FINAL REPORT:
Biofuels Scoping Review

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Foreword

The aim of the Biofuels Scoping Review is to assess the current literature on research related to eight sub-topics, identify key policy issues, and potential research gaps for future work, within the African context. Some of the terminology of the Review is outlined below:

Within the Scoping Review, the term biofuels refers specifically to liquid fuels derived from biomass through diverse chemical processes (e.g. transesterification of vegetable oils, fermentation of sugar and starch-rich crops). A commonly-used classification is between first- and second-generation biofuels. This review focuses primarily on the former, which are defined as those biofuels that are produced from sugar, starch and oil-bearing crops or animal fats that in most cases can also be used for food and animal feed. Bioenergy (i.e., other forms of biomass) are not discussed throughout this review, as the scope focuses particularly on biofuels. Energy efficiency in this context also refers to energy security, as much of the current biofuel research uses such terminology.

The Biofuels Scoping Review was discussed in a workshop discussion meeting held at DFID on the 26th June 2013, notes from the meeting can be found in **Annex 1.**

Source: Gasparatos, A., and P. Stromberg (2012)*Socioeconomic and Environmental Impacts of Biofuels*, Cambridge University Press.

Report Summary

From both a political and economic perspective, biofuels have emerged in recent decades as a plausible alternative to oil. A number of countries with important agricultural sectors and pressing needs with respect to rural livelihoods, employment, economic growth, and domestic energy supplies have opted to support the production and consumption of biofuels. In developing biofuels, a number of concerns have emerged, particularly when considered at an industrial scale.

The 'Biofuels Scoping Review' aims to assess the current literature on research related to eight sub-topics. Its aim is to identify the key policy issues alongside potential research gaps for future work. The focus is on research undertaken in the African context, although work relevant to this setting but which has been undertaken elsewhere is highlighted.

Research covered is oriented towards one or more of the following: competition over feedstocks for agricultural production; biofuels as an alternative to fossil fuels as a source of energy, and; the reduction of greenhouse gas emissions and other environmental concerns. Central to these are impacts on human welfare, with trade-offs between our demands for food, energy, and the environment.

Where poverty and direct resource dependence are present, some of these trade-offs become critical. There is certainly potential for countries on the African continent to benefit from the expansion of biofuel production and consumption. Yet, this is likely to be constrained by poor regulatory frameworks and the potential problems posed due to weak governance. This of course must be studied on a country by country basis. But where those constraints are less binding, there are two key issues that need to be addressed if biofuels in Africa are to contribute to sustainable development: insecurity of land tenure among the rural poor and overlapping institutional arrangements, and; the potential cost of meeting the basic dietary requirements of the poor in situations where biofuel production diverts crops from local food supplies.

Given the characteristics of trade-offs in a given setting, future research could focus on those two issues in order to assess the potential of biofuels to achieve both environment- and development-led policy goals.

SECTION I

Introduction

Background

From both a political and economic perspective, biofuels have emerged in recent decades as a plausible alternative to oil. Beginning with the oil shocks of the 1970s, fears about the 'end of cheap oil' and concerns about supply risks due to instability in major oil-producing countries have combined with climate concerns to drive increasing investment in biofuels (Rajagopal and Zilberman, 2007). Indeed, production of bioethanol (produced primarily from sugar- and starch-based crops) and biodiesel (produced from oilseed crops), currently the two most commonly-produced and -consumed biofuels, respectively rose by a factor of two and four between 2000 and 2005 (Martinot, 2005).[1]

Energy from biofuels, ranging from solid biomass and liquid fuels to various biogases, is derived from biological carbon fixation. Thus, they are essentially renewable sources of energy with chemical and physical properties similar to those of oil. These properties have played a role in motivating policymakers' efforts in support of their development.

Concentrated in the transportation sector, the supply of so-called 'modern' or 'first generation' biofuels, i.e. excluding traditional biomass (wood, charcoal), accounts for less than 0.5% of the global energy supply (IEA, 2007). Despite the relatively small role of biofuels in the energy mix, policymakers in less-developed countries have been attracted by their potential to augment energy supplies while improving agricultural incomes and providing new sources of jobs. However, there have also been rising concerns about the impacts of increasing biofuel demand on, for example, food security and the tenurial arrangements of the rural poor (see World Bank, 2010).

The Scope of the Review

Commissioned by the UK's Department for International Development, the 'Biofuels Scoping Review' aims to evaluate the current literature on research related to eight identified sub-topics,: energy efficiency and climate mitigation potential; food security; land-use change; livelihoods; economic growth and jobs; technology; trade; and policy The focus is on research undertaken in the African context with a view to identifying the issues of greatest policy salience as well as potential research gaps for future work. To that end, a comprehensive survey of the available literature is undertaken, covering both peer-reviewed, published research in addition to the 'grey' literature.

Much research concerning the production and consumption of biofuels tends to be oriented towards one or more of the following: competition over feedstocks for agricultural production; biofuels as an alternative to fossil fuels as a source of energy, and; the reduction of greenhouse gas emissions and other environmental concerns. Together, these three areas

[1] The raw material used in the conversion process, which can be a crop, crop residue, or agricultural and municipal waste, is typically referred to as 'feedstock'. Sugar- and starch-based crops such as wheat, sugar beet and cassava and oilseed crops, including rapeseed and palm oil, comprise the first-generation feedstocks. Wastes, residues and dedicated cellulosic crops form the vanguard of the so-called second-generation feedstocks (see Rajagopal and Zilberman, 2007).

of research have been termed the food, energy, and environment 'trilemma' (see Tilman et al., 2009). This idea forms the basis of the scope of the Review. Although not limited to less-developed countries alone, it is of particular relevance for the Review given its focus on African countries. For instance, the lack of access to clean, more reliable forms of energy remains a critical policy concern across Africa. Also, the "food vs. fuel" debate, in which increased biofuel production could potentially lead to a decrease in access to food crops, is of particular relevance for countries where malnourishment is widespread.

Although traditional biomass remains a very important energy source in numerous African countries, many have begun turning towards biofuels in order to access new supplies of energy and improve energy efficiency. Yet, at the current time households across the continent have relatively little access to biofuels, for example, in Kenya (see Kityui et al. 2001). Biofuel initiatives, both in the public and private sectors and at both village- and national-scale, have been initiated in countries as diverse as Mozambique, Mauritius, Senegal, Ghana, Egypt, Zambia, Nigeria, South Africa, and Ethiopia (Jumbe et al., 2009). Malawi, for example, currently produces 30 million litres of ethanol per year in order to decrease its fuel import bill. Ethanol is produced from sugarcane molasses as a by-product of sugar processing.

Since ethanol can be produced from a wide range of feedstocks, it has been touted as having particular potential across Africa. Initiatives not only focus on long-established feedstocks such as ethanol, however. Jatropha, in particular, is a versatile crop that has been highlighted as one of the newer, 'second generation' biofuel feedstocks with potential benefits for the rural poor[2],[3]. For example, a local NGO called the Mali-Folke Centre supports Malian communities that grow Jatropha for the purpose of producing oil. This is used to generate electricity for local consumption (Jumbe et al., 2009, p.4981). It must be noted, though, that some research has found that Jatropha grows much better on more fertilized soil, making it far from a "miracle" crop.

In this Review, eight biofuels research areas or sub-topics have been identified along with overlaps among most if not all of these. The first two research areas focus directly on the three outcomes of the trilemma: (1) 'Energy efficiency and climate change potential'; and (2) 'Food security'. At the heart of understanding the potential trade-offs underlying the trilemma and makes the link to further, development-related aspects of biofuel production is 'Land-use change' (3). . Linked to land competition and dual use of feedstocks for food and fuel is the issue of 'Livelihoods' (4), closely followed by 'Economic growth and jobs' (5). While the former addresses the welfare of the rural poor engaged or employed in agricultural production, the latter also examines employment further up the supply chain, e.g. in processing. The final three, cross-cutting sub-topics provide the bigger picture with a survey of research on issues that will be central to biofuel production and its potential contribution to sustainable development: 'Technology' (6), 'Trade' (7), and 'Policy' (8).

Biofuels Research Map

Figure 1 illustrates the biofuels research map based on the trilemma, and where each sub-topic can be found. As might be expected 'energy efficiency and climate change potential'

[2] The 'rural poor' groups a number of terms used in the literature, and broadly categorises people whose livelihoods and incomes depend on small-scale agriculture, for example, smallholders, farmers, agriculturalists, and rural households. This Review uses these terms interchangeably.

[3] DFID noted that they have an ESPA research project which contradicts that Japtropha is not a viable crop for biofuel production. The authors agree that Jatropha grows better on more fertile soil, and is therefore better as a feedstock where there is more fertile soil.

(1) is between the ‘environment’ and ‘fuel’ points while ‘food security’ (2) is located at the ‘food’ point of the triangle. Sub-topics ‘land-use change’ (3), ‘technology’ (6) and ‘policy’ (8) cross-cut all three points so are located at the centre of the map. Aspects related to ‘economic growth and jobs’ (5) and ‘trade’ (7) are often closely related to energy concerns while ‘livelihoods’ (4), particularly in rural areas, are researched in the context of agricultural production. The relative degree of research that has been undertaken in a developing country setting within each sub-topic is indicated in the map by shading: dark green denotes that much research has been undertaken; light green denotes that some research has been undertaken, and; white denotes that little or no research exists in a particular area.

