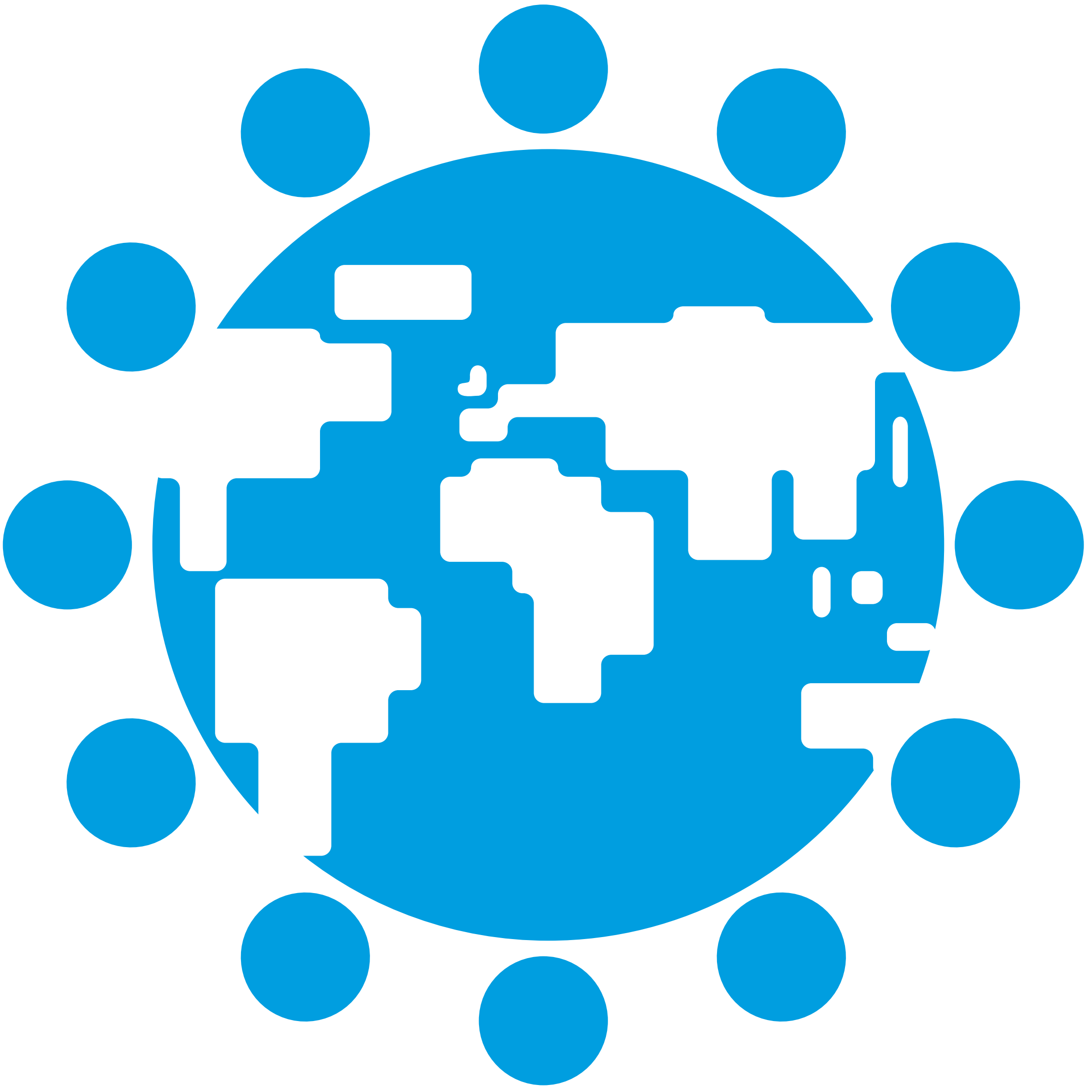

Sustainable Biofuels

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THE °CLIMATE GROUP

Breaking the Climate Deadlock
Briefing Paper

About the 'Breaking the Climate Deadlock' Initiative

'Breaking the Climate Deadlock' is an initiative of former UK Prime Minister Tony Blair and independent not-for-profit organisation, The Climate Group. Its objective is to build decisive political support for a post-2012 international climate change agreement in the lead up to the 2009 UN Climate Change Conference in Copenhagen. Its particular focus is on the political and business leaders from the world's largest economies, particularly the G8 and the major developing countries. The initiative builds on Mr Blair's international leadership and advocacy of climate change action while in office, and The Climate Group's expertise in building climate action programmes amongst business and political communities.

This briefing paper and its companions were commissioned by the Office of Tony Blair and The Climate Group to support the first Breaking the Climate Deadlock Report – 'A Global Deal for Our Low Carbon Future' – launched in Tokyo on June 27th 2008. Written by renowned international experts and widely reviewed, the papers' purpose is to inform the ongoing initiative itself and provide detailed but accessible overviews of the main issues and themes underpinning negotiations towards a comprehensive post-2012 international climate change agreement. They are an important and accessible resource for political and business leaders, climate change professionals, and anyone wanting to understand more fully, the key issues shaping the international climate change debate today.

