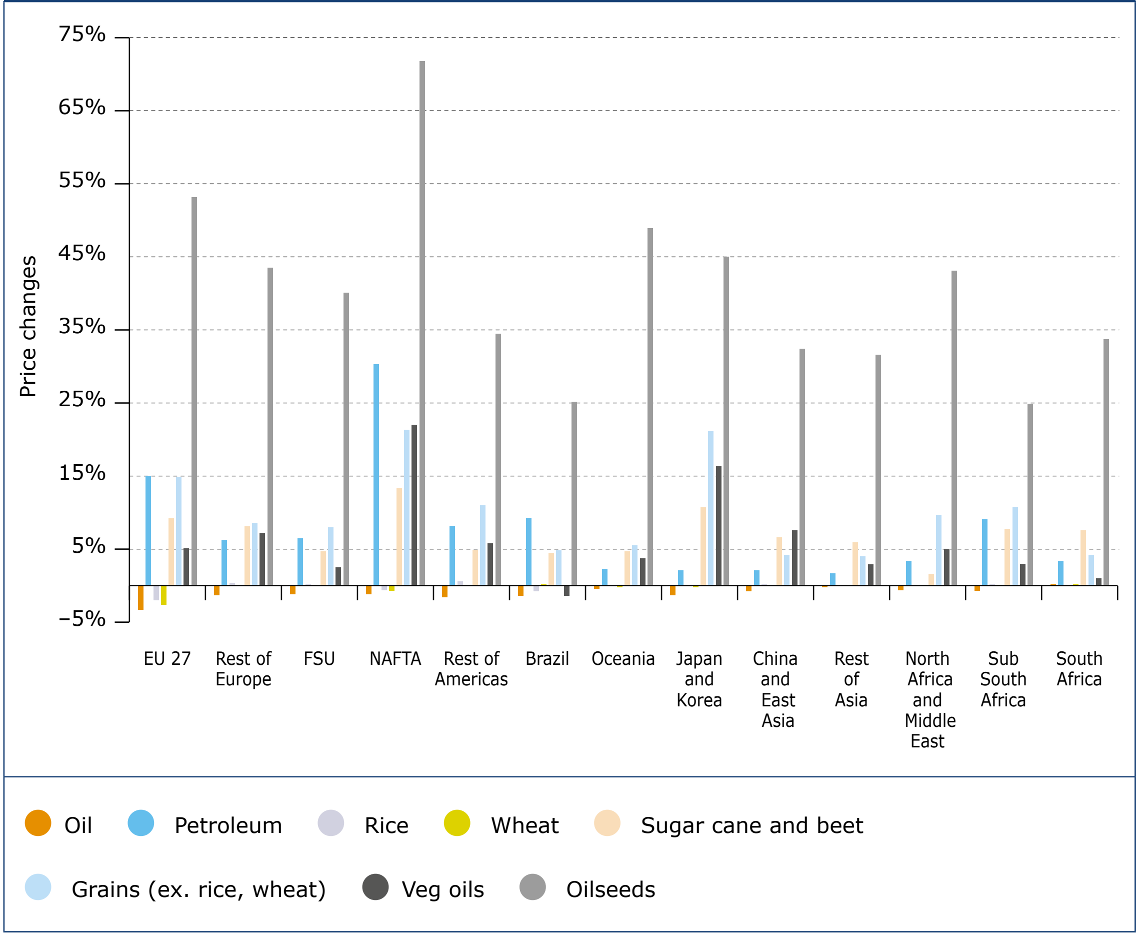
Modelling studies of the effects of expanded biofuels production on world agricultural commodity prices generally show increases, but the scale of the effects varies widely. General equilibrium models allow for almost complete adjustment throughout the economy to the initial stimulus, and hence while patterns of production, consumption and trade may change substantially, price effects are often quite small. Partial equilibrium models allow less adjustment of production and consumption, especially across sectors of the economy, with the result that prices bear the weight of adjustment and thus move considerably more.

Partial equilibrium models provide an indication of short run responses, particularly where market imperfections and friction prevent price adjustments. The results of a recent IFPRI[51] study suggest price increases of between 16 and 43% at best and between 30 and 76% at worst, depending upon the commodity.

51 International Food Policy Research Institute – www.ifpri.org/

General equilibrium models provide a better reflection of price rises in the medium-term, to 2020, where markets operate well. The observed rises are smaller and vary between feedstocks. For most crops, price rises are rarely more than 5%. However, price rises for potential feedstock crops like oilseeds, maize and sugar cane are much higher, up to 72% in one region, but generally lower than the IFPRI projections. Figure 7.1 (ODI 2008) shows the general equilibrium view of projected increases assuming that the EU and North America replace 10% of their vehicle fuels by biofuels.

**Figure 7.1: Changing prices from biofuel expansion, general equilibrium view**




Both modelling approaches contain limitations and there is a need for further model enhancement to improve predictions of market responses.

## 7.2 Effect of prices rises on consumers

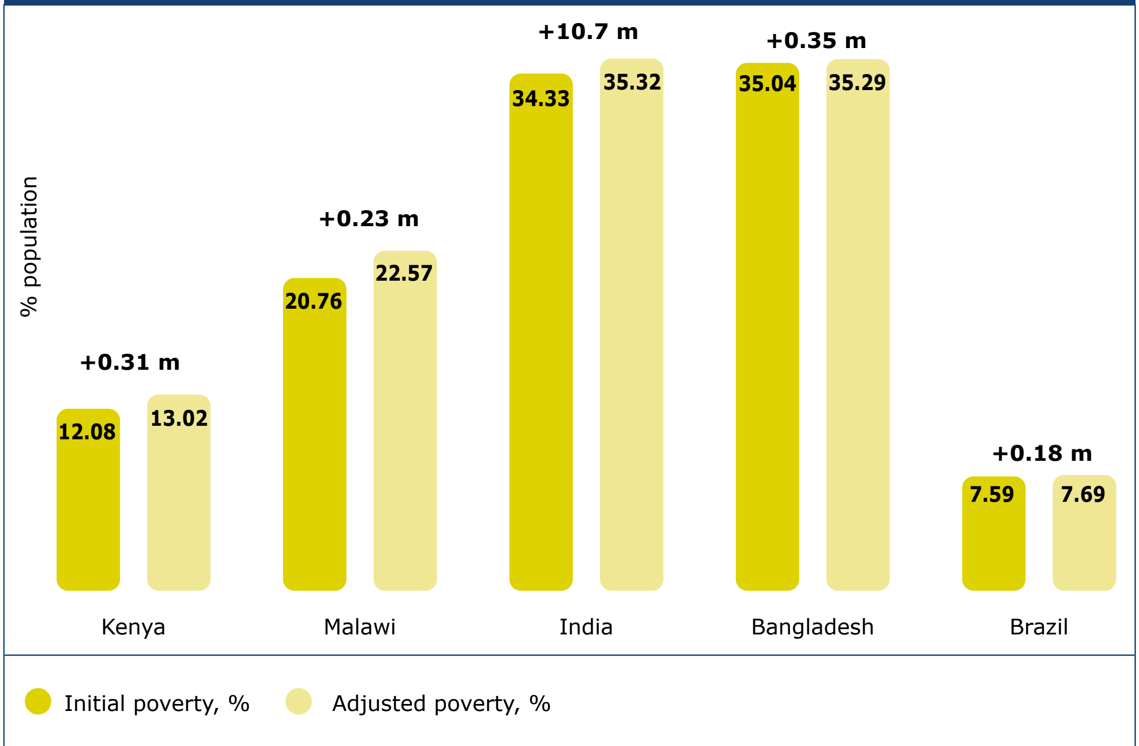
In the developing world, when food prices rise, the greatest effect is felt by the poor (since they spend more of their income on food). The urban poor are more greatly affected as they are less likely to reap some economic benefits from biofuel industry. Families and communities may have to cut their consumption of food, potentially increasing instances of malnutrition.

