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THE ECONOMIC, ENVIRONMENTAL AND SOCIAL IMPACTS OF BIOFUEL PRODUCTION

Paper drawing on the Gallagher Review and wider literature to develop an assessment of biofuel technology and its impacts.

Executive Summary

This paper draws on the Gallagher Review and wider literature to develop an assessment of biofuel technology and its impacts.

Biofuel technology is viewed as *"key to reducing reliance on foreign oil, lowering emissions of greenhouse gases… and meeting rural development goals"*. First generation biofuels derive liquid energy, in the form biodiesel or bioethanol, from the starches and sugars found in food crops.

The EU's biofuel strategy noted:

- the net greenhouse gas effect of biofuels is positive;
- development might require the use of 3 million hectares of *set-aside* land;
- a regulated approach to biofuel development could save approximately 23.5 million tonnes of oil by 2010;
- biofuels remain more expensive than their fossil fuel equivalents (at 2006 prices);
- a regulated approach to development could create 67,000 direct employment jobs in the EU 25; and
- the food/fuel issue required further understanding.

Issues

Food Prices – the Gallagher review found that increased biofuel production would raise the cost of *some* commodities, resulting in *"small net but detrimental effects"* that would be *"significant in specific locations"*. This view is broadly supported in academic literature and the by the UN. The US promote a technological solutions to the food issue, prioritising second generation technology, using co-products as animal feed and developing more efficient farming practices.

Greenhouse Gas Benefits – assuming land-use change emissions are avoided, the Gallagher Review estimates a 338 – 371 million tonne greenhouse gas saving compared to a *"without biofuel"* situation. It notes too, that biofuel should form part of an integrated green transport policy to maximise greenhouse gas reductions.

Lifecycle analyses of biofuels, which take into consideration the whole production process, differ in their greenhouse gas saving estimates. One such study concluded that biodiesel offers 40 – 50%, whereas bioethanol a 20 – 80% saving (depending on feedstock, fertiliser etc).

Land-use change – direct and indirect land-use change issues complicate life-cycle analysis studies. The concept of land-use change has increased its profile recently,

with the publication of the, somewhat controversial, Searchinger study: *Use of US croplands for biofuels through emissions from land use change.*

Direct land-use change refers to the conversion of virgin land into crop growing land – a process which releases carbon into the atmosphere through soil tillage and plant decomposition. Indirect land-use change assumes that expansion in biofuel production will cause farmers to convert food crops to biofuel crops, pushing up commodity prices and motivating farmers elsewhere to convert virgin land to food crops to account for the shortfall in the food supply.

The Searchinger report found, in conclusion:

- The US has insufficient land capacity to facilitate its planned biofuel expansion;
- Increasing bioethanol production in the US will lead to the conversion of virgin land into crop land, both in the US and globally;
- Greenhouse gas (GHG) emissions resulting from indirect land-use change will be large and net savings will not be experienced until after the period when GHG pay-back is needed;
- First generation biofuels are problematic and it would be preferable to make biofuel from waste products.

Critiques of the study argue that Searchinger pays too little attention to the chain of causation, of which biofuels are one factor amongst many. The methodology employed, particularly the studies' modelling have been questioned. One riposte to Searchinger (which was used to inform the Gallagher Review's conclusions) noted: *"The basic issues raised by Searchinger are relevant but there are fundamental differences between US bioethanol and EU biofuel initiatives".*

Industry stakeholders argue that biofuels can be developed sustainably if future efficiencies in farming practice (no-till farming, for example) and future improvements in biofuel production's GHG profile are brought forward.

Biodiversity – increases in land cultivation for biofuel development could arguably affect biodiversity in a negative way. Particularly since certain biofuel crops grow best in *biodiversity hotspots* (such as Brazil or West Africa). The EU's policy of using set aside land to meet biofuel demand has also been criticised as such land has become home to many species of wildlife.