The views expressed and information provided in this paper are the sole responsibility of the author. The Climate Group, the Office of Tony Blair and the staff of Breaking the Climate Deadlock Initiative accept no responsibility for any errors of fact or the opinions contained herein.

For further information see: *www.breakingtheclimatedeadlock.com*

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Executive Summary

- Biofuels have a potentially useful role in cutting emissions of greenhouse gases in the transport sector. They are one of the few technologies available that is compatible with existing vehicles.
- Biofuels alone cannot deliver a sustainable transport system. Technical and economic constraints limit the ability of biofuels to replace fossil fuels. They must be part of an integrated package of measures that stimulates a range of low carbon measures.
- Existing policy frameworks and targets for biofuels are sometimes based on scant evidence and may miss important opportunities to deliver greenhouse gas emission reductions. There is a real danger that a policy framework driven solely by supply targets will mean we become locked into inefficient biofuels supply chains that are potentially environmentally harmful.
- There is a huge range of biofuels and ways to produce them, each with different environmental, social and economic benefits. It is therefore not possible to make simple generalisations about their performance. However, there are real opportunities to develop biofuels that can deliver substantial greenhouse gas savings and wider environmental, social and economic benefits.
- International agreement is needed for methodologies for assessing sustainability and greenhouse gas emissions from biofuel supply chains. However, policy frameworks must be flexible enough to accommodate current uncertainties in the data and areas where there is a lack of information, as well as developments in the technology.
- Clear long term policies and incentives are needed that target the entire supply chain and that promote the development of biofuels that deliver the greatest environmental, social and economic benefit.

Recommendations

- Policies and incentives to promote biofuels need to promote those with the best sustainability performance. Policies designed to increase biofuel usage should include a mechanism to incentivise biofuels with the best greenhouse gas performance, while also reducing wider environmental harm and promoting sustainable development.
- Investment and funding of research and development is needed to accelerate the delivery of more efficient supply chains. Long term policy signals are needed for industry to encourage investment across the entire supply chain.
- Biofuels can play a useful role in reducing emissions from the transport sector. However they should not be treated as a “silver bullet” and should be part of broader transport policies that stimulate innovation in a whole range of technologies in order to decarbonise the transport sector.
- Internationally agreed sustainability criteria and certification schemes are needed to ensure that biofuels provide the greatest benefits to the environment and people, and maximise the opportunities to restore degraded land and protect watersheds. These sustainability criteria need to be given greater priority in international negotiations with a priority given to trade discussions in the World Trade Organisation.

Sustainable Biofuels

This paper sets out:

- The potential for biofuels to contribute to carbon savings in transport
- Key actions needed to promote the development of low-carbon biofuels
- Policy steps required from leaders

Biofuels' potential to contribute to carbon savings

Transport, now reliant almost entirely on oil, is a major and growing source of carbon emissions. Biofuels, derived from plant materials, have significant potential to provide commercially viable alternatives to oil and to contribute to carbon savings – provided policymakers explicitly promote both of these objectives.

Why biofuels? The drivers

Our climate is changing and there is now scientific, social and political recognition that this is very likely a consequence of increasing greenhouse gas emissions from human activity. Globally, transport now accounts for about 20 percent of human-induced carbon dioxide (CO_2) emissions. Over the past ten years, transport has shown the highest rates of growth in greenhouse gas emissions of any sector. By 2030, energy use and carbon emissions from transport are predicted to be 80 percent higher than current levels[1].

Global primary oil demand is predicted to grow by 1.3 percent per year to 2030, reaching 116 million barrels per day (up from 84 million barrels per day in 2005). The transport sector relies almost entirely on oil, and accounts for about 60 percent of this rise. While the transport sector continues to expand in the US and Europe, growth in the emerging economies of India and China is predicted to be substantially greater, growing by at least 3 percent per year[2].

Given this rising demand, issues of supply are coming to the fore. Oil is predicted to become increasingly scarce in the next few decades, with supplies vulnerable to interruption; the world may have entered a new era of sustained high oil prices. This is leading to extraction of oil from oil shale and tar sands, and the production of synthetic fuels from coal and gas; the life cycle emissions from these sources are more carbon intensive than from conventional oil[3]. Such developments will further increase the greenhouse gas emissions from fossil fuel based transport fuels and compromise objectives to mitigate climate change.

Against this backdrop, biofuels are already entering the market, driven by their potential to increase energy security and as a means to mitigate climate change. However, it is by no means guaranteed that all biofuels will deliver on these issues – that will depend on how each individual biofuel is produced, and its attendant supply chains are developed.

What are biofuels?

Biofuels are fuels, predominantly liquids, derived from plant materials, for use primarily in the transport sector. They are distinct from biomass, where the plant material is used directly to produce heat and electricity. In addition, biofuels are an integral part of the emerging "bio-economy", where plant material is used to produce specific chemicals and bulk industrial chemicals. In the future these may increasingly replace chemicals derived from fossil oil.