While these effects are clearly negative, they are not normally large. Ivanic & Martin[52], examined the impacts on households living close to the poverty line. They found that a 10% rise in the main categories of food prices raises poverty in their sample of nine developing countries by 0.4%. In the worst affected country, Nicaragua, the increase in poverty was 2% and urban households were more affected than those in rural areas. Some case studies indicate that there are significant variations in the effects on the poor within certain countries with some poor being significantly affected by rising prices. Furthermore, some of the largest countries with the most malnourished persons, such as India, have rice as a staple and some models predict virtually no effect by biofuels on rice prices. The overall effects of biofuels on the poor will, therefore, be negative but small, with some instances of significant effects.

A simple analysis was undertaken by the Overseas Development Institute of the effect of the projected price increases on the cost of food. The models used considered the implied reduction of real income and resulting changes to poverty headcounts in five selected developing countries. In their results, food bills increased by small amounts, at most 2%, with much lower impacts in countries where rice is the main staple.

Figure 7.2 (ODI 2008) shows poverty headcounts rise in all cases, although always by less than three percentage points.

**Figure 7.2: Impact of projected price rises on poverty in selected developing countries[53]**




Box 7.1 discusses the role of another driver of increasing food prices – speculation.

52 World Bank working paper no. 4594, April 2008.

## Box 7.1: The role of speculation in food price increases

In the last 3 months prices for wheat, corn, soybeans, rice and oats have all reached record highs. In the last year the price of rice has risen by 118%, wheat by 95%, soybeans by 88% and corn by 66% reaching all time high levels. A range of factors, including biofuels, are responsible for rising food prices, but market speculation has, to date received relatively little attention.

Futures prices play a valuable role in agricultural commodity markets. They are used by farmers to guide planting decisions and reduce spot market price fluctuation risks. They equally provide a basis for co-operatives to commit to purchase members products; and enable dealers to trade contracts and manage risks. A healthy futures market is an important element of a functioning agricultural commodities market.

Recently non-traditional users of futures markets have significantly increased their investment in commodities including index and hedge funds. Speculators buy futures contracts for commodities at a low price hoping that the market will rise and sell on at a profit. But there are now concerns the scale of the interventions has distorted the market such that these no longer reflect supply and demand conditions.

AgResource Co[53] estimated index fund investment in grain and meat has increased 5 fold to over $47bn in the past year. Speculative positions in the Chicago maize market are currently three times anticipated stocks for the end of the 2008/09 season (as forecast by the US Department of Agriculture).[54] The US Commodity Futures Trading Commission held a recent roundtable on agricultural markets to examine whether further controls were necessary. It has delayed immediate action but continues to monitor the markets closely.

Some futures traders argue since they never take delivery of the crop they cannot affect street prices but this ignores the affects on short term market volatility, a feature of the current high prices. In these circumstances speculative price rises lead to a positive feedback loop in which prices rise far above the underlying value of the commodity creating an economic bubble that eventually bursts and prices crash. Jian et al[55] found that increases in futures trading volumes increase cash-price volatility in major agricultural commodity markets. George Soros, the renowned financial speculator and investor is quoted as saying "You have a generalised commodity bubble due to commodities having become an asset class that institutions use to an increasing extent."[56]

Jee-hoon[57] has estimated a combination of the weak dollar and speculation has been responsible for 57% of the recent price rises in commodities. India has moved to control speculation on agricultural commodities and Head of the UN Environment Programme Achin Steiner is quoted as saying "the way that markets and supplies are currently being influenced by perceptions of future markets is distoring access to that food."

This review has only been able to touch upon this issue that requires further thorough examination by the Treasury and international action where abuses are identified.

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53 www.independent.co.uk/environment/green-living/multinationals-make-billions-in-profit-out-of-growing-global-food-crisis-820855.html)

54 Abengoa 2008, Javier Salgado, World Biofuels Congress, Seville, http://www.planetark.com/dailynewsstory.cfm/newsid/48379/story.htm

55 Jian Y, Balyeat BR, Leatham DJ. Futures trading activity and commodity cash price volatility. J Business Finance Accounting 2005; 32: 297–323.

56 Noemi Pace, Andrew Seal, Anthony Costello, 2008 Food commodity derivatives: a new cause of malnutrition? www.thelancet.com Vol 371 May 17, 2008.

57 Jee-hoon L. Why raw material costs soared and what it means for the world. JoongAng Daily April 7, 2008. http://joongangdaily.joins.com/article/view.asp?aid=2888329 (accessed May 8, 2008).

## 7.3 Opportunities for the poor to benefit from biofuels production

ODI 2008 also considered the opportunities for the poor to benefit from growing biofuels. There have been few previous studies in this area and the analysis was therefore based on potential gross margins for smallholders growing three potential feedstocks. These were: sugar cane for ethanol; palm oil and jatropha for biodiesel as shown in Figure 7.3.

**Figure 7.3: Gross margins, returns to labour in biofuel feedstock production**

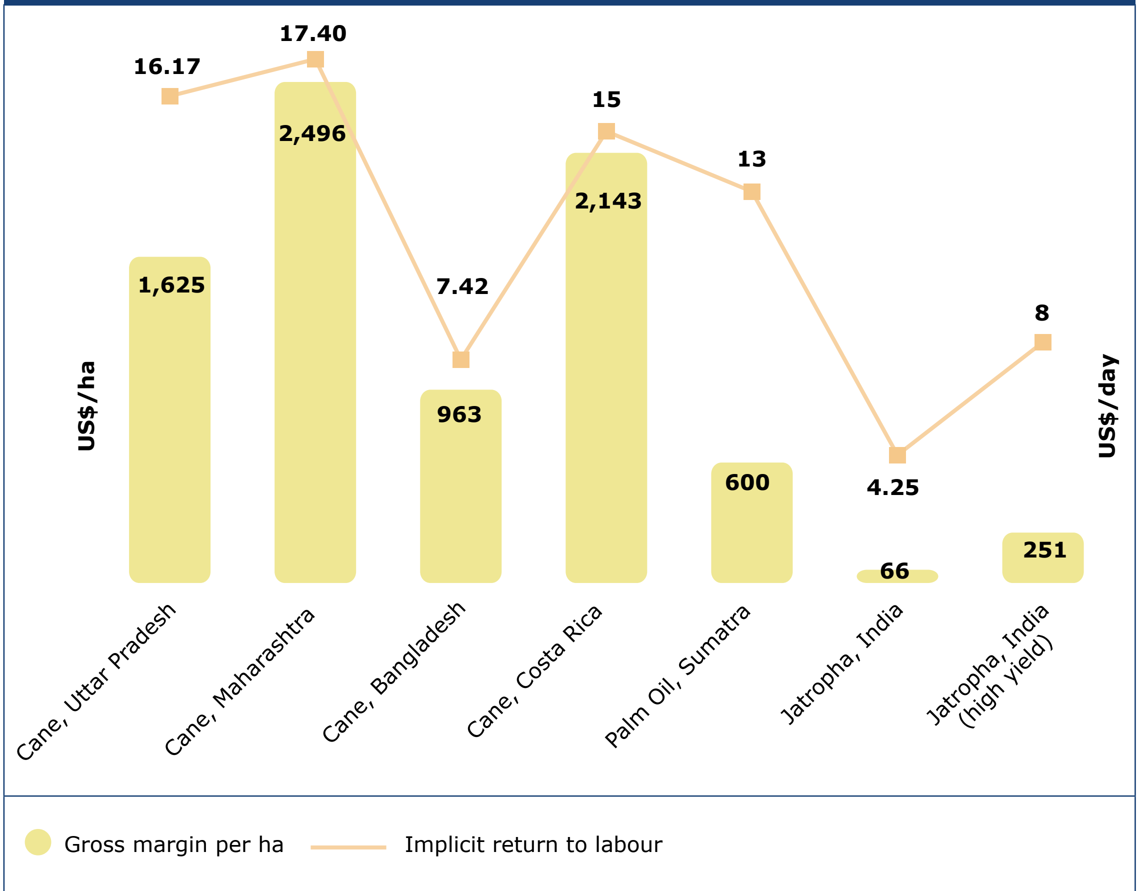



Figure 7.3 shows that growing sugar cane to ethanol potentially gives excellent returns. In countries with available land suitable for cane, there may be good opportunities for the poor whether they are small farmers, field labourers or working in downstream processing.