Water – Competition for water resources is a further threat of biofuel expansion. Development of biofuel production will lead to increased irrigation which could exacerbate existing problems. While the UN is vocal on the issue, they note: "*many of the existing concerns about water use and quality can be addressed by using water more efficiently, recycling it for fertiliser and digesting it for biogas".*

Second generation biofuel technology – although second generation biofuel systems are still in development, they appear to hold the potential to overcome the problems associated with their first generation counterparts. The technology utilises waste and residues from existing crops to create useable fuels. Despite the potential they hold: *"major technical and economic hurdles are still to be faced before the can be widely deployed."*

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1 Introduction

Following the publication of the Gallagher Review into the indirect effects of biofuel production, this paper examines wider discourse on the subject to provide an assessment of the technology's potential economic, environmental and social impacts.

The Gallagher review was conducted by the Renewable Fuels Agency and commissioned by the Secretary of State for Transport. The paper offers a contribution to the ongoing, and global biofuels debate, and has had a significant impact on the UK governments transport policy.

Biofuel development is occurring in two waves: the more prevalent first generation technology; and the in-development second generation technology. The promotion of biofuel in developed and developing nations has been encouraged due to the perception that the technology is *"key to reducing reliance on foreign oil, lowering emissions of greenhouse gases… and meeting rural development goals"*.[i]

Recent scientific studies, however, have served to undermine this perception by presenting evidence to suggest growth in first generation technology will *"raise agricultural commodity prices and could have a negative effect, particularly on the poor".*[ii] Moreover, current academic and governmental debate is centred upon the technology's ability to significantly lower greenhouse gas (GHG) emissions and the affects of land-use change.[iii]

2 First Generation Biofuel Technology

First generation biofuels are derived from food crops, converting starch and sugar from such plants as corn, sugarcane, rapeseed and soya beans, into liquid fuel.[iv] In Europe, the most common fuels derived from first generation sources are biodiesel and bioethanol.[v]

Biodiesel is the most commonly used biofuel in Europe. As a fuel, it is very similar to mineral diesel. It is produced through the mixing of feedstock with methanol and sodium hydroxide. The resulting fuel can be mixed with mineral diesel to power modern diesel engines.[vi]

Bioethanol is produced through the fermentation of plant starches and sugars. The fuel derived from the process may be used as an alternative to petrol.[vii]

The EU's 2006 impact assessment of their biofuel strategy drew a number of conclusions, including:

- while actual emissions reductions depended upon the feedstock used and production methods employed, the net greenhouse gas effect of biofuels is positive;

- the most negative environmental impact of cultivating biofuel was *"the possible use of 3 million hectares of set-aside land, the use of water (in cases where the* *biofuel/biomass crops chosen require significant water inputs); and the use of pesticides";*

- end use of biofuel could save (between strategy implementation and 2010): 7.8 million tonnes of oil, if a business as usual approach was adopted; 23.5 million tones if a regulated market approach was adopted; and 22 million tonnes with a deregulated approach;

- even small increases in fuel supply could have significant beneficial effects on oil price;

- bioethanol and biodiesel were found to be more costly than oil and petrol (at then current prices). It was noted that oil would have to rise to $90 per barrel for bioethanol to break even and $60 for biodiesel;

- adopting a regulated market approach would require an additional 4.1 million hectares of land, equivalent to 4% of the total arable in land in the EU 25. The same figures for a deregulated approach were 2.3 million hectares or 2% of arable land;

- a regulated market approach could yield an additional 67,000 direct employment jobs in the EU 25; and

- there remained little understanding of whether competition with food crops would occur but higher commodity prices *could* occur.[viii]

3 Food

On the issue of food prices, the Gallagher Review found that increased biofuel production would raise the cost of *some* commodities. Assessing the impact this would have on the poor, the review concluded that, in the longer term, there would be a *"small net but detrimental effect"* that could be *"significant in specific locations".* The review's shorter term predictions suggest greater impacts on the poor and the need for government intervention to alleviate these impacts.[ix]

This finding is broadly supported in related literature. The UN, for example, maintains:

Rapid growth in liquid biofuel production will make substantial demands on the world's land and water resources at a time when demand is also rising. Liquid biofuel growth has already begun to raise the prices of the world's two leading agricultural feedstock – maze and sugar – and soaring palm oil may be leading industrialists in Southeast Asia to clear tropical forests for new plantations.[x]

A recent Environmental Health Perspectives article points to a *confluence of factors*, suggesting *"no one is blaming the rapid prices increases solely on biofuels".* The authors continue, *"demand for biofuel feedstocks is overwhelming a food supply system that was already overextended by surging demand"* and point to a *perfect storm* within which adverse weather conditions in *breadbasket regions* are been exacerbated by biofuel development, particularly the growth of the bioethanol industry in the US.[xi]

Responding to the pressure on the food system, the Gallagher Review advocates the implementation of *"lower targets and shifting production for biofuels away from agricultural land used for food production".*[xii] The UN suggests improving the productivity and sustainability of agriculture, fully understanding the policy nexus influencing biofuel development (four spheres on influence: energy; environment; agriculture; and trade) and developing an analytical framework for food security and bioenergy (based on country typologies) will all serve to ease the problems associated with food/biofuel equation.[xiii] The US, currently undertaking a robust biofuel development programme[xiv], favours a technological solution to the food problem, prioritising the development of second generation biofuel generation. They point (as do others) towards the *co-products* of certain biofuel feedstocks, such as Distiller's Dried Grains (DDG), a left over product from corn based biofuel production, which can be used as animal feed.[xv] They also advocate the use of better farming techniques to increase yields.[xvi]

4 Greenhouse Gas Benefits

Examining the GHG benefits of biofuels the Gallagher Review estimates a CO_2 saving of 338 – 371 million tonnes, compared to a "without biofuel" scenario and assuming land-use emissions are avoided (see below). Drawing on the Stern Review (2006) the current review document highlights biofuels' appropriate role as *"reducing road transport GHG emissions".* Biofuel, while considered key to reducing vehicle GHG emission, is not deemed to be a *magic bullet,* rather it is thought to be part of an integrated approach which also includes: efficient vehicles; low carbon fuel; promotion of public transport; walking and cycling; aiding more efficient driving; and managing demand.

An important aspect of establishing the GHG benefits of biofuel is the lifecycle analysis which examines the whole process of production. The Gallagher Review, drawing on a number of lifecycle analyses, concludes that biodiesel offers a 40 – 50% saving on mineral diesel. The potential saving of bioethanol is more ambiguous, ranging from 20 – 80% depending upon feedstock, fertiliser application, use of co-products, energy source used in the manufacture, etc.

Again, these perceived benefits are repeated, with a degree of numerical variation, in associated literature. A 2008 article in Biological Conservation journal, for example, contends:

> *… biofuels are considered to be carbon neutral because all CO_2 released during biofuel combustion is offset by carbon fixation during plant growth. In reality, GHG's may be released during the production process… Therefore, the net benefit of biofuel use in terms of GHG balance can only be determined from a full lifecycle analysis.*[xvii]

The report argues that 15 years of studies have demonstrated an average net saving of 31% for bioethanol and 54% for biodiesel.[xviii] An earlier report (2006) from the University of Minnesota put forward less optimistic estimates: a biodiesel GHG reduction of 40%; and a bioethanol GHG reduction of 12%.[xix]

The UN's most recent release on the biofuels issue does not provide specific figures for GHG reduction. It does however state that, when all fossil fuel inputs in the production process are considered, and provided there is now negative land-use change effects, the use of biofuel in transport provides *some* net GHG emission reductions. They state too that when used to generate electricity *biomass combustion to displace coal can reduce GHG emissions even further than using biomass for transport fuels.*[xx]

The OECD's conclusion on the biofuel related GHG emissions was to state that the: *"current push to expand the use of biofuels won't generate significant benefits".*[xxi]

5 Land-Use Change

Estimating GHG reduction becomes more complex when the issue of land-use change is considered as part of a lifecycle analysis. There are two types of land-use change which factor into calculations: direct land-use change (DLUC); and indirect land-use change (ILUC). The second of these has recently become an issue of debate with the publication of the somewhat controversial Searchinger study: *Use of US croplands for biofuels through emissions from land use change.*[xxii]