Biofuels are currently produced almost entirely from conventional food crops. Sugar and starch from crops such as wheat, maize, sugar beet and sugar cane are converted to ethanol to replace petrol, and plant oils from crops such as palm oil and oilseed rape are used to produce biodiesel. A small percentage of biofuels are produced from residual vegetable oils and animal fats.

Future biofuels, including bioethanol and diesel replacers, are likely to be produced from a broader range of feedstocks, including the lignocellulose in plant material. This may come from dedicated energy crops, such as grasses and trees from plantations or short rotation coppicing, which present significant advantages over food crops: they can be bred for purpose to improve yields, reduce inputs such as fertilizer and water, and provide feedstock that is easier to process. Such crops – many of them perennial – can also be grown on marginal land of low agricultural or biodiversity value, or abandoned land no longer suitable for quality food production.

Lignocellulose feedstocks may also come from a number of wastes and residues from food production and forestry, such as coconut shells, rice husks and wheat stalks; forestry waste from timber operations; organic material in domestic waste and sewage; and algae from the aquatic and marine environment. The advantage of these is that they do not compete with food production although they may have other uses. Research is likely to lead to a wider range of species that could be used for future biodiesel production, such as high yielding palms – and possibly even to the direct production of hydrocarbons from plants or microbial systems.

Where does biofuels technology stand today?

Many of the technologies and production systems for biofuels and chemicals are at early stages of conception or development. However, they are founded on immense scientific progress and offer a wide diversity of opportunities and pathways for the more efficient and environmentally beneficial exploitation of plant material for biofuels and chemicals.

Advances in conversion processes will almost certainly improve the efficiency and reduce the environmental impact of producing biofuels, both from existing food crops and from lignocellulose sources. The first commercial-scale cellulosic plants in the world are being built now by Range Fuels in the US and Choren in Germany, and many more are likely to come on line in the next few years. In the US alone, some twenty small-scale lignocellulose-derived fuel plants are currently under development.

However, while biofuels have a potentially important role it must be remembered that no two supply chains for a biofuel are the same, as a result they can have widely differing environmental, social and economic impacts – these impacts need to be addressed through policy frameworks and assessments. If biofuels are to deliver a realistic, large scale substitute for conventional fuels and meet sustainability criteria, substantial improvements in efficiency will be needed in many of the supply chains – from feedstock to final use.

What is the carbon saving opportunity from biofuels?

Biofuels are one of the few means currently available that can displace oil and deliver carbon savings, as the transport sector has few other mature technologies to reduce greenhouse gas emissions. Hydrogen, fuel cells and fully electric vehicles all face significant challenges before they become prevalent, and even the widespread use of fully hybrid vehicles by 2030 will reduce world demand for transport fuel by only 10 percent, leaving it about 40 percent higher than today[4].

There are real opportunities to deliver substantial greenhouse gas savings from efficient biofuel supply chains. However, estimates of their global potential are difficult to make because their yields vary enormously by region, crop and management practices. One recent study suggest that biofuels from existing food crops such as maize and sugarcane could meet 10 percent of the world's demand for transport fuel from about 3.5 percent (183 million hectares) of the land under crops and pasture[5]. New feedstocks such as lignocellulose could greatly increase the energy yield per hectare, and so improve these figures significantly. (See box: "Biofuels from lignocellulose".) Biofuels could abate some 30 percent of global emissions from transport by 2050 – or perhaps as much as 60 percent if efficient supply and use chains are developed rapidly enough[6].

It is relevant to add that degraded agricultural lands, woodlands and watersheds are broadly estimated to amount to nearly 2000 million hectares – 500 million in Africa alone[7]. This highlights an important opportunity to produce biofuels, particularly lignocellulose crops, in ways that would help to restore degraded lands and watersheds.

It should be emphasised, though, that biofuels cannot deliver a sustainable transport system on their own. Rather, they must be developed as part of an integrated package of measures which promotes other low carbon options and energy efficiency, and which moderates the demand and need for transport. One should note also that, in many regions, biofuels have a limited capacity to replace fossil fuels, due to technical and economic constraints. Production and supply will vary globally, with many countries likely to be dependent on imported biofuels or feedstocks, and others, particularly Brazil, likely to become significant exporters.

Furthermore, it should be noted that greater reductions in greenhouse gas emissions can achieved by burning plant material in a power station to produce heat and electricity. Ultimately, this may be a more cost effective method of reducing greenhouse gas emissions and in the longer term, could be used to power electric vehicles. However, despite this greater efficiency, it must be compared to the immediate ability of biofuels to reduce greenhouse gas emissions in the transport sector and to strengthen energy security. Indeed, policies to promote these objectives may make the production of biofuels the more commercially favourable use of plant material.

Box 1

Biofuels from lignocellulose

Three key factors for improving the performance of biofuels are (1) increasing the amount of plant material produced per hectare of land; (2) improving the efficiency of the conversion processes to liquid biofuels; and (3) ensuring that biofuels are compatible and optimised for highly efficient advanced propulsion systems. The use of the lignocellulosic fraction of plants is one of the most effective ways to increase the amount of plant material – and therefore energy – that can be grown per hectare of land. This in turn will reduce the overall amount of land required to deliver biofuels.