Figure 1 Biofuels research map

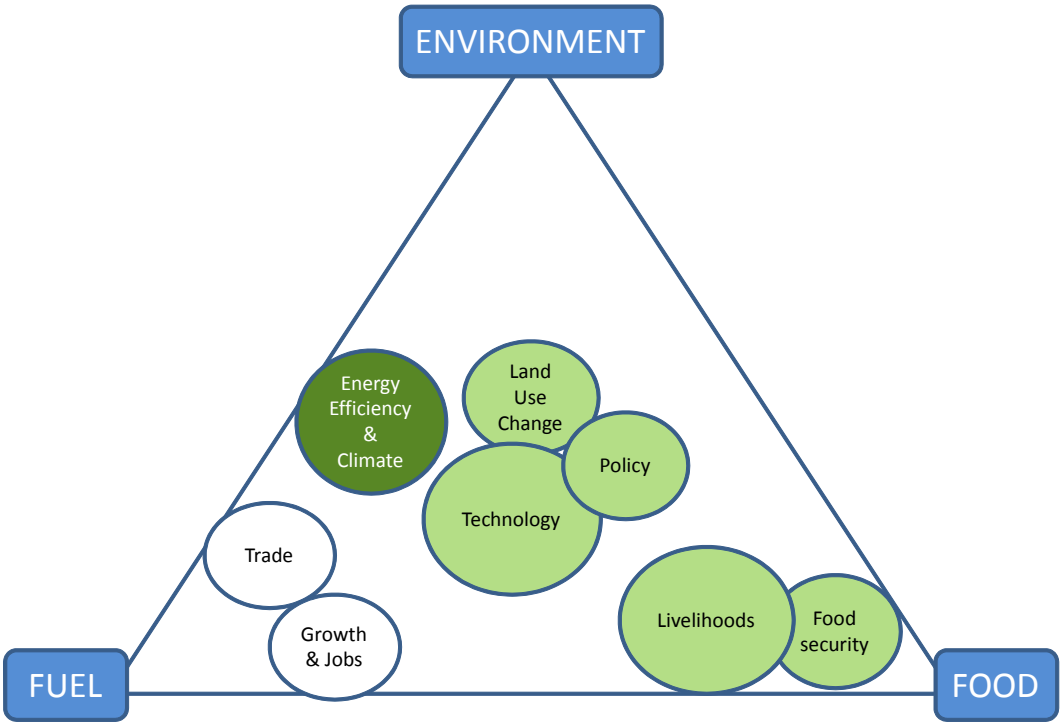
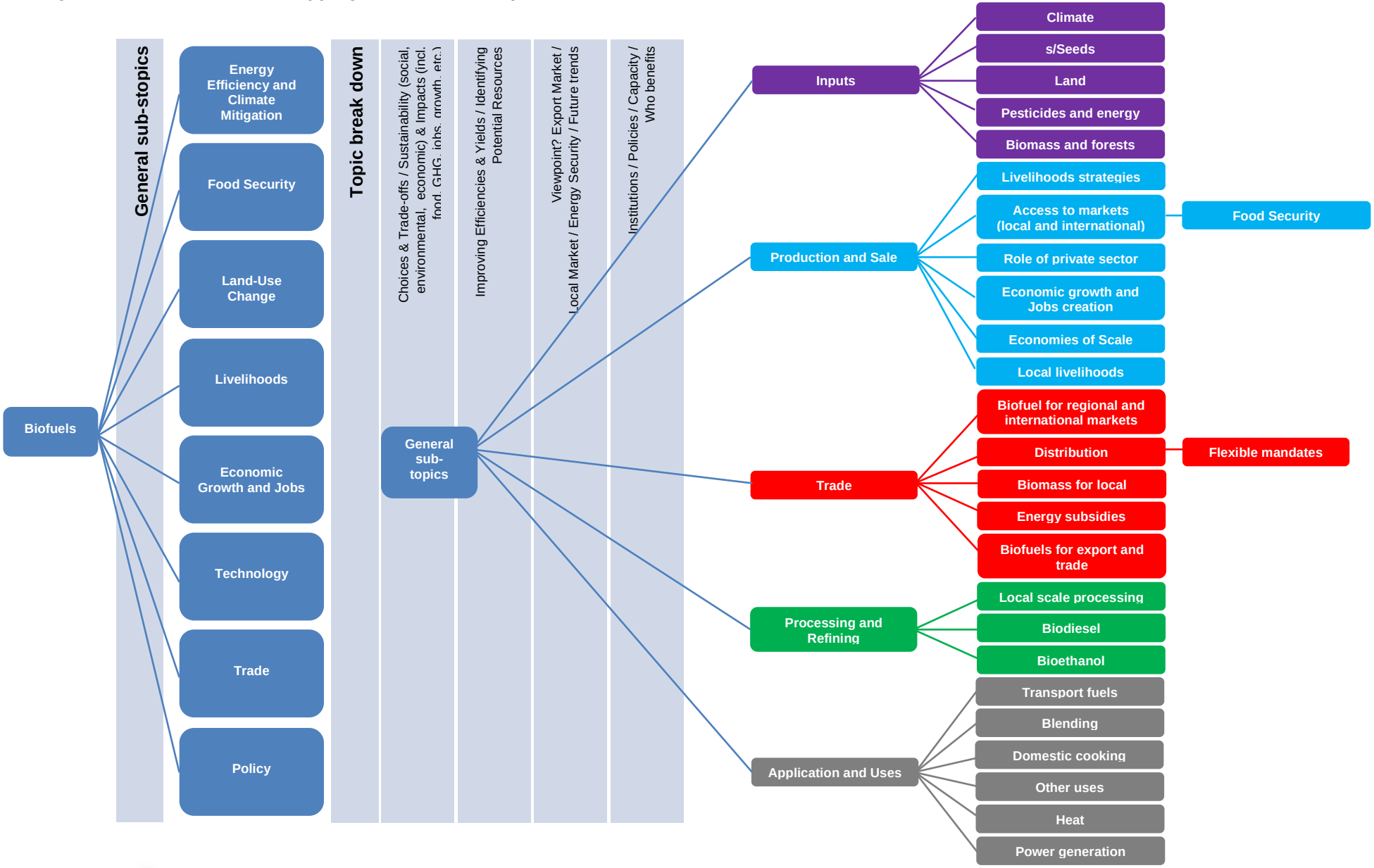


Figure 2. Gives a more detailed mapping of the various topics and sub-topics that are to be considered. The general sub-topics are broken down further, highlighting the various topics/cross-cutting themes that enter into each topic (cross-cutting themes are depicted as rectangles, which cross over the various sub-topics). Though this gives more detail, the Review is based on the sub-topics of Figure 1. That being said, all of the sub-topics in the more detailed diagram fall into the sub-topics of the simplified diagram, which presents the sub-topics in a more concise way.

Figure 2 Biofuels research mapping of further sub-topics



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The Structure of the Review

The remainder of the Review presents the current state of knowledge and understanding with respect to each sub-topic, in Section II. While certainly not an exhaustive review of these, the presentation of sub-topics highlights the main questions and issues of research interest both in and outside the African context. However, we find patchy coverage of research undertaken in the former. Much biofuels research has taken place either in a general or non-African context, which is perhaps unsurprising due to the fact that many biofuel sectors in African countries are in their infancies, compared to more developed sectors, such as that of Brazil. A number of interesting research gaps are highlighted in the text in all sub-topics, along with research questions of potential interest for DFID (noted in the text and listed under the sub-heading 'Where can DFID add value?'). After the discussion of research in sub-topics (1) to (8), Section III concludes with a cross-cutting discussion of key research gaps alongside current research programmes and operational interventions.

SECTION II

Biofuels Sub-topics

1. Energy Efficiency and Climate Mitigation Potential

This first sub-topic covers research related to both energy- and climate-related aspects of biofuels. Before discussing these two in turn it is worth noting that there is a broader range of environmental concerns associated with biofuel production, which are not covered here in any detail due to space constraints. For instance, the agricultural activities associated with biofuels can lead to soil erosion and eutrophication due to fertilizer run-off, along with biodiversity losses from habitat conversion. Land-use change is, however, discussed in Section 3.

Energy efficiency has been a major concern in the development literature for many years. Recurring power failures and lack of access to affordable energy has become an important political issue across the developing world. There has been a substantial amount of research looking into the feasibility of using biofuels to improve energy efficiency in developing countries. Given that biofuel production requires inputs such as pesticides and includes processes, e.g. harvesting, that consume fossil fuels, it is pertinent to begin with the literature on life-cycle analysis (LCA). This is essentially an engineering approach, which aggregates the material (quantity of fuel, electricity, water, etc) and the embodied energy flow associated with production and consumption of a particular biofuel (see Rajagopal and Zilberman, 2007). In doing so, environmental indicators can be derived, in particular the 'Net Energy Value' or 'fossil energy intensity', i.e. the amount of fossil energy required to produce one unit of biofuel.

One key finding in the LCA literature is that ethanol produced from sugarcane offers higher energy benefits compared to ethanol from maize. Such benefits are one reason for the success of Brazil's ethanol industry. Ethanol production in Brazil began in 1975, "with the aim of being able to substitute 20-25 percent of gasoline with anhydrous ethanol," due to increases in price of petroleum resulting from the oil shocks in the 1970s (Wilkinson and Herrerra, 2010, p.750). With support from the government both from the perspective of demand and supply (for more on policy, see Section 8), ethanol production increased from 15 billion liters in 2003 to 25 billion liters in 2008-09. Some 20 billion liters is absorbed domestically with the remainder exported to the global ethanol market. La Rovere and Pereira (2011) argue that the Brazilian biofuel industry has lessened the country's dependence on imported oil thus improving its 'energy security'.

Given the relative immaturity of biofuels sectors in many developing countries, research undertaken elsewhere tends to stress the potential rather than actual energy benefits of biofuels. For example, Zhang (2008) discusses the interest of Asian countries in turning to biofuels to help deal with increasing demands for energy, and to mitigate/reduce pollution levels. Indeed, although currently lagging far behind the world's biggest producers of ethanol, Brazil and the United States, China and India are the world's third and fourth largest producers, respectively.

Amigun and Muango (2011) review the development of biofuels in African countries through a qualitative analysis of biofuel policies with a view to improving energy efficiency, e.g. by

reducing the demand for energy and water needed in production. They note potential trade-offs of biofuel production for energy purposes with food security (see (2)), which is a common concern in much of the available literature on energy efficiency. However, we note the relative lack of empirical evidence both in the African setting and more generally (see (a)).

Turning to the literature on the climate mitigation potential of biofuels, there has been considerable research into the 'carbon balance' potential of biofuels. This work is again based on application of LCA. Against a baseline of fossil fuel use, studies attempt to estimate the greenhouse gas savings from the consumption of a given unit of biofuel. Earlier work focused on savings when there is an assumption of no land-use change as a result of establishing crops for biofuel feedstock. Gallagher (2008) reviews a number of these studies showing the range of GHG savings, which vary according to the conversion technologies and inputs used. For example, Brazilian bioethanol is shown to have among the best savings of the estimates based on ethanol produced from sugarcane. However, once land-use change is factored in, such estimates tend to change depending on the land use substituted (see Section 3). For example, Fargione et al. (2008) show how the substitution of areas of high-carbon tropical forest with say palm oil, in Indonesia, can lead to substantial 'carbon debt'.

The capacity of biofuels to reduce GHG has also been studied using economic/analytical modelling approaches. Havlik et al. (2011), for example, make an important distinction between the potentially varying outcomes of increasing biofuel production depending on whether first generation or second generation biofuels are used. They develop a partial-equilibrium model and find that second generation biofuels are more efficient at reducing GHG emissions. Simulations show that overall emissions are almost a third lower compared to a baseline in which no biofuels are produced (Havlik et al., 2011).