The Searchinger study claimed:

> *"…by excluding emissions from land-use change most previous accountings were one-sided because they counted the carbon benefits of using land for biofuel but not the carbon costs, the carbon storage and sequestration sacrificed by diverting land from its existing uses."*[xxiii]

DLUC occurs when farmers convert forest or grass land into cropland. The process of converting virgin land releases carbon stored in plants and soil through *decomposition or fire.* Furthermore the loss of mature forests or grassland *forgoes ongoing carbon sequestration* (the uptake and storage of carbon in plants and/or soil). This, according to Searchinger is equivalent to increased emissions. ILUC is the result of diverting existing cropland into biofuel, pushing up global commodity prices and motivating farmers elsewhere in the world to clear more virgin land for food.[xxiv]

Land-use change alters lifecycle analyses as:

> *Proper accountings must reflect the net impact on the carbon benefit of land, not merely count the gross benefit of using land for biofuel. Technically, to generate green house benefits, the carbon generated on land to displace fossil fuels (the carbon uptake credit must exceed the carbon storage and sequestration given up directly or indirectly by changing land uses).*[xxv]

The principal findings of the Searchinger, in summary, were:

- The US has insufficient land capacity to facilitate its planned biofuel expansion;
- Increasing bioethanol production in the US will lead to the conversion of virgin land into crop land, both in the US and globally;

- GHG emissions resulting from ILUC will be large and net savings will not be experienced until after the period when GHG pay-back is needed;

- First generation biofuels are problematic and it would be preferable to make biofuel from waste products.

The Searchinger study is not without criticism. A critique, produced in support of the Gallagher review found that there were issues of debate surrounding:

- the *chain of causation*, which was believed to be *too long and complex for land use change to attributed confidently to use of grain for biofuel;*

- the models employed by Searchinger, which were considered possibly *inappropriate or inadequate*; and

- the assumptions and/or input data, which were thought potentially *unclear or inaccurate.*[xxvi]

The critique did not refute the claim that biofuel production would result in indirect effects *including* land-use change; rather it raised a number of issues from an EU context, namely:

- Biofuel could not be considered the sole cause of ILUC, meat production, timber extraction, accessibility, migration and other factors should be considered;

- US policy favours one fuel (bioethanol), which encourages *mono-cropping,* while the EU plans to *balance bioethanol and biodiesel production, which will improve the balance of rotation;*

- The impetus behind US policy is fuel security, whereas the EU's motivation is GHG mitigation;

- The level of biofuel production in the US is high.[xxvii]

In conclusion the critique stated:

> *"The basic issues raised by Searchinger are relevant but fundamental differences between US bioethanol and EU biofuel initiatives".*[xxviii]

Furthermore, it added:

> *"… the world will need to significantly enhance food and feed production by 2050, whether or not bio fuels are made. This will entail just as great a threat to GHG emissions and biodiversity as land-use change due to biofuels. That we are facing these issues now, in time to prepare, is to be welcomed".*[xxix]

Criticism from the biofuel industry in the US has been more dismissive of the Searchinger study. One response, from the Biotechnology Organisation, accused the study of presenting an *unrealistic scenario* and of not taking into account future efficiencies in farming practice (no-till farming, for example) and future improvements of biofuel production GHG profile. The rebuttal concluded:

> *"Contrary to the findings of Searchinger et al., the vast majority of research from academia, NGOs, and federal labs suggest that **biofuels have a positive and increasingly beneficial impact on climate change** (emphasis in original)."*

The issues raised by Searchinger remain a topic of debate amongst stakeholders and they have informed the findings and recommendations of the Gallagher review. This review in turn has raised the issue of "co-products", which again should be factored into life-cycle analysis. As mentioned above co-products are useful bi-products of biofuel production, such as DDGs. The impact co-products may have in mitigating some of the effects of land-use change are not robustly addressed by Searchinger.