At present crops such as Miscanthus and Willow grown in the UK can yield about 10-15 dry tonnes of biomass per hectare annually, which when converted to ethanol using current conversion technology can yield about 200-300GJ per hectare per year. Contrasted with yields from food crops, biodiesel from oil seed rape yields about 30 GJ/ha/yr, while ethanol from wheat, maize, sugarcane and sugar beet yield 15, 40, 110 and 115 GJ/ha/yr respectively. Brazilian sugar cane can yield between 6,000 and 12,000 litres of ethanol per hectare depending on conditions. If the left-over lignocellulosic plant material (bagasse) were used, these yields could be increased by another 4,000 litres per hectare – to some 250 GJ/ha/yr.

Research suggests that yields of crops such as Miscanthus are likely to increase to 25 and in certain condition as high as 45 dry tonnes of plant material per hectare per year – yielding as much as 15,000 litres of ethanol. Improvements in the conversion processes could raise efficiencies to as high as 70 percent, which would almost double this to 27,000 litres of ethanol per hectare (over 630 GJ/ha/yr), if the entire plant material was converted and none used as fuel for the conversion processes.

These figures may be feasible in certain conditions; however, there are many factors which need to be considered when projecting them to a global scale. The amount of plant material produced per hectare is dependent on soil quality, the total amount of solar radiation, fertilizer and water inputs and agricultural practices. While assessments can be made with regards to improving geographical factors, other factors will require investment in agricultural practices. Similarly, for the conversion processes, technological developments and transfer will be required if the most efficient technologies are to be deployed globally and reconciled with realistic timelines for infrastructure and technological turn-over rates.

Action needed to promote the development of low-carbon biofuels

What, then, are the key thrusts of action needed to meet the potential of biofuels to mitigate climate change and strengthen energy security? Fundamentally, policy frameworks – and the incentives that follow them – need to target both of these objectives explicitly; this is in contrast with some current policies, which provide incentives for national supply targets but not for the development of low-carbon biofuels.

A core thrust of the action needed is the wide-scale development of efficient, integrated, low-carbon biofuel supply chains. These must be underpinned by international agreement on sustainability criteria for biofuel development including, crucially, sustainable land use and the promotion of rural development. And, to support both the expansion and sustainability of biofuels, considerable advances must be made in commercial innovation and in research and development.

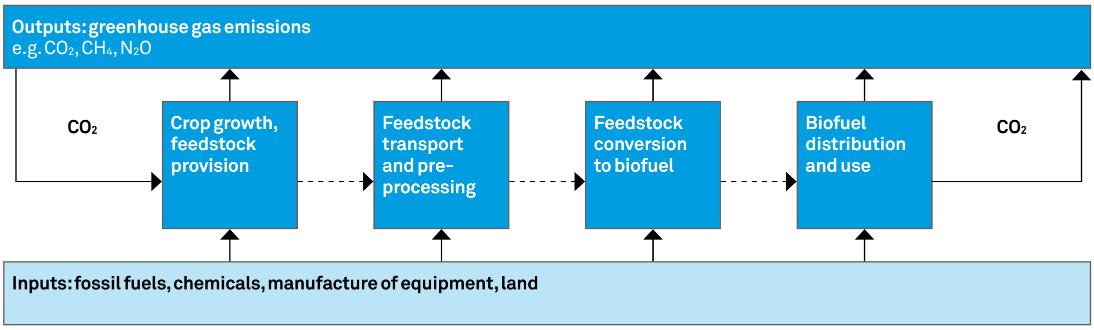
Develop efficient, low-carbon biofuel supply chains

At first sight biofuels appear to be carbon-neutral, with the carbon they emit to the atmosphere when burned being offset by the carbon that plants absorb from the atmosphere while growing. The reality, however, is much more complex, as greenhouse gas emissions arise from each stage in the supply chain, from feedstock production and transport to conversion, biofuel distribution and end use (see Exhibit 1). Improving the greenhouse gas performance of a biofuel is therefore dependent on several factors throughout its supply chain, including the choice of crop; management practices such as the amount of fertilizer applied; the conversion process and the source of energy for that process; and the use of co-products. Accordingly, highly efficient and integrated supply systems will need to be developed if biofuels are to contribute to a meaningful reduction in greenhouse gas emissions.

Exhibit 1

Greenhouse gas emissions from production and utilisation of biofuels

Source
Royal Society, Sustainable biofuels report 2008[8]



When this full production and use chain is assessed, existing biofuels programmes yield starkly different greenhouse gas savings. For example, ethanol produced under average Brazilian conditions results in reductions in greenhouse gas emissions of some 80 percent compared with those of standard petrol[9]. In contrast, current practices mean US maize-based ethanol can struggle to deliver reductions of 10 percent[10]. Estimates of UK potential from wheat-based ethanol could achieve reductions of anywhere between 10 percent and 80 percent[11]. Current estimates indicate that lignocellulose feedstocks will provide substantially better performance, with most supply chains capable of achieving 100 percent reduction in greenhouse gases emissions[12].