Oil from palm gives similarly attractive returns, but it may be that its parity price for use in biofuel is below the price offered for uses in other industries. The reasons for the boom in palm oil plantations are clear but opportunities for smallholders are limited by the fairly demanding requirement for rainfall or irrigation.

Jatropha, sometimes seen as an ideal feedstock since it can grow on marginal land and does not compete with food crops, shows more marginal returns. Much depends on the yields obtained, and experience so far has been that yields achieved in practice have been below those expected. Jatropha may not be the complete solution that has been widely expected, but it may have an important role in some niches – for example, in serving local energy needs.

General equilibrium modelling provides some support to the existence of opportunities, showing that returns to the unskilled labour force rise slightly in some parts of the developing world. For the poor to benefit from biofuels production, large-scale investments will be needed for establishing the necessary infrastructure e.g. the processing, collection and distribution networks.

Governments with an interest in realising the potential of biofuels as a stimulus to development need to establish consistent and coherent policies and establish a framework of regulations to facilitate this. A key challenge is to link the big investors to small rural producers. Contract farming, in which processors advance inputs to small farmers in return for the right to buy the crop, is one way to do this. Capacity building is a key need as it is difficult to design functioning schemes as a blueprint.

## 7.4 Effect of biofuels on national economies

The main effect on national economies will be due to increased import bills for foods whose prices have risen from the expansion of biofuels. The rising cost of food imports will reduce gross national income. For most countries the effects would be small, less than 1% even if the overall price rise were as much as 10%: but there are some low-income food deficit countries that could see falls of more than 1%, including Armenia, Côte d'Ivoire, Egypt, Eritrea, Ghana, Guinea, Haiti, Honduras, Lesotho, Malawi, Mongolia, Senegal and Uganda.[58]

## 7.5 Social impacts of biofuels

Biofuels initiatives should be sensitive to conditions of local level governance such as rights to land, crops and trees, and take into account the views of local stakeholders. There is some evidence that attractive prices for some biofuel feedstock, especially palm oil, has led to land grabbing and the involuntary displacement of people. Such problems arise with many cash crops, and not just those that are potential feedstock for biofuels.

Governments need to assign clear rights to land and police violations, civil society organisations can publicise abuses and help the poor to defend themselves, and responsible private enterprises can set standards and follow codes such as those of the Roundtable on Sustainable Palm Oil (RSPO).

## 7.6 Recommendations

- Biofuels targets and policies should be constructed to ensure long-term impacts on food prices do not significantly disadvantage the poor. For example, this could be achieved by focusing production away from existing agricultural land except where this is made possible by intensification;
- International, short-term, targeted assistance should be provided to reduce the effects of the current spike in food commodity prices on the poorest;
- Social criteria, including land rights, should be incorporated within biofuels sustainability requirements; and
- Targeted support to develop biofuel feedstock production should be directed to Southern Africa, Latin America and parts of South-East Asia where the existence of underused arable land offers considerable potential for biofuels to realise economic benefits.

58 The general equilibrium model shows that overall effects on economies in the developing world are also small: Sub-Saharan Africa would be the worst affected region in the developing world, with reductions of gross domestic absorption — a measure of economic output — of up to 0.3%.

# 8. The direction of policy

**Mechanisms do not yet exist to accurately measure, or to avoid, the effects of indirect land-use change from biofuels. Consequently, the net GHG emissions from current biofuel targets cannot be assessed with certainty, and there is a risk that any biofuel target could lead to a net increase in GHG emissions. The assessments underpinning the EU 2020 10% target and RTFO did not adequately address indirect land-use change. A framework to prevent biofuels causing land-use change has been proposed but is challenging and will take time to develop. The practical details, implementation and enforcement regime, need to be defined and will determine the overall effectiveness of the approach. In the meantime the rate of introduction of biofuels should be slowed.**

## 8.1 Policy options

The evidence presented in this report indicates there are three possible directions for a biofuels policy focused upon delivering GHG-savings:

1. **Stop or freeze –** If the risks of biofuels are too high, and there is little potential to establish a genuinely sustainable industry, all support should stop, or targets be frozen, until new evidence emerges and/or adequate controls are introduced to ensure that biofuels are genuinely sustainable;
2. **Slow down –** If the risks are high, but biofuels offer potential, the growth in market penetration of biofuels should be slowed until adequate controls are put in place;
3. **Business as usual –** If the risks are considered manageable the expansion of the industry can continue to develop as proposed with stronger controls implemented over time.

## 8.2 The business as usual option

Although there are significant uncertainties, the balance of evidence within this review clearly shows that the potential risks of biofuels could outweigh their benefits. Notably:

- With current, and currently planned controls, it is not presently possible to direct biofuel feedstock production onto land that will not cause indirect land-use change that may offset any GHG-benefits from the biofuel;
- There is a significant risk that a continuation of current policy will not lead to a net reduction in GHG-emissions and could cause an increase;
- Current requirements to manage direct effects address only a limited range of sustainability criteria;
- There are uncertainties over global land availability for food, feed and bioenergy; and
- The evidence indicates that biofuels contribute to food price increases that disadvantage the poor.

These risks will not be addressed if a business as usual approach is adopted which will rapidly increase the proportion of biofuels in the market. As part of this review, Ecofys (2008) examined the European Commission's impact assessment of meeting its proposed 10% renewable energy from transport target. This found that the impact assessment did not take into account the effects of indirect land-use change in evaluating the target. This omission further calls into question the basis for the current 10% (by energy) target.

The RTFO policy was also established before evidence of the scale of possible indirect effects was known. This proposes to increase biofuel supply to 5% by volume (equivalent to about 4% by energy) by 2010. Although the UK has been at the forefront of mechanisms to encourage the sustainability of biofuels, the current system is immature and not yet proven. The UK Government has announced its intention to move to mandatory sustainability criteria and the EU Renewable Energy Directive has proposed some sustainability requirements. These restrictions are unlikely to come into force before 2010 and do not, currently, address indirect effects. Given the complex global nature of the indirect effects, developing and implementing effective controls will be extremely challenging and take several years.

Based upon this evidence the RFA have concluded that there is a significant risk the current policy will not deliver its intended objective of significant net GHG-emissions savings. Accordingly, the RFA believe it would be unwise to proceed with the introduction of biofuels in the manner, or at the pace, presently envisaged. The remaining sections focus upon examining the evidence regarding and implications of either:

- Stopping the introduction of biofuels;
- Freezing the level of biofuels in the market at the present levels (2.5% by volume in the UK envisaged for 2008/09); or
- Proceeding with a slower rate of increase of biofuels into the market – and the proposed manner and level of any increase.

## 8.3 The option to stop or freeze support for biofuels

In the light of recent evidence that emphasises the potential negative effects of biofuels, there have been calls for an immediate stopping or freezing of government support for biofuels. The new evidence presented in this review provides some support for these calls. However, a moratorium - either the removal of all support or a freeze on the current levels of fuels in the market - would have a number of implications. Specifically, a moratorium is likely to lead to a stagnant, unprofitable industry that is less prepared and able to invest in new technologies or source feedstock that does not cause land-use change. The biofuels industry is already severely affected by:

- High feedstock prices;
- Difficulties attracting investment due to the tightening in global credit;
- Loss of investor confidence concerning ongoing subsidies resulting from questions regarding their sustainability; and
- Unfair competition with subsidised US exports.