6 Other Issues

In addition to the above points, a number of other biofuel related impacts have been highlighted by commentators.

Biodiversity – in addition to contributing to GHG emissions and having a role in driving up commodity prices it is argued that biofuel production could potential threaten biodiversity. A 2007 study estimated that global biodiesel demand would reach 227 million tons per year by 2050, requiring substantial increases in cultivated land. In addition, a further study contended that because the most intensively cultivated feedstocks, soy-bean and palm oil, grew best in *biodiversity hotspots* (Brazil and West Africa for example) these areas would be most affected.[xxx] The problem is not only associated with developing regions. EU policy to use set aside land has criticised for threatening birds and other wildlife.[xxxi]

On the issue of biodiversity the UN have stated:

> *"Even varied and more-sustainable crops grown for energy purposes could have negative environmental impacts if they replace wild forests or grasslands. Other potential impacts include the eutrophication of water bodies, acidification of soils and surface waters, and ozone depletion (all of which are associated with nitrogen releases from agriculture) as well as the loss of biodiversity and its associated functions."*[xxxii]

Water – Competition for water resources is a further threat of biofuel expansion. As is the case with food prices, biofuels are not the only pressure on the world's water supply. Population growth, migration, climate change, natural disasters, poverty and war all contribute to increased competition for water. Biofuel expansion, will lead to agricultural growth, which will in turn lead to greater irrigation potentially exacerbating already existing problems.[xxxiii]

The UN has again been vocal on this issue, stating that their Food and Agriculture Organisation:

> *"…expects that no major water crisis will affect irrigated agriculture at the global level by 2030, by which time there will be a relatively small increase in irrigation water withdrawal compared to 1998. However, serve water shortages are already occurring at a local level… Agriculture currently uses 70% of the world's (and 85% of the developing world's) available water, primarily for the production of food and non-food raw material."*[xxxiv]

They add however:

> *"Many of the existing concerns about water use and quality can be addressed by using water more efficiently, recycling it for fertiliser and digesting it for biogas"*[xxxv]

Job creation – Job creation was noted as one of the key benefits of biofuel development by the EU and this recognition also informs the UN's sustainable bioenergy framework. The UN note that successful bioenergy industries bring jobs at all skill levels, high, medium, low and unskilled. In addition given the agricultural nature of production many of these jobs are likely to occur in rural areas. Furthermore, job creation is spread across the globe, in rich and poor countries alike.[xxxvi]

7 Second Generation Biofuel Technology

It is thought that second generation biofuel systems will offer greater GHG savings as feedstocks can be provided by the waste/residues of already existing crops or can be grown on marginal land. The nature of these feedstocks should go some way to mitigate direct competition with food crops and GHG emissions associated with land use change.[xxxvii]

That said, however, it is apparent that second generation technology is in its relative infancy. An International Energy Agency assessment of biofuel technology research, development and deployment found that:

"…major technical and economic hurdles are still to be faced before the can be widely deployed."

The analysis found too that *"in the near to medium-term, the biofuel industry will grow only at a steady rate and encompass both first and second generation technologies that meet agreed environmental, sustainability and economic policy goals".*[xxxviii]

8 Points for Discussion

- Rapid biofuel expansion is likely to have an adverse affect on an already over extended global food supply.
- One solution to this would be to decrease biofuel targets.
- More efficient farming techniques, co-products and second generation technology could lessen the impact biofuels have.

- Assuming that land-use change is not factored in the majority of lifecycle analyses conclude that biodiesel and bioethanol will have a positive impact on GHG reductions.
- Such lifecycle analyses are incomplete as they fail to incorporate direct and indirect land use change.
- Land use change is likely to at best lower GHG benefits and at worst negate them. The debate on this remains open.
- Again, second generation technology, co-products, policy interventions and better farming techniques could ease the problems associated with land-use change.
- It is argued the biofuels also have a negative effect on biodiversity and water supply.
- Against this the biofuel industry has the potential to create jobs globally across all skill levels.
- Second generation biofuel technology remains in its relative infancy.

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