In the African context, there has been relatively little research on the potential of biofuels as a substitute for fossil fuels (see (b)). One exception is Habib-Mintz (2010) who focused on the potential for biofuel policy in Tanzania to help address climate change. A qualitative/quantitative approach was undertaken, interviewing people within the industry as well as households. Stronger regulatory frameworks are advocated, although biofuel policy across Africa appears to be less driven by climate concerns and more by energy and development-led needs.

That said, the issue of weak regulatory and policy frameworks is relevant irrespective of the policy aims of biofuel production. This point was emphasised by German and Schoneveld (2012) who analysed the biofuel sector in Zambia via secondary sources and interviews with government departments, investors, and civil society stakeholders. They infer significant policy gaps which are hindering the potential of the country's growing biofuel sector to aid in climate change mitigation. Also, the introduction of biofuels, specifically feedstocks could add more crop choice to farmers. This decision is one of the main adaptation strategies that farmers implement to cope with climactic change and variability (Di Falco et al., 2011). Future research could focus on understanding how policies that incentivize growing biofuel crops may also affect farmers' strategies to privately deal with the implications of climate change and deal with food security.

Where can DFID add value?

a. To what extent might efforts towards greater energy efficiency compromise on food security?
b. What is the potential for biofuel development in Africa to contribute towards efforts to mitigate against the effects of anthropogenic climate change?

c. To what extent is the move from food to fuel crop affecting the private capacity to adapt to climate change?

2. Food Security

Alongside energy efficiency, food security is one of the most important topics in the biofuel literature, with the two overlapping in the "food vs. fuel" debate.[4] This argument centres on the potential for increased biofuel crop production leading to a re-allocation of land from the production of food crops to biofuel crops (Chakravorty et al., 2009). Of particular importance are the possible implications for those who may already have difficulties in terms of access to food. The literature on this topic is quite extensive. For example, research in Brazil by Barros et al. (2010) suggests that the production of ethanol competes with beef production. Evidence for such a trade-off offers some support for the theoretical work undertaken on land competition by Andrade de Sa et al. (2012), who show that food production, under certain conditions, is expected to decline with increasing ethanol production.

Molony and Smith (2010) outline three key aspects of the food vs. fuel debate in the African context:

1. "…there is less food available to eat because crops that would otherwise be used for human consumption are being diverted for processing into biofuels – usually for transportation."
2. "…demand for biofuels has increased competition for land and water resources that would otherwise be used for cultivating edible crops (and that also runs the risk of heightening conflicts over water use, particularly in Africa's drier areas)."
3. And as a result, "…more production of biofuels will force food prices up and make it more difficult for poor people to purchase food."

(Molony and Smith, 2010, p.495)

The third aspect became a serious political issue around the world with the commodity price boom, which began in 2007-08 and resulted in a period of high and volatile price increases (World Bank, 2010). Indeed, increasing investment in biofuel production was widely blamed by governments and NGOs for rising food prices over this period, although the evidence has not yet shown to be conclusive in this regard (see (a)). A study by the US Secretary of Agriculture stated that biofuel production contributed approximately just two to three percent to food price increases (see Molony and Smith, 2010). By contrast, a World Bank document which was leaked to The Guardian in July 2008 "calculated that biofuel production was responsible for 75 percent of the increase in food prices between 2002 and 2008" (ibid, p.496). Given rising food consumption, widespread drought and weather impacts impacting on food supply during that period, along with other factors, the reality is likely to lie somewhere in between these two estimates. Indeed, in a critical analysis by Headey and Fan (2008), it is shown that there is likely to be much variation in biofuels' impacts on price depending on the crop under study. They show that although biofuels may have had a strong influence on maize prices, the evidence for other staples suggests a weaker effect.

With respect to the African context, Molony and Smith (2010) highlight the lack of studies into the impact of biofuels production on domestic food availability. Yet, they claim that

[4] Food security is defined by the FAO as existing "when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

increase in international food prices “will have the largest negative impact in Africa” (Molony and Smith, 2010, p.498). Sulle and Nelson (2009) also voice concerns about the potential impact of biofuel production on the price of food crops, specifically in in Tanzania. As biofuel sectors grow across Africa, research is needed in order to gather evidence and test the predicted impacts of biofuel production on food prices and availability (see (b)).

The question that follows is whether these potential negative impacts on food security could be offset by the possible benefits from biofuel production. These include job creation and increased incomes, which could in turn increase peoples’ ability to purchase food (Raswant et al., 2008) (see (c), and also Section 5). If not then there is a clear need to reduce the impacts of biofuels on food production in poorer countries. Collier et al. (2008) suggest how this could be achieved, through data analysis and a qualitative review of current literature and biofuel policies. In particular, they highlight the potential of future new biofuels and associated conversion technologies. However, it is worthwhile noting that second generation biofuels such as Jatropha, which grows on poorer, more marginal land that generally cannot be used for agriculture, actually grows better on higher-quality land (Molony and Smith, 2010). Therefore, where higher productivity leads to greater profits, the potential for a food and fuel trade-off could arise. Yet, this may depend on the regulatory regime in place and its relative effectiveness in, for instance, ensuring that biofuels are not grown in areas zoned for food production.

Where can DFID add value?

a. What is the relative impact of biofuel production on food prices at different scales in different African countries?
b. To what extent does biofuel production impact on the availability of food domestically?
c. Could the potential negative impact of biofuels on food security be offset in the long term, by higher employment and income created by agricultural-led growth?

3. Land-use Change

Following from the food vs. fuel debate, much of the literature on land-use change revolves around the possible re-allocation of land that was formerly used for agriculture towards biofuel crop production. In addition to food price impacts, the main impacts studied are environmental, particularly habitat conversion, as well as the social and economic effects on smallholders.

The literature generally differentiates between **‘direct land-use change’** and **‘indirect land-use change’** (e.g. Gallagher, 2008; Searchinger et al., 2008; Babock et al., 2011; Andrade de Sa, 2012). The former focuses on easily-observable changes that occur as a result of expanding the area of land under biofuel production. In countries such as Indonesia, the rapid expansion of palm oil production has occurred at the expense of tropical forest (e.g. see Obidzinski et al., 2012). In others, the expansion of crops for biofuels has occurred at the cost of a loss of agricultural land. Then, the question is whether the former agricultural use has, in some way, been ‘displaced’ elsewhere, i.e. leading to an indirect land-use change. Recent work by Andrade de Sa et al. (2013) provides evidence for the displacement of cattle pasture from Sao Paulo State to the Brazilian Amazon as a consequence of expanding areas of land under sugarcane production. This in turn contributed to the role of cattle in deforestation at the forest frontier.[5]

[5] Based on the econometric analysis of land-use and socio-economic data over the period 1970-2006, the indirect land-use change is shown to be dynamic, occurring over a 10-15 year period (Andrade de Sa et al., 2013).

Both within a more general, developing country context as well as more specifically within the African context are questions related to the property rights and tenurial arrangements of the rural poor. Both of these aspects have been researched, mainly via a case study approach, in the literature. At one extreme, Cotula et al. (2008) discuss the potential exclusion of the rural poor due to the 'expropriation' of their land claims, which is also increasingly referred to as '**land grabbing'** in the literature. The context for this is competition for access to land among biofuel producers, governments and local resource users. All have an interest in exploiting land for agricultural production. Smallholders may not have formal property rights or strong tenure but may have *de facto* rights, whether private or common property, that are recognised by other locals. In situations where governments recognise and claim the same land as state property, this is where problems often begin. If they decide to issue leases for or even attempt to sell the land to say another country's government or a private firm for biofuel production then a failure to consider the rights of smallholders could potentially impact on their livelihoods (see Pearce, 2012).

In addition to competition over the claims to benefits from the agricultural use of land, other property rights may also be compromised as a result of expanding biofuel production. Such rights pertaining to access and use of natural resources are often weakly defined and indeed are typically informal or de facto. In Indonesia, for example, forest lands used by indigenous people have been reportedly claimed by the state for oil palm plantations, leading to a loss of customary rights to forest resources (Phalan, 2009). Likewise, in India, plots of land that were defined as "wasteland," and allocated towards the production of Jatropha were claimed by local people as a source for thatch, wood, and fodder (ibid). This ties in closely to the livelihoods of the poor, which is discussed further in Section 4.

Indeed, defining 'idle' or 'marginal' land can be problematic for biofuels such as Jatropha when the assumption that if it is 'unoccupied' then it is never used might not hold. Land and resource users with weak tenure and de facto property rights that are not recognised by the state are most vulnerable to losing their resource claims. Molony and Smith (2010) discuss how groups such as nomadic herders who depend on such land at certain times of the year, i.e. manage it as common property, could be excluded as a consequence of the land being allocated to biofuel producers. Given the complexity of land tenure in many parts of Africa (see, e.g. Unruh, 2008), property rights and land tenure are not only highly-sensitive issues but are also potentially very difficult ones to resolve (see (a), and also policy related to property rights under (9)).

Where can DFID add value?

a. To what extent do informal tenurial arrangements and property regimes affect the ability and capacity of local people to participate in land-allocation decisions regarding biofuels?

4. Livelihoods

The loss of claims to resources as a consequence of land allocated by the state for large-scale biofuel production can reasonably be expected to have negative impacts on rural livelihoods, specifically related to the wellbeing of the rural poor. The literature on this issue in the African context largely speculates on these impacts, which is perhaps unsurprising given that large-scale biofuel production is still in its infancy in many countries. Key concerns centre on the effects of an unregulated industry, which include damage to livelihoods and increases in poverty. For example Jumbe et al. (2009) state that "if left unregulated, large-scale production of biofuels could push rural dwellers off their land to pave the way for commercial exploitation of biofuels. This will damage rural livelihoods and increase poverty if

large-scale production biofuels creates artificial food supply shortage" (Jumbe et al., 2009, p.4985).

On the other hand, where smallholders have the opportunity to sell their land to biofuel producers, they could potentially benefit. This occurred in Brazil, for example, in the 1970s onwards when small-scale cattle ranchers opted to sell their land to sugarcane growers (Schneider, 1992; Arima and Uhl, 1997; Margulis, 2004). Many moved to the forest frontier in the Brazilian Amazon in search of new land for agricultural production. Concerns arise when poor farmers sell their land for what some researchers consider a 'low price' to biofuel producers (see e.g. Raswant et al., 2008). Naturally, the degree to which smallholders could benefit from selling land depends on the status of their property rights.