This is already limiting the industry's ability to attract investment and has led to some instances of plant closures. An EU-wide moratorium is also likely to lead to a further increase in fossil fuel prices (due to the additional demand created from the removal of biofuels) with knock-on impacts for both food prices and the poor. A moratorium on biofuels could also discourage much needed investment in agriculture that is required to address increasing global food demands and to encourage the development of a more productive agricultural system. This could have particular benefits for the poor in the medium and long term.

Evidence presented within the review also indicates that:

- Biofuels have the potential to reduce greenhouse gas emissions in the transport sector if land-use change can be avoided;
- There are good prospects for innovation and technological development that may lead to increased GHG savings from advanced technologies; but these developments are unlikely to enter the market in the short or medium term without specific market drivers;
- The balance of evidence is that there is sufficient land available for bioenergy production (though this is not certain). There are, however, significant challenges in utilising suitable land, and the GHG-benefits may, in many cases, be lower than previously anticipated; and
- Progressive policy measures to avoid land-use change could be developed, but remain to be practically demonstrated and will take time to develop, implement and enforce.

The RFA has concluded, on balance, that a moratorium will reduce the ability of the biofuels industry to invest in new technologies or transform the sourcing of its feedstock to the more sustainable supplies necessary to create a truly sustainable industry. It will make it significantly more difficult for the potential of biofuels to be realised.

However, to manage the risks inherent in the current policy a much more cautious growth in the biofuels market is required than currently envisaged by the UK RTFO and EU Renewable Energy and Fuel Quality Directives. This is to ensure that the amount of biofuel entering the market is limited until appropriate controls are in place to guarantee the GHG-benefits of biofuels and adequately address wider sustainability concerns. The future growth of biofuel supply should then be dependent upon the industry delivering sustainability performance milestones, including those that take account of indirect land-use change.

## 8.4 The proposed way forward

The terms of reference for the review (Annex A) asked the RFA to advise on appropriate targets. The available evidence does not support a definitive answer due to the many uncertainties in the available data and information. Appropriate future targets cannot be set on an entirely scientific quantitative basis – although neither were current targets. The RFA has therefore used its expert judgment to describe a possible pathway to a demonstrably sustainable industry linked to delivery of biofuels with an increasingly improved sustainability performance that includes managing indirect land use. From this we are able to derive estimates of what we consider are appropriate levels of biofuel in the market to 2020. Decisions on both targets and supporting measures to ensure sustainability ultimately require political judgements that this review has sought to inform.

Within the time available we have only been able to propose a possible framework through which the market for biofuels can develop and other approaches may be possible. Each of our proposals requires refinement and consultation but provides a useful starting point for necessary consultation.

## Transforming the market for current technologies

The current biofuel industry sources much of its feedstock from crops grown on existing agricultural land through international commodity markets. In many cases this is likely to cause indirect land-use change and makes tracking the extent to which feedstock sustainability criteria are met extremely difficult. This review has proposed to reduce the risk of indirect land-use change by shifting crop-based feedstock production to idle land that would not otherwise have been used for food production; or, land made available as a result of productivity improvements (plus appropriate waste oils and fats and marginal land). Action to promote the shift to production on idle land is needed at an EU-level and eventually internationally. The UK should begin this process by amending the current carbon and sustainability requirements within the RTFO to require reporting of production on idle and marginal land from 2009/10 that will assist in the process of establishing robust definitions. Requirements for sourcing feedstock from idle land should be made mandatory, through the EU Renewable Energy Directive.

Shifting production onto idle land will require robust criteria to be developed that define appropriate idle land. It will also require site specific assessments, certification schemes and the development of a robust chain of custody to demonstrate that feedstock has been grown accordingly. These systems are all envisaged as part of the Renewable Energy Directive, and are in the early stages of implementation in the UK's RTFO. Managing indirect land-use change therefore can be affected by including additional criteria within the Renewable Energy Directive. We should emphasise, however, that defining idle and marginal lands (and appropriate wastes and forms of intensification) and implementing the scheme will be much more challenging than the current sustainability systems. The proposed arrangements for bilateral agreements, supported by rigorous monitoring, could provide a basis for ensuring feedstock from outside the EU complies with these requirements.

The RFA suggests that the increase in biofuels required by the EU is slowed whilst measures to promote demonstrably sustainable renewable fuels are developed and implemented and further data and analysis is conducted. For the UK, we suggest an increase of 0.5% by volume per annum (from the present 2.5%) up to a maximum of 5% by volume in 2013/14 (equivalent to 4% by energy). This would maintain the UK Government's current commitment, whilst slowing the rate of increase in biofuels and reducing the risks whilst adequate controls are put in place. To complement and coincide with the 2011/12 EU review of member states' progress on biofuels targets, it is recommended that progress on sustainability is also reviewed. During the period to 2011/12, comprehensive, mandatory sustainability criteria within the EU Renewable Energy Directive should be implemented for biofuels and bioenergy, including requiring feedstock that avoids indirect land-use change.

Operation of equivalence trading arrangements, such as already operates within the RTFO carbon and sustainability reporting scheme and EU Energy Crops Scheme, could provide market flexibility.

The different levels of biofuels currently being supplied in EU Member States presents a challenge for harmonised policy. It is not anticipated that many EU Member States are likely to achieve a level of biofuels more than 4% by energy in the next few years. One approach would therefore be for the European Commission to propose that no Member State goes beyond the 2010, 5.75% (by energy – around 7% by volume) target until biofuels are demonstrably sustainable – but that Member States that wish to be more cautious could supply up to 4% (by energy).

An assessment should be made by the European Commission, by 2013/14, of whether policies to shift production of biofuels to be demonstrably sustainable have been successful. In the case that the controls are not found to be sufficiently robust, or that the policy was not succeeding in its objective to reduce GHG-emissions, or that the effects on food prices were unacceptable, no further increase in biofuel supply would be permitted until these issues were resolved.

If measures were successful, a further increase in supply of biofuels could proceed. This approach provides the industry with a level of market certainty and license to operate in return for meeting sustainability criteria, including those for indirect land-use change. The approach provides the time necessary for governments to work with industry to develop, implement and test the robustness of the framework. It would also enable scientists and other experts to gather and analyse further data to narrow the bounds of uncertainty.

By 2020, this approach would lead to between 4% and about 6% by energy (between 5 and 7.5% by volume) of current generation biofuels, with the upper level triggered only by a demonstrably sustainable market which avoids indirect land-use change. If towards the end of the decade further evidence emerged to indicate that it was safe to move faster, it might be possible for an accelerated trajectory to be followed that increased the rate of penetration of the biofuels beyond that suggested.

### Stimulating the market for advanced technologies

This review has also highlighted the importance of developing supplies of feedstock for advanced technologies that avoid competition with food production entirely, including use of appropriate wastes and residues, feedstocks grown on marginal land (unsuitable for food production) and options such as algae. These technologies have been on the horizon for some time, but have consistently been '5 to 10 years' away from commercial deployment. Given the technical and economic challenges of developing new technology and logistic and agronomic challenges of sourcing feedstock sustainably, we suggest that the EU Renewable Energy Directive should drive the development and deployment of these technologies more directly than is currently proposed, by requiring an element of the proposed EU target to be met from such processes.

The RFA propose that the Renewable Energy Directive should include a specific obligation for feedstock grown on marginal land, using wastes and residues or non-crop based feedstock, possibly starting in 2015. By 2020, the Directive should stipulate that this obligation should have increased to 1-2% (by energy). A firm date for the introduction of the obligation, how it should operate and the annual increase in the target require more detailed consideration – but the proposed approach provides an appropriate framework upon which consultations and assessments could proceed.

Identifying appropriate marginal land for biofuel production will require site specific assessments, ideally undertaken before the development of the land for biofuel cultivation. These would specify how the site should be prepared in order to minimise impacts on carbon stocks, on biodiversity and on local communities. In this respect it would be similar to the type of process employed to assure CDM[59] projects. The plantation would be provided with certification of its appropriateness to supply feedstock to meet the specific obligation.