Secure international agreement on sustainability criteria for biofuels

If biofuel development is to contribute sustainably to reducing climate change and improving energy security, policymakers will need to develop a coherent approach to addressing the fuels' environmental, economic and social impacts. Sustainability criteria need to be agreed at the international level, partly because the impacts of biofuels are global issues and partly because international trade in biofuel commodities is likely to expand in coming years.

While the key goal for future biofuels must be the generation of substantially better results in terms of net greenhouse gas emissions, it will also be essential to establish a common and accepted set of sustainability criteria and carbon certification schemes by which to assess not only the different biofuels, but also the different feedstocks, both food and non-food, and their production systems. This process is likely to involve extensive international collaboration to ensure comparability of results, and a high degree of transparency and stakeholder engagement to maximise public acceptability.

It should be a priority to establish common methodologies and a robust evidence base to inform the sustainability criteria and policy development platform for biofuels. As part of this effort, comprehensive assessments are needed of the complete supply chain of each biofuel – including their impacts on such dimensions as land use, energy use, water consumption, biodiversity and air quality. These studies would:

- **Assess each biofuel on its own merits** – acknowledging that the term "biofuel" covers a wide variety of products with many different characteristics and a wide range of potential savings in terms of greenhouse gas emissions.
- **Assess the environmental and economic aspects of the complete cycle** – including growth of the plant, transport to the refinery, the refining process itself (including potential by-products such as animal feed or speciality chemicals), wastes produced, distribution of the resultant fuel to consumers, end use, and potential for pollution. Such assessments would help to determine the extent to which different biofuels are carbon neutral.
- **Assess land use impacts.** Widespread deployment of biofuels will have major implications for land use, with associated environmental, social and economic impacts that must in turn be assessed. Here, in particular, direct and indirect impacts need to be considered, as unintended consequences may reduce or override the expected benefits. (See "Ensure sustainable land use", below.)
- **Assess global and regional impacts.** The assessments must address the global and regional impacts, not just local ones.

A global policy approach, combined with a stronger evidence base, will contribute significantly towards improving the performance and widespread acceptability of biofuels – by directing incentives towards low carbon fuels, and by accelerating the development of more efficient technologies across the biofuel supply chain[13].

Ensure sustainable land use

Policymakers are already promoting an expansion of biofuels – the EU, for example, is proposing a target for renewable fuels of 10 percent of total transport fuel requirements by 2020. Clearly, this will require increased allocation of land to produce biofuel feedstocks – and if biofuels are to meet the sustainability criteria discussed above, it is essential that land selection and use are based on thorough assessments against these criteria.

Without such assessments, the allocation of land to biofuel crops could exacerbate, not mitigate, climate change. For example, the clearing of tropical forests or use of peatlands for the cultivation of crops would risk releasing enough greenhouse gases to negate any of the intended future climate benefits – and could have major impacts on conservation of biodiverse habitats. In addition, where biofuels are competing with land for food production, the emissions from any displaced crops need to be considered, wherever in the world they occur – along with possible food shortages, local or global. These opportunity costs, side effects and indirect impacts must be fully factored into any decision to assign land to biofuel feedstocks – and they must be underpinned by robust science, as there are considerable uncertainties in their assessment.

On the other hand, biofuel feedstocks can also be produced in ways that would improve the productivity of agriculture – through agro-forestry practices, for example, or by restoring degraded agricultural lands, woodlands and watersheds. Further, the production of biofuel co-products, such as animal feed, could reduce the amount of land needed to grow such crops. Such potential environmental and economic co-benefits need also to be taken into account in the assignment of land for biofuels.

There are further key environmental considerations that must be included in sustainability criteria for biofuels. For example, the input of artificial fertiliser to increase yield must be carefully regulated or reduced in order to prevent emissions of nitrous oxide (N_2O), a potent greenhouse gas, either directly from the area of application or from drainage waters downstream.

Understand rural development and food production

Biofuels directly touch upon agricultural and rural issues. In many regions in the world, particularly developed countries, domestic production of food and forestry is subsidized. The main motivation for this is the maintenance of indigenous food production capacity (food security), even if the food is much more expensive to produce than imports. In addition, the benefits of environmental services that are derived by land management are also used to support this, such as soil and watershed protection, biodiversity management and visual amenity, although these are mainly unquantified[14]. Although such subsidies have become increasingly controversial, the farming lobby continues to be a powerful political force and subsidised land management remains likely for the foreseeable future[15]. Agricultural development in many developing countries has been severely damaged by the "dumping" of surpluses on world markets and the economic distortions caused by market protectionism[16]. Biofuels could provide part of the answer to these problems by diverting "surplus" production to a new market while maintaining productive capacity.