Instead of opting to sell land, smallholders could attempt to adopt biofuel production. Aside from the fact that large-scale farms tend to be more efficient for the production of biofuel crops, production can be capital intensive and often requires access to infrastructure and processing facilities (World Bank, 2010). Since the rural poor tend to lack access to capital and credit as well lacking formal land title (thus depriving them of a source of further collateral) they may not be in a position to benefit directly from increases in biofuel demand. Alternative institutional arrangements have emerged, however, in order to partially overcome these constraints. For example, smallholders account for around a third of Indonesia's oil palm production, which includes participation in out-grower schemes. Given the processing requirements of palm oil and the rapid deterioration of harvested fruit, large-scale production tends to be close to processing units. These are often complemented by out-grower schemes. Although participants in these schemes may have limited independence due to their dependence on partnerships with oil palm companies, there is evidence that the expansion of oil palm has reduced poverty. In one study, Rist et al. (2010) found that average incomes from oil palm cultivation were often higher than from other agricultural activities.

In other settings, the evidence points the other way. Hought et al. (2012), for example, utilised satellite images, remote sensing data, and a household survey to research the impact of the increased cassava market for biofuels in Cambodia. They found that the failure of the cassava market had a negative impact on the livelihoods of farmers in smallholder economies. Similarly, Montobbio et al. (2010) used empirical analysis to determine how the cultivation of jatropha affected the livelihoods of farmers in India. The authors find that jatropha cultivation is neither 'pro-poor' nor is it profitable. They also show that jatropha cultivation favours better-endowed farmers while possibly reinforcing processes that contribute to the marginalisation of small-scale farmers. Similar potential consequences have been hypothesised in the literature on African countries; the relative lack of empirical evidence, however, implies a need for more research in this area.

Following from the discussion of food security in Section 2, any impact on food prices from biofuel production is also expected to affect livelihoods; in particular, those households – both rural and urban - who are net consumers of food. Indeed those who might be most vulnerable to increases in food prices include the urban poor who spend relatively high proportions of their income on food. Autarkic, usually rural households, on the other hand, consume what they produce. They may not respond to changes in market prices. Net producers of food, on the other hand, could potentially benefit from price rises. Biofuel markets may also provide an alternative destination for the sale of crop output. Assessing the impacts of changes in food supply on different groups of the poor, according to their livelihoods and income sources, is a promising area for further research (a, b).

The potential to improve the livelihoods of the rural poor is linked to job creation in the biofuel sector (see also Section 5). Oil palm, for example, is highly labour intensive (World Bank, 2010). Ideally, an expanded biofuel sector would create jobs at all levels, including

employment for the poor. The landless poor, for example, could be employed in agriculture. If this were to take place, rising food prices could potentially be offset by improvements in the livelihoods of the rural poor due to employment in the biofuel sector (Ewing and Msangi, 2009). Thus, there is a need to determine the scale of job creation and estimate the degree of improvement in livelihoods due to employment in the biofuels sector. However, as discussed in Section 2 determining the degree to which food price changes are due to biofuels might be problematic.

Where can DFID add value?

a. How does biofuel production impact on local food supply and the livelihoods of (i) the rural poor and (ii) the urban poor?
b. Does the adoption of biofuel feedstocks lead to a possible 'rural safety net' in the sense of providing two routes for the sale of output, i.e. to food and energy markets? Under what conditions might such a safety net be sustainable?

5. Economic Growth and Jobs

One benefit of a successful, expanding biofuel sector is the potential growth to the economy it can bring, along with various employment possibilities, i.e. from agriculture, to processing, and to trade and end uses. For example, Wang and Tian (2011) state that one of the goals of Chinese biofuel policy is to increase rural employment. Indonesian biofuel production is anticipated to create 2.5 million jobs over the coming years (Phalan, 2009). Expanding biofuel production is also estimated to contribute one million jobs in Venezuela, nine million jobs in China, and 1.1 million jobs in Sub-Saharan Africa (De Keiser and Hongo, 2005). Although most of the currently available literature is clear on the potential for economic growth and jobs, empirical evidence is lacking, particularly in the African context (a). Work has, however, been undertaken in well-established biofuel settings. For example, research undertaken in Indonesia's biofuel sector, and reported by the World Bank (2010), suggests that the recent expansion of oil palm cultivation has increased levels of employment in turn leading to a reduction of poverty.

In a study of the biofuel industries in India and Tanzania, Peters and Theielmann (2008) highlight the difficulties in determining the country-level net employment effects of an expanding biofuels industry. Counting employees in the biofuel sector alone does not explain net employment effects. Also, determining the net employment effects from expanding biofuels is far from straightforward since the impact of that sector on other complementary sectors could be affected, in turn influencing economic growth. Indirect effects – namely crowding-out and budget effects – have to be taken into account. First, the crowding-out effect accounts for job losses in the (mineral) oil industry. Since oil is typically imported, this effect is restricted to the processing and logistics industries, i.e. refineries, ports and transport. In addition, jobs in the food industry could be crowded out if biofuel feedstocks and food compete for land. Different methods need to be developed in order to calculate the net employment effects (b).

Vermeulen and Cotula (2010) discuss evidence for the number of jobs created through land deals for biofuel production in Africa; out of 150 land deals, 130 offered fewer than 50 full-time equivalent positions. Habib-Mintz's (2010) research into biofuel investment in Tanzania emphasises the uncertainty regarding the number of jobs that may actually be created, with estimates ranging from 1000 to 4000 jobs per village. Most of these jobs are expected to be unskilled and involving manual labour. Yet Habib-Mintz notes that with more modern agricultural production systems the level of employment is likely to decline, particularly with respect to the employment of manual, unskilled labour. This implies that the potential of

biofuel production to provide new sources of employment may vary depending on the scale of production, the nature of production, and the capabilities and skills of local people.

Where can DFID add value?

a. Does the production of biofuels contribute to economic growth and job creation at both the local and national level, and if so, how? If not, what are the effects, e.g. crowding out of employment opportunities in other sectors?
b. What methods could be used to determine the net employment effects of an increased biofuel sector? How will this affect economic growth?

6. Technology

Technology is relevant for all stages of biofuel production[6], processing, and end uses. It is also relevant for overcoming environmental concerns, e.g. new feedstock varieties that can be grown on marginal lands, as well as emerging technological processes that reduce GHG emissions, improve energy efficiency and food production. The development of **second generation biofuel** feedstocks is instrumental in efforts to improve the contribution of biofuels to sustainable development. Research in this area is mostly general and not country or context specific. That said, an emerging literature addresses technological improvements that may benefit small-scale production and the determinants of technology adoption. Within the developing context, potential **'leap frogging'**, i.e. skipping over older technologies into new, cleaner technologies, to newer ones could significantly aid in biofuel adoption.

Considering biofuel technologies within developing countries, von Braun and Pachauri's (2006) qualitative study concludes that "in order to make a difference in the lives of poor people as both energy producers and consumers, and to make strong environmental and economic contributions, biofuel technology needs further advancement, and investments and policies facilitating agricultural innovation and trade will have to be considered" (p.1). Focusing on the success of the ethanol industry in Brazil, the authors emphasised the role of the government in providing crucial support to new, biofuel technologies. With improved technologies, it became possible, for example, to use food crop residues instead of food to supply energy.

Jumbe et al. (2009) highlight the need for training in biofuels technologies in order for African countries to reap benefits from producing biofuels. New technologies that allow non-food feedstocks to be used to produce biofuels are also a potential resolution to the food vs. fuel debate; "such technologies are expected to filter in Africa through foreign investors who have already started developing infrastructure for processing biofuels" (ibid, p.4984).

The importance of biofuels technologies within developing countries is discussed in the literature, but mainly in rather speculative ways. Further studies are necessary. For example, the ability of certain countries to develop, implement and support biofuel technologies in order to sustain biofuel production must be assessed, as well as the potential ability to facilitate 'learning-by-doing'. The conditions under which 'leap-frogging' can be effectively facilitated may be useful for countries at the early stages of developing their biofuel sectors (a, b, c).

[6] DFID noted that there was no mention of 3rd generation biofuels, i.e algae and halophytes. The authors suggest that these are too speculative, and both technologically and commercially immature to be considered at this point.

Where can DFID add value?

a. Can technological improvements in the production, processing and/or refining of first-generation biofuels, either by developed or developing countries, lead to their adoption (production, processing, etc) at the local scale? What factors might facilitate adoption by local people?
b. Under what conditions might second-generation biofuels provide a sustainable and commercially viable source of energy in developing countries?
c. What criteria are necessary in order for developing countries to support biofuel technologies, and potentially leap-frog to the use of emerging technologies?

7. Trade

The potential to trade in biofuels is often cited as another positive impact for developing countries embarking on biofuel production. With a natural endowment of land, countries could produce biofuels, minimise their need to import oil, as well as engage in biofuel trading. The literature looks into the effect of import/export tariffs that could affect biofuel trade, and is linked to economies of scale and the potential for developing domestic biofuel markets, with the mature, Brazilian bioethanol market of particular research interest. This sub-topic overlaps with economic growth and job creation (Section 6), a key concern of many emerging biofuel producers, as well as policy (Section 8).

Doku and Di Falco (2012) empirically assess the effect of import tariffs on the motivations of countries to undertake biofuel policy. The authors find some evidence that high tariffs on primary goods such as agricultural commodities are a deterrent to the implementation of biofuel policies. Eggert and Greaker (2012) model the demand and supply side of the transport fuels market in order to research trade policy in biofuels. They first look at optimal trade policies and then at optimal trade policies in regards to blending mandates. For the former, the authors "find that the combination of an import standard and a border carbon adjustment welfare dominates using only a border carbon adjustment (BCA)," and for the latter, "the optimal BCA depends on the domestic subsidy to biofuels production" (Eggert and Greaker, 2012, p.281). In contrast to those studies, von Braun and Pachauri (2006) suggest that opening up the trade in biofuels could help decrease food price fluctuations. Research could be undertaken to better understand the relationship between trade and volatility in food prices (a).

Turning to biofuel trade within the African context, there is an argument that opening up to biofuel trade could help countries which engage in biofuel production through increasing incomes and decreasing their reliance on foreign oil. Amigun et al. (2010) argue that "for sustainable biofuels production in Africa, priority should be given to strengthening local production to satisfy national need and benefits at local level while international trade should only be considered as a secondary option" (p.11). Habib-Mintz (2010) called for research into how governments and agricultural markets might be linked to the international trade in biofuels, and its effect on the poor in Tanzania. Since biofuels have the potential to influence and be influenced by a number of different sectors and markets, research is needed to better understand the role of international trade in biofuel end-products (b).