59 http://cdm.unfccc.int/index.html

The obligation for production using specified advanced feedstocks should allow a 'buy-out' option providing suppliers with a choice whether to meet their targets in any given year or make payments in proportion to their shortfall in meeting the target. The advantages of the buy-out mechanism include:

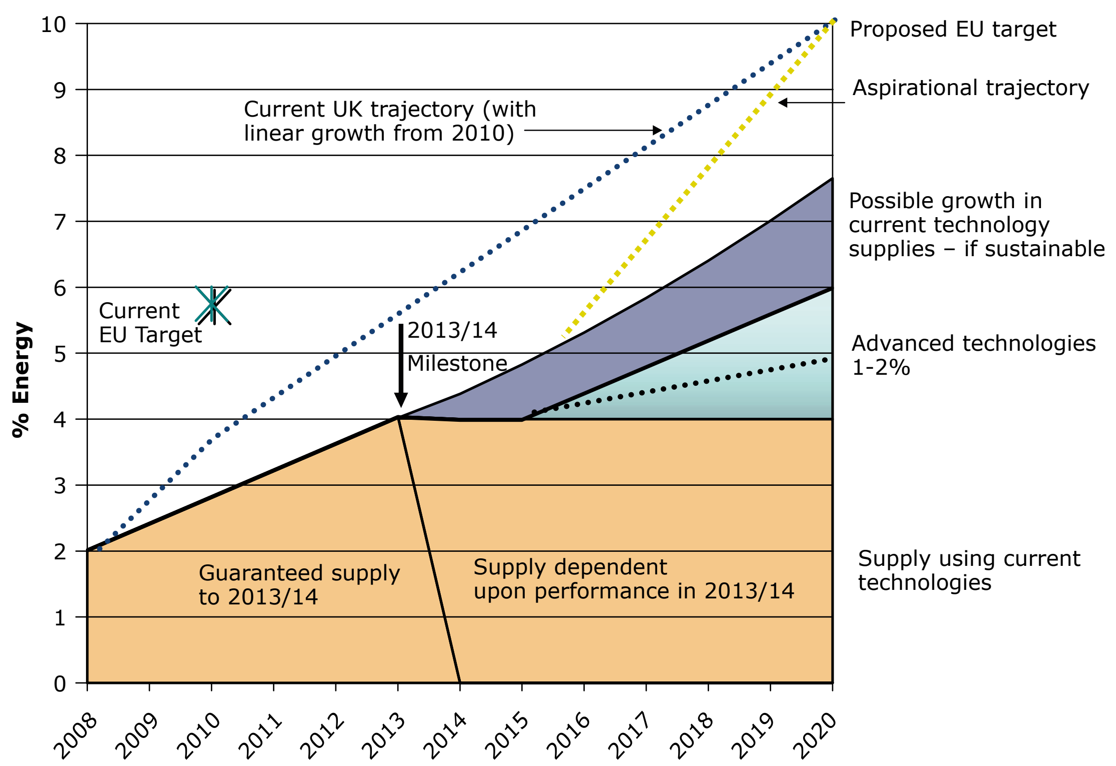
- Placing a cap on the overall cost of renewable fuels;
- Enabling the renewable fuels market to respond to market signals, such as significant increases in feedstock (i.e. food) prices;
- Providing an alternative option in the case that sustainable fuels are not available in sufficient quantity; and
- Providing an alternative option in the case that sufficient technological development has not been forthcoming.

The latter point is significant for the additional 1% to 2% target we propose for renewable fuels that will, in the main, require significant innovation and advances in technology. A buy-out price, set at an appropriate level, would both provide industry with a clear economic signal to invest in R&D, and also a clear penalty framework in the case that targets were missed. The obligation model decreases the level of certainty about the extent of the market for renewable fuels in any given year. However, we consider that provided the buy-out is set at an appropriate level it should provide sufficient certainty to deliver a sustainable market whilst offering the significant advantages set out above.

## 8.5 Overall targets

Figure 8.1 illustrates how these proposals might interact. The orange section provides a guaranteed market for renewable fuels to develop whilst control measures are introduced. This is shown rising to 4% by energy (5% by volume) by 2013/14. Supply after 2014 would be dependent upon the performance of the industry in meeting sustainability criteria (including those for indirect land-use change).

**Figure 8.1: Proposed trajectory of EU policy**



The green section illustrates the proposed mandatory obligations on fuel suppliers to supply fuels made from feedstocks grown on appropriate marginal lands or derived from appropriate wastes and residues or other advanced processes (e.g. algae). This commences in 2015 rising to 1-2% by energy by 2020.

The blue section shows how the market for current technology might develop beyond 2013/14 if measures to ensure the sustainability of biofuels supplied proved successful including in avoiding indirect land-use change.

The level of the EU target for 2020 has become the primary focus of debate on biofuels policy. However, it is the availability of appropriate land and the success (or otherwise) of ensuring that only sustainable feedstocks, that use appropriate land and processes, are used that will determine the appropriateness of the level. The net effect of the RFA proposals is a target range of about 5-8% by energy by 2020 depending upon how effective the controls are and how quickly the market for advanced technology can develop.

In the event that a globally sustainable market emerged rapidly and new evidence indicated that it was safe to do so, it might be possible to accelerate the rate of introduction of the fuels to achieve a higher target level than 8% by 2020. This aspirational trajectory is illustrated by the yellow dotted line commencing in 2016 and rising to 10% by 2020. Supply of biofuels to this level would only be possible if comprehensive controls are effective to avoid indirect land-use change and prevent damaging increases in food prices. This may require:

- Establishing effective controls to manage deforestation and account for emissions from land-use change, such as within an effective global climate agreement;
- Comprehensive and enforced sustainability standards that ensure wider social or environmental impacts of biofuels are managed;
- Further evidence that sufficient land available is available to meet demand for food, feed and bioenergy beyond 2020 recognising further population increases and the onset of climate change; and
- That advanced technologies deliver high levels of GHG-savings and efficient use of land.

As previously indicated, the RFA supports the replacement of volume or energy based targets with comparable GHG-saving targets as soon as possible and to incentivise the supply of fuels with a lower carbon intensity. However, further analysis is required to better understand the overall implications of such a move given the new evidence on the possible increased land requirement for GHG-based target scenarios and role of co-products. If such a methodology can be developed a less prescriptive approach to specifying the type of feedstock, and where it has been grown, could be employed. This would use specific GHG-based criteria to determine minimum levels of performance and additional incentives for better GHG-performance.

## 8.6 Recommendations

- The current RTFO target for 2008/09 should be retained but the RTFO Order amended to require a lower rate of increase of 0.5% pa rising to a maximum of 5% by volume by 2013;
- The C&S reporting should be revised to include idle and marginal land and increasing targets set for companies for the proportion of feedstock that demonstrably does not cause indirect land-use change. These targets should be made mandatory (along with other sustainability criteria) as soon as possible;

- Mandatory sustainability criteria within the EU Renewable Energy Directive should be strengthened and consistently implemented for biofuels for transport and heat and power. This should include requirements for biofuel feedstock to avoid indirect land-use change;
- To complement and coincide with the 2011/12 EU review of member states' progress on biofuels targets, it is recommended that progress on sustainability is reviewed in 2011/12;
- Until biofuels are demonstrably sustainable, including addressing indirect land-use change, the European Commission should not allow Member States to supply more than 5.75% (by energy) of biofuels; and allow more cautious Member States to supply biofuels to 4% (by energy);
- Progress to higher targets for current technologies should only be implemented beyond 2014 if biofuels are demonstrably sustainable, including avoiding indirect land-use change;
- A second obligation to produce feedstock from appropriate wastes, residues and production on marginal land should commence in 2015. A target of 1-2% by 2020 is proposed but should be subject to further detailed consideration along with the buy-out price;
- A lower EU 2020 target is proposed in recognition of the risk of indirect land-use change and absence of adequate control measures. A target range of 5-8% (including 1-2% from advanced technologies) is suggested with the higher target triggered only if milestones in 2013/14 are met. Higher targets, up to 10% (by energy) might be possible if sufficient controls are enforced globally on land-use change and new evidence provides further confidence that the effects upon food prices are manageable. An accelerated rate of biofuel introduction should not be introduced before around 2016;
- Biofuel targets should not be mandates but obligations with an appropriate "buy-out" price set; and
- The Fuel Quality Directive should not imply a higher level of biofuels than suggested for the Renewable Energy Directive.