In the current debate on rising global food prices, biofuels have been put forward by many as an important factor for food scarcity. However, biofuels must be considered alongside other drivers for prices for food based commodities, such as increasing global demand, the rising cost of fuel and the impact of large scale crop failure. This is a complex issue, and there is a real danger of oversimplifying the food versus fuel debate and of missing the synergistic opportunities for food and fuel production. In developing countries, particularly those of the tropics and subtropics, rising prices for food-based commodities, such as cereals and vegetable oils, could assist investment in agriculture and forestry which, in turn, could help to improve yields and production efficiencies[17].

With careful implementation, a new biofuel-inspired development dynamic could provide major benefits for the rural poor of these countries, who are mainly farmers. However, unless this leads to wider economic prosperity with a reasonable amount of the value generated by biofuels retained locally, specific intervention will be required to reduce the number of urban poor in developing countries suffering as a result of increased food prices[18].

Promote commercial development and innovation

Estimates of the costs of biofuels vary between countries and even between studies, making the uncertainties large (Exhibit 2). Similarly, in terms of cost per tonne of CO_2 avoided, these uncertainties associated with the wide range in carbon emissions from the various supply chains, mean that, as discussed above, each biofuels option should be assessed in its own right. Nevertheless, the scale of the uncertainties does not obscure two general points: (1) Higher oil prices are beginning to make current biofuels commercially more attractive; and (2) The possibilities for cost reductions through economies of scale and innovation are appreciable for all biofuels, with lignocellulose technologies (row 8) anticipated to fall into the same range as foodstuff-based technologies by 2030 (see rows 4–7 and 9–10), possibly sooner depending on how rapidly new technologies are developed and are deployed.

Exhibit 2

Estimated costs of biofuel compared with the prices of oil and oil products (biofuels exclusive of taxes)[19].

Biofuel	Cost by volume of fuel: 2006 (US$ cents/litre)	Cost by volume of fuel: Long-term about 2030 (US$ cents/litre)	Cost per unit of delivered energy[d]: 2006 (US$ cents/MJ)	Cost per unit of delivered energy[d]: Long-term about 2030 (US$ cents/MJ)
1 Price of oil, US$/barrel	$50–$80		0.82–1.31 US$ cents/litre	
2 Corresponding pre-tax price of petroleum products US cents/litre	35–60[a]		Approx 1.0–1.8	
3 Corresponding price of petroleum products with taxes included, US cents/litre (retail price)	150–200 in Europe [b] About 80 in USA		Approx 4.4–5.9 in Europe Approx 2.4 in USA	
4 Ethanol from sugar cane	25–50	25–35	1.2–2.4	1.2–1.7
5 Ethanol from corn	60–80	35–55	2.8–3.8	1.7–2.6
6 Ethanol from beet	60–80	40–60	2.8–3.8	1.9–2.8
7 Ethanol from wheat	70–95	45–65	3.3–4.5	2.1–3.1
8 Ethanol from lignocellulose	80–110	25–65	3.8–5.2	1.2–3.1
9 Bio-diesel from animal fats	40–55	40–50	1.2–1.7	1.2–1.5
10 Bio-diesel from vegetable oils	70–100	40–75	2.1–3.0	1.2–2.3
11 Fischer-Tropsch synthesis liquids	90–110	70–85	2.6–3.2	2.1–2.5

(a) Note range differs from row 1, for several factors such as refinery costs.
(b) Excluding a few outliers above and below this range
(c) It should be noted that the energy content per litre for ethanol is about two thirds of the energy content of fossil oil based products and biodiesel.
(d) Energy content based on lower heating value.

Such estimates do not allow for changes in prices and land values that may arise from competing demands from agriculture. As with oil and gas, the prices of the product cannot be disconnected from pressures on the available resources, primarily on the availability of land for agriculture, most of all in developing regions. Since the early 1960s, pressures on land resources have been eased in developing regions by, among other things, the growth of yields associated with the green revolution and improvements in husbandry: yields roughly doubled on average over the 40–50 year period. The economic prospects of biofuels will likewise depend on improvements in yields both in the growth of the crops and in the efficiency of the conversion processes.

Current investment and technology choice is largely driven by policy targets aided by high oil prices. This is leading to different regions promoting different technologies. Compatibility with existing vehicle engines and supply infrastructure is also important, and developments in end use technologies could have implications for which supply options are viable.

Major synergies and gains in efficiencies are possible if engine technologies are developed co-operatively and in parallel with compatible biofuel feedstock and conversion technologies. For vehicle manufacturers to make the investments needed, a long-term market for transport fuels containing a high blend of biofuels must be established.

A range of incentives and policies are needed to incentivise biofuels at various stages of development. However, one of the most significant would be the introduction of a carbon price, applied to all transport fuels. This could be either through the inclusion of the transport sector in an emissions trading scheme, or through a direct ‘carbon’ tax on fossil fuels. This would provide a clear incentive for the biofuel supply chains with the lowest greenhouse gas emissions. Set as part of a long term strategy this would help incentivise less mature technologies. Identifying the carbon equivalent price would require a life cycle approach to assess the emissions throughout the supply chain, including the cropping practice and conversion processes.