Where can DFID add value?

a. How might trade in biofuels, and policies which facilitate or hinder trade, impact on food prices in developing countries?
b. Under what conditions might African countries be competitive in and benefit from trade in biofuels, both at the regional and international level?

8. Policy

Policy that influences the production and consumption of biofuels is not only confined to that designed and implemented by governments specifically for biofuel sectors, e.g. policies to support research and development in biofuels. Since biofuels are situated at a nexus of different sectors and markets – for example, agricultural commodities, land, energy, labour, and potentially carbon – it influences and is affected by policy targeted at those as well. In particular, since agricultural inputs comprise up to half of the cost of producing biofuels, policies in that sector may have a particularly influential role (a). Additionally, biofuels have competing policy demands and balancing these is complex and challenging for policy makers. 'Biofuel policy' thus loosely defined cuts across all the other sub-topics presented in this Review. Especially with regards to research undertaken in developing country settings, many researchers advocate appropriate and efficient biofuel policy creation. Yet given the emphasis on the livelihoods and welfare of the rural poor that may be more difficult to achieve in comparison to more-developed settings.

What might constitute 'appropriate' and 'efficient' policy has been subject to research on biofuel policy frameworks. For example, China's bid to develop in a more sustainable and 'clean' way has led to a search for alternative forms of energy. In order to guide its biofuel policy and sectoral development, the Chinese government has researched the biofuel policies of other countries. Indeed, a number of different ministries and departments collaborated on a government document entitled 'Opinions of the Finance and Taxation Supportive Policies on Biofuels', issued in September 2006. Wang and Tian (2011) suggest that this is expected to play a significant role in China's biofuel development, and conclude that "biofuel development depends on financial support, price intervention, and trade barriers, which all call for government support" (p.161).

Turning towards biofuel policy within Africa, Peters and Thielmann (2008), who utilise data from India and Tanzania, find that biofuel programs could create opportunities for developing countries if they are "carefully implemented under the appropriate conditions" (p. 1538). These include strategies and regulatory frameworks, which need to be established by governments. Yet in their discussion of biofuel policies in countries in Sub-Saharan Africa, Jumbe et al. (2009) find that many biofuel interventions lack "concrete strategies and institutional frameworks for implementation" (p.4983).

Other conditions necessary for sustainable biofuel development in Africa can be seen from the results of a survey of international experts and literature review undertaken by Duvenage et al. (2012). Similar to other studies, they show that "projects which display a high degree of transparency, incorporate local stakeholder involvement, and ideally include local villagers as partners are more likely to achieve sustainable biofuel production" (p.993). Although there are examples of African countries undertaking measures to expand their respective biofuel sectors, much of the available research states that, by comparison to other countries, there is typically a lack of government support for the industry. However, a distinction should be made between the establishment of appropriate regulatory frameworks and co-ordinated biofuels strategy and 'government support' in the sense of providing finance, e.g. in the form of subsidies or trade measures that protect domestic sectors.

Much of the literature discusses the current demand for large subsidies to support the biofuel market, and research has been undertaken on the potential economic viability of this market in the absence of subsidies. Defined as direct or indirect monetary transfers, the experience of the use of subsidies in Brazil's bioethanol industry is instructive. Its PróAlcool programme distributed subsidies to expand sugarcane production, construct distilleries and conduct research on biofuel technologies (Andrade de Sa et al., 2013). It also established fuel blending mandates in order to drive domestic demand for ethanol. The programme's subsidies were never officially terminated but have been gradually withdrawn from 1998

onward, to the extent that Brazil's ethanol sector can be considered profitable yet free of such support. However, it has taken decades of often intensive government support for the sector to reach this stage (b). By contrast, biofuel subsidies elsewhere have been shown to lead to waste and inefficiencies, for example, in the maize ethanol programme established by the United States. In such cases, subsidies can be characterised as being perverse when they are economically inefficient (Myers and Kent, 1998). In the US, they may have crowded-out the development of other clean fuel technologies in addition to diverting maize from the food supply thus contributing to global price increases. As discussed by López and Toman (2006), subsidy regimes once in place can be notoriously difficult to remove due to vested interests and rent-seeking (c).

All policies directed at developing a biofuels sector require clear land tenure policies, which is a particular challenge in the African context. These "…are required to guide investments and the proper allocation of land, and must incorporate an understanding of national and local land tenure systems as well as a comprehensive assessment of pastoral practices" (Molony and Smith, 2010, p.493). Currently, many African countries do not have well-researched biofuel policies that consider land tenure, which is necessary in order to mitigate against any negative long-term effects. Where tenure is secure smallholders may be in a better position to benefit from biofuel investment, although this might not be sufficient. For example, the Village Land Act in Tanzania provides compensation payments for displaced citizens, although it is not certain whether such compensation can adequately aid in promoting opportunities for alternative livelihoods (Sulle and Nelson, 2009).

Note, however, that good policies alone may not be sufficient to develop a successful and sustainable biofuels industry. Doku and Di Falco (2012) research the motivations for OECD and non-OECD countries to implement biofuel policy. They analyse whether the motivations in countries of various incomes are similar. Through empirical analysis, they find some evidence that GDP is a more significant biofuel policy driver for OECD countries, while the amount of arable land and feedstock prices prove to be a more significant driver for non-OECD countries.

Where can DFID add value?

a. Do different types of agricultural policy help or hinder the development of a biofuels sector?
b. Are biofuel policies in countries, such as Brazil and Indonesia, transferrable to various African countries given the differences between these countries, e.g. in terms of policy settings? What would be the pros and cons of such policy transfers?
c. What are the effects of corruption and rent-seeking on biofuel policies?

SECTION III

Discussion and Conclusion

With increasing interest from developing countries to initiate and expand biofuel production and consumption, the 'Biofuels Scoping Review' surveyed the current state of knowledge with respect to eight sub-topics. Placed within the trilemma of policy concerns related to food, fuel, and the environment, the literature on these sub-topics is reviewed both in general (developing country) settings as well as specifically in African settings. The former expanded the scope of the Review but given the importance of Brazil and Indonesia, for example, as producers of respectively, bioethanol (from sugarcane) and biodiesel (from oil palm), it is pertinent to include research based on the experiences of such countries. Moreover, the Review aimed to identify potential research gaps in African settings. It is clear from the survey of the available literature that there is a general lack of strong empirical evidence for questions arising in many sub-topics, which is perhaps not surprising given the relatively small scale of biofuel production across the continent. Inclusion of studies undertaken outside the African context could help guide approaches to addressing those gaps.

This section aims to bring together the main insights from the literature surveyed in Section II, identify the most important cross-cutting themes and research gaps, and compare these to current research programmes and operational interventions. The latter are described first.

Known Research Programmes and Operational Interventions

Table 1 describes examples of some of the known research programmes and operational interventions related to biofuel production in Africa as well as other developing countries; since many of the biofuel industries within Africa are in their infancies, other research programmes and operational interventions in other developing countries are included for comparison. Information in the table was obtained from web sources, the links to which are provided in the final column. The focus here is on public programmes and interventions and not on private sector initiatives. Some of the research programmes and operational interventions will be discussed in greater detail.

Beginning with international agencies and bodies, both the World Bank and United Nations (via UNEP) have quite comprehensive research programmes covering many of the sub-topics identified in this Review. The Bank, in particular, has an African-focused programme of research, which looks at the 'opportunities, prospects, and challenges' of biofuel production across the continent. The European Union has a strategy for engaging with developing countries that are potentially affected by measures to reform its sugar industry. While it is not region specific it is clearly aimed at ethanol production. The G8+5 (Brazil, China, India, Mexico and South Africa) has established the Global Bioenergy Partnership, which focuses on the development of policy frameworks while the World Watch Institute is assessing the risks and opportunities of the large-scale development of biofuels. The latter is working in a number of countries, including Tanzania.

Moving to national agencies, the Agence Française de Développement (AFD) has a programme of work focused on energy efficiency and climate change in South Africa. The United States Agency for International Development (USAID) has programmes for biofuel development, including ones with a regional focus (particularly in Asia) and one that covers

developing countries in general. The aims of these are broad, covering almost all the issues surveyed in this Review, although with a focus on understanding how private sector finance might be leveraged for the expansion of biofuel production and consumption.

Finally, some space is given to an intervention, initiated by the Gbimsi Women's Group in Ghana. This is a technological intervention focused on Jatropha production. There are likely to be many such interventions across Africa, although coverage is limited by the scope of the Review and by what is available on the web.

Research Gaps

Throughout the review, various examples of existing research gaps were highlighted. In fact, there are many current research gaps that exist within the literature of biofuels in Africa. As was mentioned in the report summary, two key issues exist that must be addressed if biofuels in Africa are to contribute to sustainable development:

1. Insecurity of land tenure among the rural poor and overlapping institutional arrangements, and
2. The potential cost of meeting the basic dietary requirements of the poor in situations where biofuel production diverts crops from local food supplies.

Below is a list of more specific research gaps that have been identified in the current literature:

- Determining the actual energy benefits of biofuels in developing countries, rather than just the potential benefits. Here, a case study of a biofuel industry in a specific African country could help fill this gap.
- There is a significant lack of empirical studies of biofuels within the African context. For example, there is a lack of empirical evidence on the impact of biofuels on economic growth and jobs in African countries.
- There is an abundance of literature on life-cycle analysis, but a lack within African countries.
- Similar to the research of Habib-Mintz (2010), there is a need for further research into the potential of biofuels as a substitute for fossil fuels in African countries.
- Research into understanding how policies that incentivise growing biofuel crops may also affect farmers' strategies to privately deal with the implications of climate change and deal with food security.
- Further studies into the impact of biofuels production on domestic food availability and food prices within African countries. There is a need for greater diversity in the type of research undertaken in this area.
- The role of tenure rights in biofuel production in Africa is essential when discussing the development of biofuel production. Though there is some research on the topic, there is a need for increased research in this area.
- Similar to the topic of land-use change, increased empirical research on the differing effects of biofuel production on small-scale and large-scale farmers is needed.
- Focusing on the poor, there is a lack of research within African countries on assessing the impacts of changes in food supply on different groups of the poor, according to their livelihoods and income sources. Also, research which attempts to determine the scale of job creation and estimate the degree of improvement in livelihoods due to employment in the biofuels sector is pertinent.
- Finding further methods to calculate net employment effects.
- The potential of leap-frogging within the biofuels industry, as well as determining the different potentials of different types of biofuel technologies (i.e., first-and second-generation biofuel technologies) in Africa. The ability of certain countries to develop,

implement and support biofuel technologies in order to sustain biofuel production must be assessed, as well as the potential ability to facilitate “learning-by-doing.”