# 9. Addressing uncertainty

**Large areas of uncertainty remain in the overall impacts and benefits of biofuels. International action is needed to improve data, models and controls to understand and to manage effects.**

The study has highlighted the need for further work in a range of areas. Overall, better quality data is required to accurately model and assess land-use change and its impacts. The timescales of this review have constrained the analysis and research that has been possible (see Annex B). Further work is needed to obtain a more comprehensive understanding of the indirect effects and to enable these to be translated into impact assessments of future policy recommendations.

The range and scale of the uncertainties require action at the international, regional, national and local level. For example; improved understanding of land use requires satellite imagery with improved resolution that can only be made available through international activities. Enhancements to the RTFO's carbon and sustainability reporting methodology are the responsibility of the RFA. The areas of further work, level of the organisation that needs to take a lead (international, EU or UK), and priority are tabulated in Table 9.1.

## 9.1 Recommendations

- There should be an urgent meeting of international experts to consider the findings of the study along with other recently published research and take forward the suggestions for further work given here. This workshop should focus upon the areas of uncertainty highlighted by the review;
- The Government should seek to take forward, or encourage others to initiate, the further work indicated in the supporting table.

**Table 9.1: Summary of principal areas of further work**

| | International | EU | UK |
|---|---|---|---|
| Development of improved datasets and tools to monitor and evaluate agricultural land use and land availability globally, particularly idle and marginal land. Revised assessment of idle land availability in the EU to 2020 | Green | Amber | |
| Development of robust criteria to define land that will not otherwise be used for food production including:<br>• idle and marginal land suitable for biofuel production<br>• appropriate wastes and residues<br>• intensification | | Green | Green |
| Modelling of the likely land use changes stimulated by current and possible future EU biofuels policy and impacts upon GHG-emissions and biodiversity as part of an updated impact assessment of EU biofuels policy | | Green | |
| Investigation of the potential wider social impacts of biofuels demand and production including land grabbing, involuntary displacement and potential conflict resulting from food shortages. This should include consideration of improved systems of governance to reduce negative effects | | Blue | Blue |
| Examination of the impact of shifting production to idle and marginal land upon biodiversity and options to mitigate effects | | | Amber |
| Development of enhanced capacity and indicators to monitor biodiversity, soil organic matter and above ground carbon stocks in key regions across the world | Amber | | |
| Examination of the potential effects of the use of novel or perennial crops for advanced biofuels upon biodiversity | | | Blue |

**Green: High Priority   Amber: Medium Priority   Blue: Lower Priority**

**Table 9.1: Summary of principal areas of further work** *(continued)*

| GHG-Life cycle analyses | International | EU | UK |
|---|---|---|---|
| Research to improve knowledge and understanding of nitrous oxide emissions from soils including the effects of different farming practices. This should include consideration of how to incorporate uncertainties into regulatory GHG-calculation methodologies including consideration of the possible role of IPCC Tier II and III methodologies | | ● (Amber) | ● (Green) |
| Development of improved methodologies to quantify emissions from indirect land use change for use in regulation including consideration of both deterministic and partial equilibrium modelling approaches | ● (Green) | ● (Green) | ● (Green) |
| Research, possibly including field trials, to improve estimates of GHG-emissions arising from conversion of set-aside land and permanent grassland and the effects of different cultivation techniques | | ● (Amber) | ● (Amber) |
| Examination of the opportunity costs in GHG-savings of growing biofuels feedstock versus other land uses options | | | ● (Blue) |
| **Feedstock, co-products and yield** | | | |
| The effect of co-products on avoided land use and GHG-savings should be further examined including consideration of the effects of using different systems of allocation and co-products from advanced technologies | | ● (Blue) | ● (Green) |
| Determination of the potential for biofuels supply to stimulate price-induced yield improvements | | | ● (Amber) |
| Examination of the availability of EU wastes and residues and potential competition with other applications including a comparative LCA | | ● (Amber) | |

**Green: High Priority Amber: Medium Priority Blue: Lower Priority**

**Table 9.1: Summary of principal areas of further work** *(continued)*

| GHG-Life cycle analyses | International | EU | UK |
|---|---|---|---|
| **Feedstock, co-products and yield** | | | |
| The opportunities, benefits and issues with growing perennial low input high diversity native species on marginal land needs further consideration | | | Blue |
| Further R&D is needed to improve agricultural yields and productivity without causing wider environmental damage | Green | Green | Green |
| Improved predictions of future regional yield improvements are required to improve modelling of future land demand. This should include use of Global Agroecological Zone modelling (GAEZ) approaches to be extended. Also, further examination of the reasons for 'yield plateaus' observed in some major crops in important producing regions | Amber | | Amber |
| Examination of the potential for improvements in grassland or livestock productivity and the likely GHG-emissions arising from conversion to croplands | Amber | | |
| Further examination of the potential and implications of the use of genetically modified (GM) crops for biofuel production including the likely environmental effects and the public acceptability | | | Blue |
| **Economic effects and investment** | | | |
| Detailed design of the proposed EU-obligation for advanced technologies to ensure that this encourages the necessary investment including: criteria for appropriate feedstock and biofuel supplied, date of introduction and pace of ramp-up, buy-out price etc. | | | Amber |
| Monitor closely the continuing market volatility and examine the effects of both biofuels and market speculation | Blue | | Blue |
| **Economic effects and investment** | | | |
| Re-modelling of the effects on food commodity prices, and the poor of a slower introduction and lower targets for biofuels along with shifting production to idle and marginal land. This should include the potential benefits of biofuel support policies on the poorest households | | | Blue |

**Green: High Priority Amber: Medium Priority Blue: Lower Priority**

**Table 9.1: Summary of principal areas of further work** *(continued)*

| GHG-Life cycle analyses | International | EU | UK |
|---|---|---|---|
| Determination of the potential benefits of biofuels in stimulating agricultural investment and economic development in less developed countries. This should include further analysis on the potential 'farm gate' returns to developing country producers of growing jatropha and other possible crops on appropriate idle and marginal lands. | ● (Blue) | | ● (Blue) |
| Determination of key technical and non-technical barriers to increased biofuels supply in less developed countries and design of appropriate capacity building | ● (Amber) | | ● (Amber) |
| Examination of the extent to which the first generation biofuel market serves as a driver of investment in both agriculture and advanced technologies. | | | ● (Blue) |
| Consideration of alternative policy options, e.g. fiscal measures, instead of targets, mandates and obligations. | | | ● (Blue) |
| Immediate work should be undertaken to establish the priority recipients of short term financial assistance. | | | ● (Green) |

**Green: High Priority   Amber: Medium Priority   Blue: Lower Priority**

# Abbreviations

1G – First generation

2G – Second generation

C&S – Carbon and Sustainability

CAP – Common agricultural policy

CHP – Combined heat and power

DDGS – Distillers dried grains solubles

Defra – Department for Environment, Food and Rural Affairs

DfT – Department for Transport

DLUC – Direct Land-use change

EEA – European Environment Agency

FAO – Food and Agriculture Organisation of the United Nations

FQD – Fuel Quality Directive

FT – Fischer-Tropsch

GAEZ – Global Agroecological Zones

GE – General equilibrium

Gha – Giga Hectares

GHG – Greenhouse Gas

HaGtC – Hectare per giga tonne carbon

IEEP – Institute for European Environmental Policy

IFPRI – International Food Policy Research Institute

IIASA – International Institute for Applied Systems Analysis

ILUC – Indirect land-use change

IPCC – Intergovernmental Panel on Climate Change

LCA – Life cycle analysis

LUC – Land-use change

Mha – Million hectares or mega hectares

MODIS – Moderate-resolution Imaging Spectroradiometer

ODI – Overseas Development Institute

OECD – Organisation for Economic Cooperation and Development

OSR – Oil seed rape

PE – Partial equilibrium

R&D – Research and development

RED – The Renewable Energy Directive

RES – Renewable Energy Strategy

RFA – Renewable Fuels Agency (Office of the)

RTFO – Renewable Transport Fuel Obligation

TOE – Tonne of Oil Equivalent

WTO – World Trade Organisation

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# Annex A – Terms of reference

## Introduction

Biofuels have the potential to deliver significant environmental benefits, and it is this principle that has underpinned UK Government support for them. Government support mechanisms have been justified in particular on the grounds that biofuels can deliver considerable net reductions in greenhouse gas emissions compared to fossil fuels.