Undertake a major research and development effort

A major research and development effort is needed in both the public and private sectors. Key objectives should include:

- Increasing the yield per hectare of feedstock while reducing negative environmental impacts
- Developing new feedstocks that can, for example, be grown in more hostile environments, be more readily processed and be capable of generating a variety of products

- Developing improved methods of processing and conversion, in particular for lignocellulose feedstocks
- Developing and demonstrating integrated biorefineries
- Integrating the supply chain to gain maximum efficiencies
- Integrating biofuel development with engine development
- Developing internationally agreed methods of assessing sustainability, both at the production chain level and with regard to indirect impacts

These multiple but linked aims will require considerable effort and investment, particularly to achieve global policy objectives. The research and development must be multi-disciplinary, drawing in a broad range of expertise. It should include, for example, lifecycle assessments to fast-track plant breeding; socio-economics and systems biology; biotechnology; engine design; understanding and quantification of soil N_2O emissions for biofuel production; and calculating more accurate land use figures and biofuel supply potential. Experts in these areas should be stimulated to achieve the most effective demonstration of sustainable biofuels. Incentives to take the outcomes from research and development through to demonstration and deployment are essential. In addition, there are research groups throughout the supply chain that are working on related areas, such as the chemical industry, biotechnology and pharmaceuticals, which are not yet focused on biofuels. There is an urgent need for greater coherence between public and private sector funders and the research community.

Policy action steps

What, then, are the policy steps required from leaders to achieve the widespread development of sustainable biofuels? The following are key:

- Clarify and align policy needs
- Incentivise the production of biofuels with the best greenhouse gas performance
- Put in place internationally agreed criteria for sustainability assessments
- Balance growth of feedstock supply against other existing and potential land uses
- Promote watershed improvement and restoration of degraded land
- Facilitate technology transfer
- Commit to adequate public and private investment in the required research and development
- Develop an integrated approach for a sustainable transport system
- Develop a process for effective public engagement on biofuels issues

Each of these policy steps is outlined in turn.

Clarify and align policy needs

The overarching action required from national, regional and global policymakers is to ensure that the development of biofuels is driven by climate change mitigation, energy security and rural development. This is crucial, as policies designed to target just one of these drivers can be detrimental to the other drivers. For example, policies aimed at improving energy security may result in increased greenhouse gas emissions if they promote the use of local fossil fuels, particularly coal, in processing biofuels – rather than promoting more efficient, integrated processes that use waste material.

Incentivise biofuels with the best greenhouse gas performance

Policy frameworks and targets are sometimes based on scant evidence and may miss important opportunities to deliver reductions in greenhouse gas emissions and promote sustainable development. Policies and incentives to promote biofuels need to include a mechanism to incentivise biofuels with the best greenhouse gas performance. Economic and regulatory incentives are needed to accelerate the technology developments needed to deliver biofuel supply chains that can deliver substantial emissions reductions and provide the greatest environmental, social and economic benefits. Unless the appropriate policies and economic incentives are put in place there is a risk that we may become locked into inefficient – and potentially environmentally harmful – biofuel supply chains, and that the benefits of alternatives based on new technologies still under development may be lost.

Put in place internationally agreed criteria for sustainability assessments
Frameworks such as a carbon reporting and sustainability certification scheme are needed for the quantification and comparison of the environmental, social and economic impacts of each biofuel across its entire supply chain. Co-operative international effort is needed, through international development organisations and bodies such as the OECD, WTO, Convention on Biological Diversity (CBD) and Commission on Sustainable Development (CSD), to shape and implement the sustainability criteria for biofuels. Attempts at international harmonisation of methodologies to measure the greenhouse gas emissions impacts of biofuels by the Global Bioenergy Partnership (GBEP) are relevant in this regard.

Significant uncertainties remain in the estimates of environmental, social and economic impacts of biofuels. Considerably more information is required to reduce these uncertainties, but policy frameworks cannot wait until these are resolved as biofuels are already entering the market. These frameworks must therefore be sufficiently flexible to accommodate new understanding and encourage innovation.

Balance growth of feedstock supply against other existing and potential land uses
Carbon certification and sustainability assessments for biofuels can only become fully effective if applied to all forms of land use, so as to understand the indirect impacts of biofuels. Assessments of competing land uses such as for food, conservation and urban development could increase the full use of all parts of the plants for food and non-food use, increase yields, and encourage cultivation of biofuel feedstock on marginal land.

Promote watershed improvement and restoration of degraded land
Where possible, mechanisms should be put in place to promote the environmental co-benefits of producing crops for biofuel, such as the restoration of degraded lands, watersheds and forests.

Facilitate technology transfer
As most of the technologies are likely to be developed in the OECD and rapidly emerging economies, there is a need for mechanisms to facilitate effective technology transfer to and between developing countries. This will be vital to ensure that biofuels develop sustainably irrespective of geography.

Commit to adequate public and private investment in the required research and development
There is an urgent need for further formulation and application of policy which fosters the commercialisation of low-carbon biofuels. Research, development and innovation, both short and long term, need encouraging across the entire supply chain, from feedstock production through to conversion and end use, to develop biofuels with the greatest benefits.