- Further research to better understand the relationship between trade and volatility in food prices in Africa.
- Habib-Mintz (2010) called for research into how governments and agricultural markets might be linked to international trade in biofuels, and its effect on the poor in Tanzania. This research could be extended to other African countries.
- The role of international trade in biofuel end-products.

Where can DFID add value?

Within each sub-topic, a list of questions is identified, signifying areas where DFID could add value. Here, a summary of these areas is presented. The section on Research Gaps also outlines gaps in the current literature where DFID could aim to research.

Within the sub-topic of energy efficiency and climate mitigation potential, there is a lack of research into the extent that efforts towards greater energy efficiency would compromise food security. As was stated earlier, such a topic is of significant importance within the development context. DFID could aid in determining how the severity of such a policy change could affect the lives of the rural and urban poor. The effects that moving towards biofuel production would have on mitigating the effects of anthropogenic climate change, as well as the private capacity to adapt to climate change, are also areas where DFID could expand knowledge.

Food security is another essential area where DFID could increase knowledge. As was stated in the section on Research Gaps, there is a lack of literature on the relative impact of biofuel production on food prices at different scales, within different African countries. Tying into this, the impact biofuel production has on food availability within Africa should be researched; though there is extensive literature on this topic, further investigation into this topic within African countries is needed. Linking with economic growth and job creation, DFID could undertake a study to determine if the potential negative impact of biofuels on food security could be offset in the long term, by higher employment and income created by agricultural-led growth.

Property rights is a major topic within development economics, and ties into the biofuels dialogue. Understanding how biofuel production could affect populations in nations with a lack of property rights is essential; here, DFID could determine to what extent informal tenurial arrangements and property regimes affect the ability and capacity of local people to participate in land-allocation decisions regarding biofuels. How this affects the livelihoods of the rural and urban poor could be studied, along with how biofuel production affects the local food supply within different African countries. Still within the topic of livelihoods, a project determining whether the adoption of biofuel feedstocks could lead to a possible ‘rural safety net’, which would mean to provide two routes for the sale of output (i.e., to food and energy markets), and under what conditions might such a safety net be sustainable, could be undertaken.

Turning to Economic Growth and Jobs, as has been mentioned throughout this Report, there is a lack of empirical evidence in this sub-topic. DFID could attempt to find different methods of determining net employment effects of increasing the biofuel sector, and how this would affect economic growth. How biofuel production would contribute to economic growth and job creation at the local and national levels could be studied, determining the potential effects. As economic growth and job creation would depend on the technologies available, it could be interesting to determine the potential role of developing countries to contribute to the development of new technologies. Similarly, determining what criteria is necessary in

order for developing countries to support biofuel technologies, and leap-frog to emerging technologies is essential. If technologies are to be used through leap-frogging, the factors that would lead to the adoption of first-generation biofuels at the local scale could be researched further. Looking at second-generation biofuel technologies, DFID could attempt to determine what conditions second-generation biofuels could provide a sustainable and commercially-viable source of energy in developing countries.

The topics in which DFID could add value within Trade tie into the other sub-topics mentioned in the Review. For example, determining how policies which help or hinder trade in biofuels impact food prices within Africa would be an important piece of research which DFID could undertake. Equally important, determining the conditions under which African countries could be competitive in and benefit from trade in biofuels at the regional and international levels is essential.

Lastly, within the Policy sub-topic, DFID could attempt to determine whether biofuel policies in other countries, such as Brazil and Indonesia, could be transferable to different countries in Africa. Research into the effect of agricultural policy on the biofuel sector could be researched. Since this research would be conducted within a development context, it is important to note how potential differences in factors such as corruption and rent-seeking could affect biofuel policies.

There are a number of areas in which DFID could potentially add further value within the topic of biofuels in Africa. Each area would entail projects of different capacities, and differing time frames (i.e., short-term or long-term projects); thus, DFID could determine what areas are essential, as well as the scale of the study or studies is/are to be undertaken. Each potential project could be implemented in various ways, giving much flexibility as to where and what DFID could examine. More detail into biofuels in specific African countries, rather than a general overview, should be researched.

Regarding the commercial viability of biofuels, some of the operational interventions listed in Table 1 from companies such as Eni and the WWF defend the argument that countries in Africa could have sustainable and profitable biofuel industries. Though Shell and BP deal in biofuels in Brazil, a country with a more stable biofuel market which was first created in the 70s, by comparison, the biofuel industry in many African countries are in their infancy. Smeet et al. (2004) write on the projected potential of biofuel production globally. Below is a graph, highlighting some of their findings:

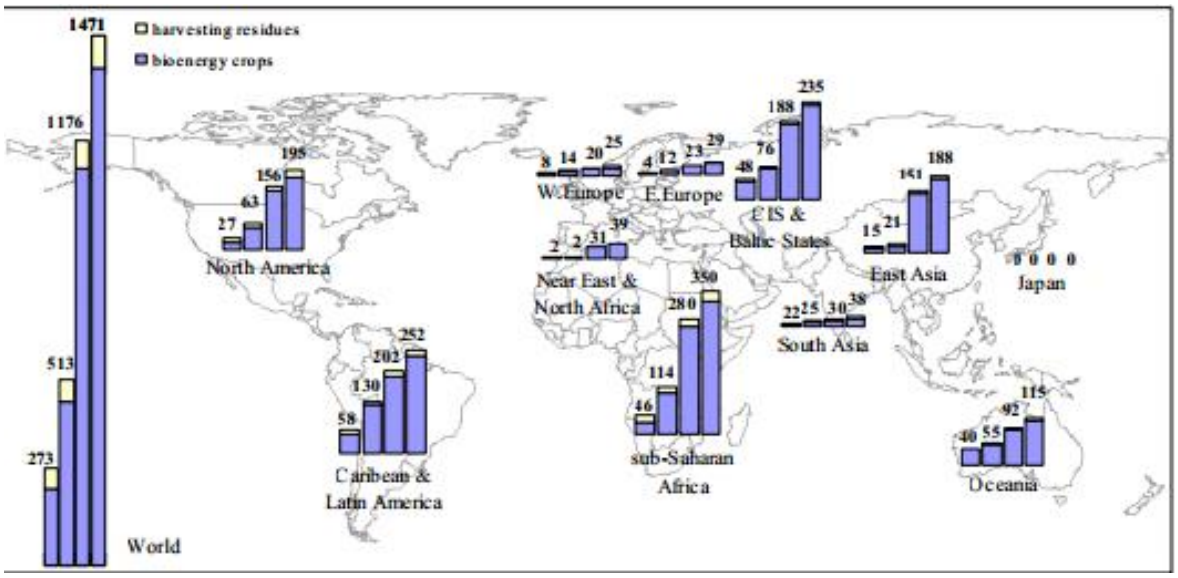

Figure 3 Total bioenergy production potential in 2050

(Smeets et al, 2004 pp.57)

As the diagram in Figure 3 illustrates, the authors find that sub-Saharan African, East Asian, and the Caribbean and Latin America have the most promising potential for large-scale bioenergy supply. In sub-Saharan Africa, this is equated to the large availability of land, factoring rising populations. They state this, though, with the following caveat: "A prerequisite for the bioenergy potential in all regions is however, that the present inefficient and low-intensive agricultural management systems are replaced in 2050 by the best practice agricultural management systems and technologies. In addition, per capita food consumption projected for 2050 in these regions has not reached saturation levels. Thus, the potential…may be limited if food intake (income) increases more than projected in this study" (Smeets et al., 2004, pp. 58). Hoogwijk (2004) also created projections, looking at future production costs of energy crop production.

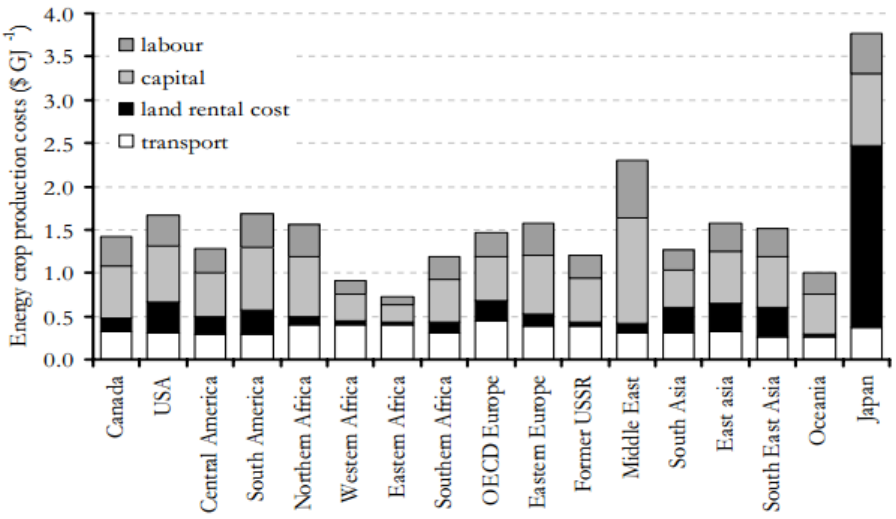

Figure 4 Cost breakdown for energy crop production in 2050

(Hoogwijk, 2004, pp.105)

This illustrates the low projected costs of energy production in East Africa. The authors further illustrate spatial distribution;