New evidence has emerged in recent months on the net greenhouse gas benefits of certain types of biofuels. There is currently little consensus on much of this new evidence and there are widely diverging views on the sustainability of current and future biofuels targets.

The Government is keen that biofuel targets and support policies should be underpinned by robust scientific evidence. To this end, it commissioned in 2007 a review of work on the environmental sustainability of international biofuels production and use, and this review is due to report shortly.

To complement and build on this work, the Government is inviting the Renewable Fuels Agency to lead a review of the fast-emerging new evidence of displacement effects of biofuels on land-use and impacts upon GHG savings. This RFA-led review will – alongside the review of work on the environmental sustainability of international biofuels production and use – inform the development of future biofuel policies and targets, including in particular proposed EU targets for future biofuel consumption.

## Scope

The RFA-led review will focus on recent evidence on the indirect or "displacement" impacts of biofuel production, both within the EU and internationally, and evaluate, for current and future demand and production scenarios:

- The extent to which the production of biofuel feedstocks leads to land-use change
- GHG-emissions arising from changes in land-use change and cultivation practices.

It will seek to make an objective, evidence-based assessment of the risks and uncertainty around these impacts and how this can be quantified.

It will seek to put the impacts of biofuels into perspective, by quantifying the extent to which the demand for biofuels – as opposed to other pressures – is likely to pressure on available land resources in the period to 2020. It will also consider the extent to which these impacts would be reduced if advanced biofuel technologies became commercially viable in the medium term.

It will consider and describe the risk that biofuel policies will affect international food commodity prices in the period to 2020 and indicate the uncertainties attached to that appraisal.

It will make recommendations as to how all of the above should be built into future calculations of the net greenhouse gas impacts of biofuel policies and future biofuel targets. It will also define the requirements of the further modelling and analysis that would be needed to consider a range of policy and demand scenarios, and their wider economic, environmental and social impacts, including for example on food prices.

It will make recommendations, as far as this is possible from the available evidence, on prudent levels and forms of biofuel targets and ways to manage and reduce the risk of displacement effects.

### Participants

The UK's Renewable Fuels Agency will lead the work and will seek to draw upon knowledge and expertise globally. The study will be led by Professor Ed Gallagher, Chairman of the RFA, and former Chief Executive of the Environment Agency. The RFA will assemble a small team of experts to undertake the study including individuals with specific knowledge and skills in relevant areas.

### Methodology

The study will include the following elements:

- Studies examining evidence concerning:
  - Global drivers, pressures and availability of land and the effect of current and future demand and production scenarios for biofuels
  - GHG emissions arising from land-change and cultivation of biofuels and uncertainties in science and methodologies
  - Drivers of rising food commodity prices and effects upon food security
- Written stakeholder consultation on these issues, disseminated globally to encourage a wide range of expert respondents
- Stakeholder workshops and meetings with experts from the UK, EU and elsewhere to consider land-use change effects and the impact on agricultural markets

The review will as far as possible draw in expertise from other EU Member States and elsewhere. The findings will be peer-reviewed by the Government's Chief Scientific Advisers.

### Timetable

An initial report will be provided to Ruth Kelly and Hilary Benn by Friday 27 June including recommendations for further work. This initial report will include the outcomes of the stakeholder consultation, literature review and workshops. A draft report will be provided to Government officials by the end of May which will inform UK negotiations in Brussels.

# Annex B – Table of commissioned studies

| Topic | Studies | Lead Contractor |
|---|---|---|
| Anticipated demand for biofuels | Use of information on global targets for biofuels to develop four scenarios to examine the potential global demand for land for biofuels. The scenarios developed in this work were used as a basis for work by CE Delft and Ecofys. | E4Tech |
| Global land agricultural availability and demand | Examination of the drivers for land use demand by 2020. Includes current and anticipated drivers for land and feedstock for food, feed and other commodities. Provides an assessment of the availability of agricultural land for the scenarios developed by E4Tech. | CE Delft |
| Examination of the background analysis for the proposed EU 10% target | Critique of the impact assessment undertaken for the 10% biofuels target proposed in the Renewable Energy Directive. | Ecofys |
| Analysis of proposed EU target | Analysis of the impact on land use in 2020 of the proposed EU biofuel target using a range of scenarios, including a range of biofuel targets | Ecofys |
| Anticipated and potential improvements in agriculture production with intensification | Review of available information on the yields of main commodity crops and those used for biofuels (first and second generation), the role of intensification in driving productivity and other factors that drive and influence yields. Examination of how global land production could respond by 2020 to increased demands, including for biofuel production. Yield improvements on a regional and crop basis. Productivity projections to 2020 with low, moderate and high trajectories. This work was fed into the scenario analysis by E4Tech and CE Delft. | ADAS |
| Use of by-products from biofuels production | Review of the potential for use of by-products as animal feed or as a fuel for heat and/or power. Examination of the effect of these uses on global land use and on land-use changes. | CE Delft |

| Topic | Studies | Lead Contractor |
|---|---|---|
| Land-use change impacts and opportunities at regional level | Examination of the current rate and the principal location and types of land-use change; where biofuels are likely to be grown; and what is the potential role of feedstocks cultivated on poor quality soils, salt water environments and in arid areas. | Themba |
| | Case studies on representative areas: India, China, the UK, Brazil, SE Asia and Southern Africa. | Themba |
| Review GHG emissions from land-use change | Review of impacts and uncertainties in GHG emissions from a variety of land-use changes. Examination of the impact of carbon sequestration by fallow land on total GHG emissions of biofuel production in the EU. Estimation of the effects of low or no till on yields of biofuels crops in the UK. | North Energy Associates and ADAS |
| Review the evidence on GHG savings of current and future biofuel technologies and identify key areas of uncertainty | Evaluation of the impact of GHG emissions of current and future biofuel production. Review of work on N20 emissions from soils arising from fertiliser application and an assessment of Crutzen's paper on this topic. | North Energy Associates |
| Review of the Searchinger paper | Critique of Searchinger's results, including their relevance to the EU, the robustness of the approach for feedstock conversion and displacement, price increases, crop productivity, indirect land-use change and GHG emissions. | ADAS |
| The potential contribution of advanced technologies and feedstocks with limited or no land demand and resulting GHG savings | Examination of development potential for second generation biofuels by 2020. | E4Tech |

| Topic | Studies | Lead Contractor |
|---|---|---|
| The economic benefits and food insecurity impacts of biofuels production | How will expansion of biofuel production affect prices on the world market?<br>How do international price changes affect domestic prices?<br>How will prices rises induced by biofuels affect consumers in the developing world?<br>What is the potential for the poor to earn more by producing biofuels?<br>How will the economies of low income countries be affected by biofuels?<br>What may be the social impacts of biofuels? | Overseas Development Institute (ODI) |
| GHG saving calculations | Graphs illustrating the range of GHG savings which can be achieved by different biofuels if they did not cause indirect land-use change. | E4Tech |

# Annex C – Acknowledgements


**This review was prepared by a core team comprising:**

| | |
|---|---|
| • Professor Ed Gallagher | Review Lead |
| • Aaron Berry | Review Author |
| • Greg Archer | Review Author |
| • Sue McDougall | Project Director |
| • Anthony Henderson | Project Manager |
| • Chris Malins | Communications Co-ordinator |
| • Liz Rose | Project Support |