Industry needs clear and coherent policy signals that provide a long-term, favourable framework for development. For example, policies need to be sufficiently long term to fit investment cycles, to extend carbon pricing to transport fuels and to bring forward the early development of an agreed and consistent set of metrics that indicate the properties of "efficient" biofuels supply chains.

Policies for biofuels need to be integrated across a range of other policy areas so as to avoid creating conflicting messages and creating uncertainty for commercial development. Different sectors are affected by bioenergy and biofuel provision and each have their own policies and environmental regulations. For example, feedstocks could come from agriculture, forestry or waste disposal – each with their own policies and regulations affecting storage, air and water qualities and planning. Similarly, fuel distribution requires the development of appropriate standards for infrastructure and fuel.

Develop an integrated approach for a sustainable transport system
Biofuels alone cannot deliver a sustainable transport system and should be developed as part of an integrated package of measures. Biofuels have a limited ability to replace fossils fuels and should not be regarded as a "silver bullet" to deal with transport emissions. Progress towards a sustainable solution requires an integrated approach that also includes, for example, greater energy efficiency, electric vehicles, hydrogen

and fuel cells, integrated and effective public transport systems, technologies which replace the need for transportation, and price and tax incentives such as carbon pricing based on avoided greenhouse gas emissions.

Develop a process for effective public engagement on biofuel issues

Public attitudes and the actions of stakeholders can play a crucial role in realising the potential of technological advances. Biofuels raise several concerns and opportunities that require an informed discussion, based both on the scientific case and an understanding of public and stakeholder views. It is important therefore to foster a process of iterative dialogue with the public and interested sections of society to help frame, identify and think through the issues.

Glossary of Terms

Bagasse:	Plant residue from sugar cane processing
Barrel:	1 barrel of oil = 159 litres or 35 UK gallons
Biodiesel:	A diesel-equivalent processed fuel that is derived by transesterification of plant oil or animal fats. A synthetic diesel can also be produced from lignocellulose but has different chemical makeup
Bio-economy:	All economic activity derived from the application of our understanding of mechanisms and processes, at the genetic and molecular level, to any industrial process
Biofuel:	Any transport fuel that has been derived from biological material
Biomass:	Any biological material that can be used either directly as a fuel or in industrial production or fibre production
Biorefinery:	Any facility that produces a variety of products, such as fuels, heat, power and chemicals, from bio-based materials
CH_4:	see Methane.
CO_2:	Carbon dioxide
EU:	European Union
Feedstock:	Any material that can be converted to another form of fuel, chemical or energy product.
Fischer-Tropsch:	A thermo-chemical process for producing biofuels. Feedstock is gasified into carbon monoxide and hydrogen, which are then converted, using a catalyst, into synthetic transport fuels such as petrol, diesel and kerosene. These 'synthetic fuels' have exactly the same properties as fossil fuel derived fuels.
Gallon:	1 gallon = 1.2 US gallon
GJ:	Gigajoule = 10^9 joules, a unit of energy.
IEA:	International Energy Agency
IPCC:	Intergovernmental Panel on Climate Change
LCA:	Life cycle assessment
Lignocellulose:	Plant cell walls are composed of lignin and cellulose, which provide mechanical strength. Can be broken down to lignin and cellulose, or used directly as a feedstock.
Litres:	Metric unit of volume. 1 litre (l) = 1,000 cm^3. 1 UK gallon = 4.55 litres
Mha:	Megahectare (millions of hectares), where one hectare = 10,000 m^2

Methane:	A greenhouse gas (CH_4) produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and oil, coal production, and incomplete fossil-fuel combustion. One of the six greenhouse gases listed under the Kyoto Protocol.
Miscanthus:	Also known as Elephant grass. A hardy perennial grass from tropical and subtropical, originated in Asia and Africa.
N_2O:	Nitrous oxide. A powerful greenhouse gas emitted through soil cultivation practices, especially the use of commercial and organic fertilizers, fossil-fuel combustion and biomass burning. One of the six greenhouse gases curbed under the Kyoto Protocol.
OECD:	Organization for Economic Co-operation and Development
Sustainability:	The balancing of environmental, social and economic factors in order to meet the need of present generations without compromising the need of the future
Synthetic biofuels:	Fuels produced via thermochemical conversion of biological material, such as petrol, diesel and kerosene, which have exactly the same properties as fossil fuel derived fuels. These are defined differently to synthetic fuels, because synthetic fuels can also be made from coal, gas and oil
Tonnes:	Metric unit of weight, where one tonne (t) = 1,000 kg. 1 metric tonne = 1.1 US ton.
t/ha:	Tonnes per hectare
t/yr:	Tonnes per year
WTO:	World Trade Organisation

Endnotes

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Acknowledgements

Thanks to Professor Chris Somerville FRS, Dr H Marc Londo, Vinod Khosla for their thoughts and comments, and also the Royal Society Biofuels Working Group.