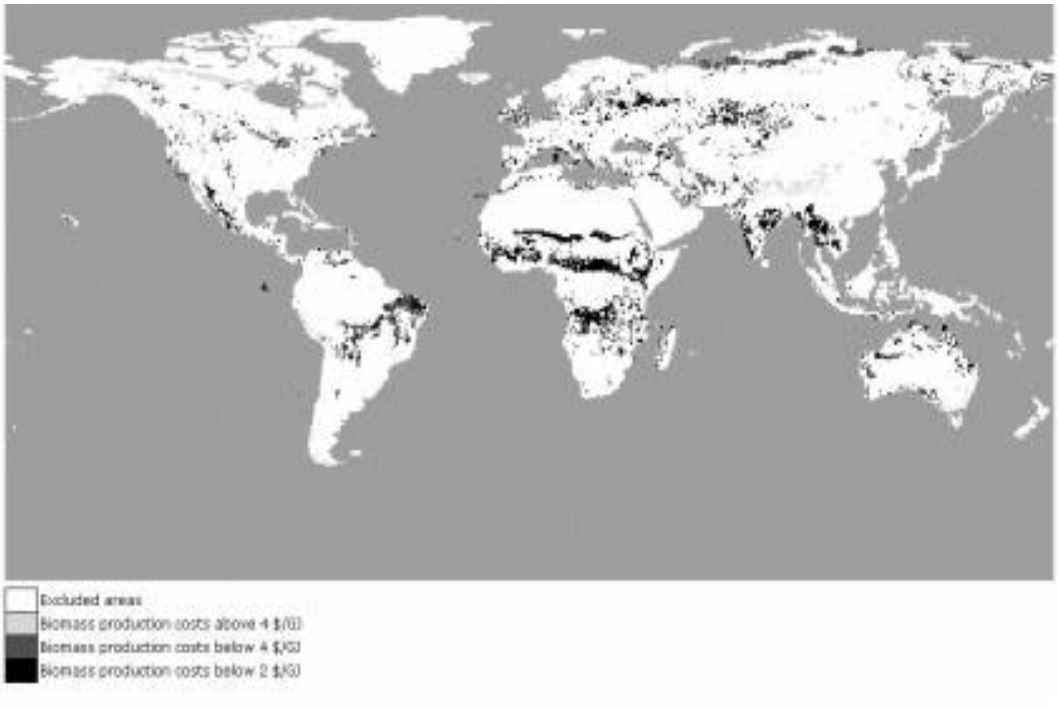

Figure 5 Spatial distribution of production of energy crops for abandoned and rest land in 2010

(Hoogwijk, 2004, pp.106)

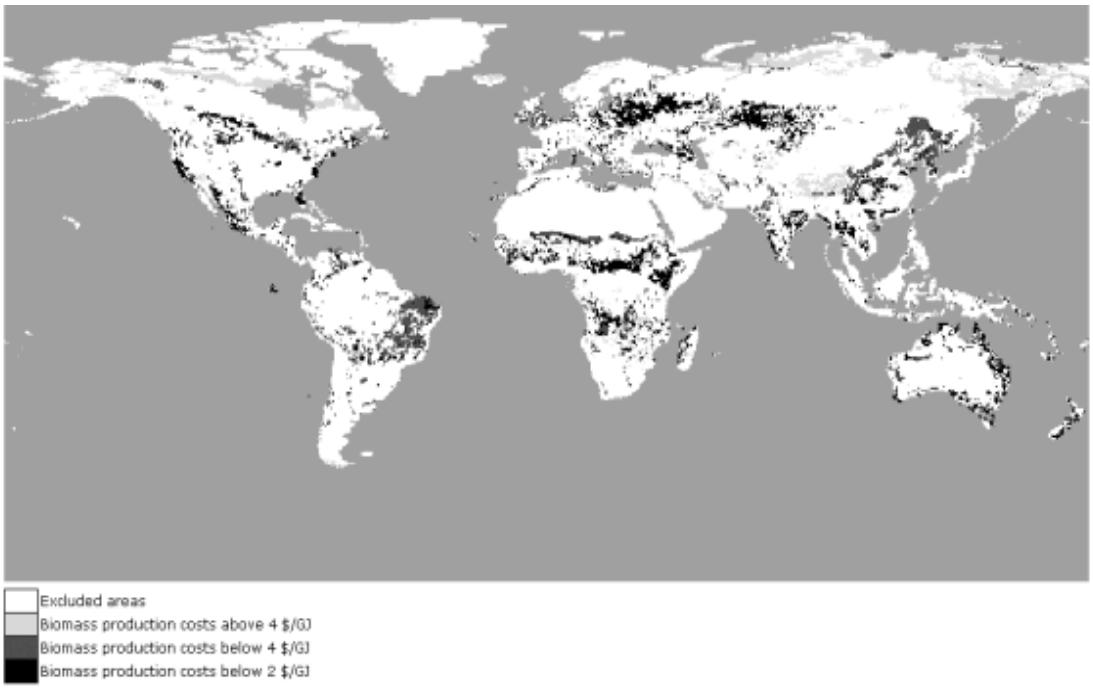

Figure 6 Spatial distribution of production of energy crops for abandoned and rest land in 2050

(Hoogwijk, 2004, pp.106)

Figures 4 and 5 further illustrate the potential low-cost of energy crop production in the future in Africa.

Projects from the WWF and Eni encouraging biofuel production in Madagascar and Angola respectively are examples of foreign companies investing in biofuel production in Africa. As most of the literature cited in this study states, biofuels in African countries should be commercially viable. Research into what is needed for the biofuel market to be success could be further researched by DFID. It is clear that if done well, biofuels in Africa can be successful, making further research into biofuels in Africa pertinent.

Conclusion: Mind the Gap

The interventions and research programmes highlighted are, with the exception of the one established by the AFD, not country- or even region-specific. Given this lack of depth and the sheer size of the African continent, this opens up numerous possibilities for future programmes of research,. These could be based on the sub-topics and questions of potential interest for DFID presented in Section II.

Clearly, there are a number of countries that have an interest in stepping up the development of their biofuel sectors, in particular with respect to ethanol production and feedstocks such as Jatropha. The governments of these countries appear to view biofuels primarily as a domestic source of renewable and clean energy, one that may also provide a source of economic growth and employment along the production chain, i.e. not in agriculture alone. Realising these policy aims is the challenge particularly if biofuel production is to contribute to sustainable development in those countries.

For African governments keen to develop their biofuel sectors, there are two main issues that have to be addressed in order for this to be achievable: insecurity of land tenure among the rural poor and overlapping institutional arrangements, and; the potential cost of meeting the basic dietary requirements of the poor in situations where biofuel production diverts important crops from local food supplies. These overlap and require, first and foremost, the close engagement of said governments. Outside agencies may be able to assist governments in addressing these issues where the political will exists to address them internally as well.

The emphasis of biofuel policy on energy access and efficiency while crucial for economic development needs to ensure that this does not adversely impact on local food supplies. Huge numbers of both urban and rural households across Africa remain vulnerable to food price shocks. Indeed, net importers of key agricultural commodities may be vulnerable to price movements in global commodities markets irrespective of the degree to which biofuels impact on these – unless those countries have market power. One strategy is, of course, to produce more food domestically. In countries with a scarcity of arable land, a policy to expand biofuel production could reduce their capacity to produce food, however. To some extent, improvements in agricultural productivity could help mitigate against the food vs fuel trade-off. Future interventions and research programmes could focus on first identifying those countries and regions of Africa which have relative land scarcities and import significant quantities of their food needs. These are the ones that are least likely to benefit from biofuel policies, particularly those focused on first-generation feedstocks. Countries and regions with a relative abundance of arable land are most likely to benefit, although there is a risk that those with rapidly increasing populations may find that abundance turns into scarcity if biofuels are expanded in parallel with continued increases in food production.

As shown in Section II, land is typically not ‘unused’ or ‘unclaimed’. The expansion of agricultural production for food and/or biofuel, especially in the absence of improvements in

productivity, may encroach on land used and claimed by smallholders and pastoralists. As the growing literature on ‘land grabs’ shows, this has become a growing concern among policymakers and researchers on a par with rising and volatile food prices. Governments looking to boost their economies through the expansion of their biofuel sectors need to pay attention to this issue and establish transparent and accountable mechanisms for land reform with a view to formalising tenure and rights to natural resources. This is often a complex and lengthy process but necessary if the expansion of biofuels on so-called ‘unclaimed’ land is to be viewed as legitimate. Governments keen to develop large-scale biofuel production should first undertake efforts to mitigate against overlapping and conflicting claims to land. A failure to do so will not only marginalise the rural poor but may also act as a deterrent to investment in agriculture.

Table 1 Known Research Programmes and Operational Interventions

Country/Region	Agency	Research programme/ Operational Intervention	Details	Relevant sub-topic(s)	Source
	Food and Agriculture Organisation (FAO)	Various research initiatives into biofuels	The FAO has conducted numerous studies into biofuels, some focussing on developing countries in particular	1. Energy Efficiency and climate change 2. Land-use change 3. Technology 4. Policy 5. Trade 6. Economic growth and jobs 7. Livelihoods 8. Food security	One example of such research is "Biofuels and the sustainability challenge: A global assessment of sustainability issues, trend and policies for biofuels and related feedstocks."
	United Nations Environment Programme	Towards sustainable production and use of resources: Assessing Biofuels	An overview of the perspectives and problems of sustainably producing and using biofuels; discusses developing country implications.	1. Energy efficiency and climate mitigation potential 2. Land-use change 3. Technology 4. Policy 5. Trade 6. Food security	UNEP report on assessing biofuels
	World Bank	Research into biofuels in Africa	Discusses opportunities for biofuels in Africa; challenges posed; biofuel production costs in Africa; and policy framework and development strategies.	1. Energy efficiency and climate mitigation potential 2. Land-use change 3. Policy 4. Trade 5. Economic growth and jobs 6. Food security	Biofuels in Africa: Opportunities, Prospects, and Challenges

Country/Region	Agency	Research programme/ Operational Intervention	Details	Relevant sub-topic(s)	Source
	World Watch Institute	An assessment of the risks and opportunities of large-scale international development of biofuels	Reports on country studies in India, Tanzania, Brazil, China, and Germany.	1. Energy efficiency and climate mitigation potential 2. Technology 3. Policy 4. Trade 5. Food security	Biofuels for Transportation: Global Potential and Implications for Sustainable Agriculture and Energy in the 21st Century
G8+5 (Brazil, China, India, Mexico and South Africa)	Global Bioenergy Partnership (GBEP)	The aim of this partnership is to promote renewable energies (including biofuels) in developing countries	GBEP aims to develop effective policy frameworks to promote bioenergy and biomass development; help facilitate bioenergy investment; promote R&D in bioenergy; and advance project development and implementation	1. Energy Efficiency and climate change 2. Land-use change 3. Technology 4. Policy 5. Trade 6. Economic growth and jobs 7. Livelihoods 8. Food security	Global Bioenergy Partnership
EU	European Commission	EU Strategy for biofuels	The Commission "wants to support developing countries with potential in terms of biofuels, particularly by means of accompanying measures for countries affected by EU sugar reform, a specific aid programme for biofuels, and a framework for effective cooperation that would include among other things the development of national biofuel platforms and regional biofuel action plans" (http://europa.eu/legislation_summaries/internal_market/single_market_for_goods/motor_vehicles/interactions_industry_policies/l28175_en.htm)	1. Energy efficiency and climate mitigation potential 2. Land-use change 3. Economic growth and jobs 4. Policy	EU Strategy for Biofuels
France	Agence Française de	The report describes a project to assist South	The development of biofuels is part this programme, along with	1. Energy efficiency and climate mitigation	Supporting the Central Energy Fund in its