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**The studies and data that informed the review team were commissioned by the RFA from a range of different parties. These are:**

- AEA Energy and Environment
- The Overseas Development Institute
- E4Tech
- North Energy Associates
- Themba
- ADAS
- CE Delft
- ECOFYS

**RFA Advisory Group**

- Dr. Paul Jefferiss – RFA Board Member and Director of Environment at BP
- Adam Harrison/Jean-Phillipe den Ruyter – WWF Scotland/European Policy Office
- Jayne Redrup – Department for Environment, Food and Rural Affairs
- Andrew Randall, Jonathan Reeves – Department for Environment, Food and Rural Affairs
- Jeremy Woods – Imperial College, London
- Simone Pfuderer – DEFRA Agricultural Economics Unit
- Jonathan Lingham – Department for International Development
- Malcolm Fendick – Department for Transport

**Peer Review Team**

- Professor John Beddington, Chief Scientific Advisor to the UK Government
- Professor Brian Collins, Chief Scientific Advisor to Department for Business Enterprise and Regulatory Reform and Department for Transport
- Professor Robert Watson, Chief Scientific Advisor to Department for Environment, Food and Rural Affairs
- Mrs Vicky Pryce, Director-General Economics BERR & Joint Head, UK Government Economic Service
- Professor Michael Kelly, Chief Scientific Advisor to Department for Communities and Local Government
- Professor Sir Gordon Conway, Chief Scientific Advisor to Department for International Development

The above team was supported by Nick Grout, Jonathan Reeves, Taro Hallworth and Paul Wilson.

**Call for Evidence Contributors**

The RFA review team thanks everyone who took the time to contribute evidence to this review. Over a four week period, we received over 70 submissions. Some of this was well known to the review team, other evidence was very recent and in some cases, very relevant.

Nordeco, The Lord Christopher CBE, Jim Roland, Abengoa Bioenergy, Spain, Agricultural Industries Confederation, AIDenvironment, Amphos XXI Consulting S.L, Argent Energy UK, BBSRC, Bio-Power UK, Biopurefuels, Biotechnology Industry Organization, US, BP International Limited, British Sugar plc, Cargill, Chalmers University, Sweden, CIAA, the Confederation of the Food and Drink Industry of the EU, CNG Services Ltd, CO2 Star, Cornell University, Croda, Defra, Delphi Diesel Systems, East of England Development Agency, Edinburgh Centre for Carbon Management, Empa - Materials Science & Technology, Switzerland, ENSUS Ltd, Environment Canada, Environment Industries Commission, Ferrand Stobart, Food and Drink Federation, Forecourt Equipment Federation, Friends of the Earth, General Motors Ltd, Greenpeace UK, GreenSpeed, HGCA, IEA/REU, Joint Research Council, JouleVert, LACORS, Land Network International Limited, LifeMosaic, Marine Resource Management Ltd, Methanogen (UK) Ltd, Natural England, Natural Environment Research Council, Natural Gas Vehicle Association, Next Generation, NFU, North East Process Industry Cluster (NEPIC) Ltd, Office of Climate Change, Oxfam GB, Potters Waste Management, Renewable Energy Association, Sawit Watch, Shell International Limited, The Environment Agency, The National Non-Food Crops Centre, The Resource Efficiency Knowledge Transfer Network, The Royal Society, The RSPB, The Society of Motor Manufacturers and Traders Ltd, Tim Joslin, TMO Renewables Ltd, Tyndall Centre for Climate Change Research, UK Petroleum Industry Association Ltd, University of Bath, University of Cambridge, University of Campinas, Brazil, University of East Anglia, University of São Paulo, Vireol plc, Wildlife and Countryside Link, Wood Mackenzie, World Land Trust, Wuppertal Institute for Climate, Environment, Energy, WWF, Brazil, Atlantic Consulting, Frontier Agriculture Ltd, LowCVP, Overseas Development Institute, USDA.

**Contributors to Expert Seminars**

**Department for Transport Seminar, London, 28 April 2008**

Peter Hazell, Imperial College

Michael Obersteiner, International Institute for Advance Systems Analysis

Jan-Erik Petersen, the European Environment Agency

Sir Rob Margetts, Alwyn Hughes, Warwick Lywood and John Pinkney, ENSUS

Mark Avery, the Royal Society for the Protection of Birds (RSPB)

**SenterNovem Seminar, Utrecht, Netherlands, 8 May 2008**

André Faaij, University of Utrecht

Bas Eickhout, Netherlands Environmental Assessment Agency (MNP)

Martin Banse, WUR/LEI

Geert Bergsma, CE

Anton Haverkort, WUR

Jan Joost Kessler, AIDEvironment

John Neeft, SenterNovem

Simone te Buck, SenterNovem

**University of Illinois Seminar, Urbana-Champaign, USA, 12 and 13 May 2008**

Keith Wiebe, FAO

Jurgen Scheffran, UIUC

Madhu Khanna, UIUC

Amani E Elobeid, Iowa State University

Tim Searchinger, Princeton

Bruce Babcock, Iowa State University

David Zilberman, UC Berkeley

Siwa Msangi, IFPRI

David Roland-Holst, UC Berkeley

Ben Senauer, University of Minnesota

Harry de Gorter, Cornell University

Tom Hertel, Purdue University

Wally Tyner, Purdue University

Kristiina Vogt, Univ. of Washington

Deepak Rajagopal, UC Berkeley

Bruce McCarl, Texas A&M

Vincent Camobreco EPA

Irene Tinker, UC Berkeley

Gale Summerfield, UIUC

Richenda van Leeuwen, Good Energies

Russ deLucia, S3IDF

Cliff Singer and Hadi Esfahani, UIUC

**São Paulo Seminar, Brazil, 13 and 14 May 2008**

Prof Goldemberg, Cenbio/USP

Marcos Jank, UNICA

Angelo Bressan, Conab

Alexandre Strapasson, MAPA

Delcio Rodrigues, FoE and Vitae Civillis

Jose Tubino, FAO representative – Brazil

Eduardo Assad, Embrapa

Geraldo Martha, Embrapa Cerrado

Suani T. Coelho, Cenbio/USP

Luis Laranja, WWF

Marcelo Moreira, ICONE

David Cleary, TNC

Juliana Falcao, FCO

**Seminar at the UN Food and Agriculture Organisation (FAO), ROME, 9 June 2008**

Jeff Tschirley, Chair, Inter-Departmental Working Group on Bioenergy, FAO

Keith Wiebe,ESA

Merritt Cluff, EST

Erika Felix, BEFS, NRC

John Latham, NRC

Mette Loyche-Wilkie, FO

Freddy Nachtergaele, NRL

Astrid Agostini, FAO

# Annex D – Conversion Table

The table below shows the conversion factors used in this study between % volume and % energy targets.

| Volume % | % | Energy % |
|---|---|---|
| 1.2 | 1 | 0.8 |
| 2.5 | 2 | 1.6 |
| 3.7 | 3 | 2.4 |
| 5.0 | 4 | 3.2 |
| 6.2 | 5 | 4.0 |
| 7.4 | 6 | 4.8 |
| 8.7 | 7 | 5.7 |
| 9.9 | 8 | 6.5 |
| 11.1 | 9 | 7.3 |
| 12.4 | 10 | 8.1 |

To use the table, start in the centre column and move down until you find the value (volume or energy) that you would like to convert. Convert that value by either moving left for the volume equivalent or right for the energy equivalent.
For example:

- 2% by volume is 1.6% by energy
- 4% by energy is 5% by volume

Renewable Fuels Agency
Ashdown House
Sedlescombe Road North
St Leonards-on-Sea
East Sussex
TN37 7GA

Tel: 0207 944 8229
E-mail: rfa.info@dft.gsi.gov.uk
www.renewablefuelsagency.org


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