Biofuels Review:
Scenario development

For the Renewable Fuels Agency

May 2008

E4tech

1. Scope and key aims

The aim of this piece of work was to develop scenarios for future global demand for different feedstocks for biofuels in 2010 and 2020. These can be used to derive land area requirement for biofuel production.

The demand for biofuels is largely driven by policy, so in order to understand the implications of biofuels demand, the scenarios developed differ in terms of the type of policy target that may be implemented. The scenarios also differ in terms of whether new crops and advanced biofuel technologies are used by 2020. As many of these advanced technologies use non-food feedstocks, whether or not they are used commercially by 2020 may have a significant bearing on the volumes and types of feedstocks required.

The scenarios are global, providing projections of estimates of volume demand for biofuels and feedstock type in each of ten world regions (OECD North America, OECD Europe, OECD Pacific, Transition Economies, China, Other Asia, India, Middle East, Latin America and Africa). The scenarios also give an indication as to where these feedstocks are likely to come from.

A list of references used in developing the scenarios are provided at the end of this document.

2. Development of scenarios - methodology

Scenarios are made to test uncertain situations. In our case we have selected to investigate the implications of a situation where biofuels demand is driven by policy targets currently proposed for the different regions (a likely scenario) and a situation where there is a GHG reduction target across all regions (to understand the resource implications of a material contribution of biofuels to GHG emissions reductions at a global level). The scenarios are further differentiated by the deployment or not of 2nd generation biofuels and new crops.

One scenario for 2010 and four scenarios for 2020 were developed. The policy situation explored in each region is as follows:

- **2010 baseline scenario** – This is assumed to be the same for all scenarios and is based on the aspirational targets each region currently has for biofuels. There are no 2G biofuels in this scenario.

- **2020 scenario 1** – This looks at *volume based targets* that different regions may be likely to put in place by 2020 and how these targets might be met if there were *no 2G biofuels*.

- **2020 scenario 2** – This looks at *volume based targets* that different regions may put in place by 2020 and how these targets might be met if *2G biofuels are available*.

- **2020 scenario 3** – this looks at *GHG based targets* (a 7% reduction in emissions from transport fuel to come from biofuels, for each region) and how these targets might be met if there were *no 2G biofuels*. Emissions reductions are assumed to be split proportionally to gasoline and diesel consumption.

- **2020 scenario 4** – this looks at *GHG based targets* (a 7% reduction in emissions from transport fuel to come from biofuels, for each region) and how these targets might be met if *2G biofuels are available*. Emissions reductions are assumed to be split proportionally to gasoline and diesel consumption.

The main purpose of the scenarios developed was to calculate the total quantities of biofuel feedstocks in these different situations. The quantities calculated were later used to calculate the land area required to grow these feedstocks, based on low, BAU and high projections of crop yields.

2.1 Routes considered

The following biofuel routes have been considered:

- Bioethanol produced from cassava, wheat, sugar beet, sugar cane, sorghum and maize
    - Molasses was not included separately as a feedstock for ethanol production, but was considered as part of the broader category of ethanol from sugarcane.
- Biodiesel produced from soy, palm, sunflower, jatropha and oilseed rape
    - Refined used fats have not been taken into consideration because of the lack of available data at a global level. The use of refined used fats for biodiesel production reduces the demand for land based biodiesel feedstocks. Their uptake could be easily integrated in the model by subtracting the contribution that used fats could make from the biodiesel targets or from the GHG target. Alternatively, a resource column could be added for used fats. As an example, 90PJ of refined used fats could be available in Europe in 2020, according to the Refuel Study and underlying data from the Viewls project[1].
    - Biodiesel can be produced from these feedstocks either by esterification or by hydrogenation. Biodiesel produced through hydrogenation routes can be blended at higher percentages in diesel and it is therefore believed that by 2020, an increasing volume of biodiesel would be produced through this route. However, as the GHG emissions and efficiency associated with conversion are currently similar for the two routes, they have been considered together, rather than separately.
- Lignocellulosic ethanol from bagasse, wood residues and agricultural residues (from straw and stover)
    - Willow, poplar, eucalyptus, miscanthus and switchgrass were considered as potentially being used as second generation biofuel feedstock crops. However, it was felt that the residues would be preferred over energy crops on a cost basis, and assumed that residues would be available in sufficient quantities to supply these routes to 2020. Therefore the scenarios do not consider biofuels using energy crops as feedstocks.
    - It was also considered that second generation biofuel technology would not be ready to use MSW as a feedstock by 2020. The scenarios therefore do not include any biofuel using MSW as a feedstock.
- Syndiesel from wood residues (including black liquor) and agricultural residues (from straw and stover)
    - As for lignocellulosic ethanol, willow, poplar, eucalyptus, miscanthus and switchgrass are not considered to be used as feedstocks for syndiesel production on cost and availability grounds.

[1] Viewls (2005) Biofuel and Bioenergy implementation scenarios. Final report of Viewls WP5, Modelling studies.

- As for lignocellulosic ethanol, MSW was not considered to be a suitable feedstock for syndiesel production by 2020.