Country/Region	Agency	Research programme/ Operational Intervention	Details	Relevant sub-topic(s)	Source
	Développement (AFD)	Africa in promoting renewable energy sources, such as biofuels. "The project aims to increase energy efficiency and the share of renewable energy in the South African economy, in order to reduce the pressure placed on fossil fuels and to reduce CO2 emissions" (AFD, *Supporting the Central Energy Fund in its actions against global warming*, p.1)	electricity cogeneration, establishing a solar water heating industry, and energy efficiency in the construction and industry sectors. "The project involves providing technical assistance to the CEF [Central Energy Fund, which consists of various public companies in the energy sector in South Africa], and the Department of Energy by on the one hand implementing policies for energy efficiency and renewable energy, and on the other hand preparing investment programmes for these two themes" (AFD, *Supporting the Central Energy Fund in its actions against global warming*, p.1)	potential 2. Policy	actions against global warming
Ghana	Gbimsi Women's Group	Jatropha production	Helping to fund the production of Jatropha oil in order to run a multi-functional platform for processing cereals.	1. Technology	Biofuels Assessment Report – ECOWAS Sub-Region
United States of America	United States Agency for International Development (USAID)	Report on biofuels in Asia	Analyses the risks and benefits of biofuel development in Asia.	1. Energy efficiency and climate mitigation potential 2. Land-use change 3. Technology 4. Policy 5. Trade 6. Economic growth and jobs 7. Livelihoods 8. Food security	Biofuels in Asia: An Analysis of Sustainability Options
United States of America/Brazil	USAID	An overview of the potential for biofuels in	Research concerning the feasibility of biofuels in developing countries.	1. Energy efficiency and climate mitigation	An introductory guide for assessing the

Country/Region	Agency	Research programme/ Operational Intervention	Details	Relevant sub-topic(s)	Source
		developing countries.	USAID also aim to help countries in Central America and the Caribbean "to stimulate private investment for local production and consumption of biofuels" (USAID, *An Introductory Guide for Assessing the Potential of Biofuels in Developing Countries*, p.28). The type of support depends on the country, but USAID programmes would likely focus on the following: " 1. Providing assistance to governments to ensure that sound regulations and policies are in place to attract private sector investment in biofuels; 2. Helping ensure access to financing through a Development Credit Authority loan guarantee program 3. Promoting public-private biofuel partnerships through the development of Global Development Alliances (GDAs) with the private sector; 4. Working with governments and the private sector to ensure that growth in the biofuels sector in sustainable and does not have a negative impact on the human and natural environment" (USAID, *An*	2. Land-use change 3. Policy 4. Economic growth and jobs 5. Food security	potential of biofuels in developing countries

Country/Region	Agency	Research programme/ Operational Intervention	Details	Relevant sub-topic(s)	Source
			Introductory Guide for Assessing the Potential of Biofuels in Developing Countries, p. 29).		
Brazil	Shell	Raízen	A joint venture between Brazilian firm Cosan and Shell to produce ethanol.	1. Energy Efficiency and climate change 2. Technology 3. Trade	Raízen
Brazil	British Petro (BP)	Ethanol production in Briazil	BP has a 100% share in Tropical BioEnergia SA, a Brazilian biofuel company; BP owns and operates three ethanol mills in Brazil.	1. Energy Efficiency and climate change 2. Technology 3. Trade 4. Economic growth and jobs	BP biofuels investment
Angola	Eni and Sonangol	Biodiesel development in Angola	Italian oil company Eni, and Angolaian oil company Sonangol have established a framework for joint mining initiative, both within Angola and abroad. A part of this initiative is to create a pilot project in biodiesel in Angola	1. Energy Efficiency and climate change 2. Trade 3. Food security	Eni
Nigeria	Nigerian National Petroleum Corporation (NNPC)	Nigerian biofuel initiative	NNPC has developed a biofuel project which aims to develop ethanol fuel and palm oil diesel. Ethanol is to be derived from processed cassava or sugarcane.	1. Energy Efficiency and climate change 2. Economic growth and jobs 3. Livelihoods	NNPC biofuel initiative
Madagascar	World Wildlife Fund (WWF)	Jatropha biofuel project	The WWF and the United Nations Development program created a program to develop sustainable biofuel processing of jatropha.	1. Energy Efficiency and climate change *It is stated that this project aims to create a guide on social and environmental impacts on biofuel investment; therefore, it is likely to cover further sub-topics.*	WWF Jatropha biofuel project

Known Research Programmes and Operational Interventions

EVIDENCE ON DEMAND
CLIMATE & ENVIRONMENT
INFRASTRUCTURE | LIVELIHOODS

SECTION IV

Glossary

Biodiesel - Biofuel produced from oilseed crops, such as palm oil

Bioethanol Biofuel produced primarily from sugar and starch based crops, such as sugarcane and maize

Biogas - A gas produced by the decay of organic matter

Biomass - Organic matter (such as plants) that can be converted to fuel

Border Carbon Adjustment (BCA) - A trade measure that attempts to create a "level ground" between low climate change costs faced by foreign producers, and the high climate change measures faced by domestic producers (Cosbey, 2008).

Carbon balance - The balancing of carbon emitted into the atmosphere. Within biofuels, this entails the greenhouse gas savings from the consumption of a given unit of biofuel.

Carbon debt - The difference between carbon offsetting and the carbon footprint

Carbon fixation - The process of converting inorganic compounds (e.g., carbon dioxide) to organic compounds

Direct land-use change - Within the biofuels context, this refers to expanding the area of land under biofuel production, replacing activities that took place on that land (e.g., expanding biofuel production at the cost of a loss in agricultural land)

Energy security - The ability of all individuals to easily access energy

Feedstocks - Renewable, biological material that can be converted to fuel for energy use

First-generation biofuels - Fuels derived from sources such as animal fats, starch, vegetable oil, and sugar (e.g., biodiesel)

Indirect land-use change - Within the biofuels context, indirect land-use change refers to whether increased biofuel production, which has, for example, displaced agricultural land, has caused these agricultural activities to be 'displaced' elsewhere.

Jatropha - A versatile crop that is used as a second generation biofuel feedstock

Land grabbing - The potential exclusion of the rural poor due to the 'expropriation' of their land claims

Life-cycle analysis - An engineering approach, to estimate the net emission or consumption of a resource to compare the environmental footprint of competing products and processes by tracing how a fuel is made.

Net Energy Value/ Fossil energy intensity - The amount of fossil energy required to produce one unit of biofuel

Second generation biofuels - Fuel created from different types of lignocellulosic biomass, agricultural residues, waste, or woody crops. This requires a more complex process than that of first-generation biofuels.

SECTION V

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Annex 1 Biofuels discussion workshop 26th June 2013

The scope of the review and purpose of the discussion workshop

The Biofuels Scoping Review was commissioned by DFID to inform their opinion on biofuels, and suggest future areas of research. A discussion workshop provided an opportunity for a peer-review of evidence, through discussion of the document.

Attendees: David Woolnough (DFID), Alessandro Moscuzza (DFID), Misbah Siddiqui (DFID), James Green (HTSPE), Angela Doku (HTSPE), Donald Lunan (HTSPE), Naomi Erskine (HTSPE), Mary Wilcox (Practical Action), Professor S. Dasappa (IISC), Ben Muok (African Centre for Technology Studies), Ed Brown (Loughborough University), Sheila Oparaocha (Energia), Colin Pritchard (Edinburgh University), Mosad El-Missiry (Nepad), Jeremy Woods (Imperial).

Report's assumptions and areas the review didn't cover

- **Energy efficiency:** when discussing energy efficiency, the review focused specifically on access to energy, and transport. The workshop participants suggested that the topic should be expanded to consider electrification concerns. There is also an implicit assumption that biofuel production increases energy access.

- **Food versus fuel:** There are two key issues at stake when considering biofuels; competition with food production, and competition with other forms of energy access. The workshop participants suggested this area could be looked into in greater depth.

- **Selected sectors:** The authors of the review said that the 8 main sectors chosen for the review were driven by the literature review. The workshop participants suggested that the environment, governance and socio-economic analysis are three key themes which should be considered in a general Biofuels Scoping Review.

- **The sector diagram:** The workshop participants were interested in the rationale behind the inter-linkages between the sectors in the diagram, and wanted to note that there were positive and negative aspects to each sector outlined in the report.

Quality of research

- The authors noted that much of the literature related to biofuels in Africa was dated, so there was less focus on current biofuels interventions; and a lot of the research has been speculative. Jeremy Woods from Imperial mentioned that the recent IFPRI reports could be useful for looking at the econometric impacts of biofuel interventions.

- The recent Global Land Matrix's publication on land-use change should be looked into, as it suggests that major issues regarding land-use change were overhyped.

- The 2012 IPCC report has a useful chapter (12) on a high-level review of biofuels energy, which could supplement this review.

Areas where DFID could explore further and add value

- More research could be carried out into case studies on what works and what doesn't work related to food security and land in the biofuels field.
- Universal access to energy: research could be undertaken on whether biofuels offers a viable energy source vis-à-vis other energy solutions.
- Resource mapping could be done on current biofuels interventions within Africa; India has already developed a biomass atlas.
- DFID could map research on current Biofuel technologies, which could be used as a baseline going forward. More research into innovation in Biofuel technologies would be a good example of DFID adding value.
- A key African policy focus has been on meeting national and regional energy needs through bioenergy production; however research also needs to be undertaken on surplus energy supplies, and energy wastage. If there is an energy surplus, it is important for countries to look into export markets.
- It would also be useful to look at lessons learned from Brazil's biofuel production, even though the regional context is markedly different. Research has already been undertaken on the macroeconomic impacts of Brazil's biofuels.
- The workshop participants noted that Brazil's ability to invest in co-generation has increased the demand for energy. This raises the question of competitive impact versus resilience.

Possible research call question

Bioenergy for Sustainable Local Energy Services and Energy Access in Africa.

The research call could then be broken down into three themes: heat, energy and transport/productive power. This could then be researched using 4 pillars: economic choices/trade-offs; social inclusiveness; governance (institutional set ups/regulatory frameworks); technology/innovation; and a cross cutting theme on the scalability of energy programmes.