2.2 Breakdown of feedstocks

The following general assumptions have been made:

- For the volume based targets, we have assumed that most crops used for biofuel production would be produced regionally and complemented by traded biofuels and feedstocks such as ethanol from sugarcane which would generally come from Brazil, palm oil which would generally come from Indonesia and Malaysia, and soybean oil which would largely come from Argentina and Brazil and be exported to the EU. For the EU, we have based the feedstock breakdown on that assumed in the European Commission's report on how a 10% biofuel target in the EU would be met[2].

- For the GHG target based scenarios, the feedstocks used to produce biofuels are based on a prioritisation based on the CO2 savings associated with biofuels made from those feedstocks. It is assumed that biofuel routes with the lowest GHG intensity will be used first, imported or produced regionally, and that these will be complemented by feedstocks with the lowest GHG intensity produced within the region of interest. Imports are assumed to take place as in the volume scenarios but we have also assumed some trade of OSR and jatropha in the more challenging situations such as a 7% GHG target for biofuels in the Middle East.

- The assumptions surrounding feedstocks used to make biofuels have been subjected to two rounds of reviewing from CE Delft, Ecofys, Themba and ODI. Their comments have been considered in preparing the final version of the scenarios.

2.3 Other assumptions

There are some regions where some feedstocks may not be allowed to be used – e.g. China and Africa have or are considering policies preventing the use of maize for biofuels. As these are policy measures which have been put in place to minimise impact on food prices, we have not included these policies in our scenarios. This is so that these scenarios can be used to investigate the indirect impacts of biofuels without such policies already in place.

Assumptions have been made regarding the conversion efficiencies and GHG emissions associated with the different fuel chains. These are based on data in the RTFO methodology for first generation biofuels and data from the JRC/Eucar/Concawe Well to Tank report (2007) for second generation biofuels.

Key assumptions of note are recorded below:

- GHG emissions for 1G biofuels in 2020 are based on a 20% improvement on the lower bound emissions quoted in the RTFO feedstock and origin defaults (applies to the GHG target scenarios)

- Penetration of 2G biofuels in 2020 is expected to increase by 10% if governments have GHG targets instead of volume targets

[2] EU Commission (2008) The impact of a minimum 10% obligation for biofuel use in the EU-27 in 2020 on agricultural markets

3. Methods/models used

The projections of road transport fuel demand to 2020 are based on data from the WBCSD sustainable transport project (2004) and the IEA World Energy Outlook 2004.

World biofuel demand is split into ten different regions: OECD North America, OECD Europe, Latin America, Middle East, Africa, OECD Pacific, China , India, Transition economies, Other Asia. A definition of the regions is provided in annex.

Data from the Food and Agricultural Organisation (FAO) was used for the types and volumes of crops currently grown in different world regions.

The scenarios include calculations for land area requirements for biofuel production. The yields used to calculate the land areas have been provided by ADAS. ADAS have provided three scenarios for yields in 2020 (low, business as usual and improved). In this report, we have used the BAU yield scenario to provide an estimate of the land use requirement associated with biofuel demand under the different scenarios.

4. Key interactions

4.1 Interactions with, and dependencies on, other study teams

Other study teams were dependent on the development of these scenarios and therefore they were discussed and developed closely with the relevant study teams to ensure that they were relevant and useful to the further modelling undertaken by the other study teams.

4.2 Discrepanices and inconsistencies in approach with that of other study teams

There were no major discrepancies or inconsistencies in approach with that of other study teams. Comments and suggestions were discussed and included if necessary.

One area for improvement relates to land area calculations; more accurate estimates of the land area required in the different scenarios could be obtained by replacing the average regional yield with the average yield of the country (or even the region within the country) that is most likely to produce the feedstock.

5. Key uncertainties

The biofuel and feedstock estimates are not projections of what is likely to happen but estimates of what may happen under certain conditions (e.g. policy targets) and assumptions (e.g. shares of biofuel types and feedstocks). They are intended as input to estimating the impacts of possible future biofuels demand and to test different situations. As such there is much uncertainty around the estimates. This is related to assumptions made and to uncertainty related to input data used in formulating the scenarios:

- The projected fuel demand in the different world regions for 2010 and 2020
- The GHG emissions savings for the different biofuel routes in 2020
- The biofuel volume targets each world region will have in place in 2010 and 2020
- The share of feedstocks used for the production of different biofuels

- Penetration rates of new crops and 2nd generation technologies to 2020, and respective yield and conversion efficiency
- Crop yield estimates and yield averages for the different regions

5.1 Discrepancies in assumptions made by those working on related subtasks

We are not aware of any discrepancies in assumptions made by others working on related subtasks. We have attempted to ensure that there is consistency between the scenarios proposed and the requirements of others working on other subtasks.

5.2 Limitations

One of the key limitations of this work is that in the GHG scenarios, the GHG intensity of the biofuels used is based on the GHG intensity without land use change (direct or indirect) included in the emissions. This allows for an investigation of the direct and indirect effects of neglecting such emissions (which is the objective of the review). However, we realise that prioritising the use of different biofuels without taking into consideration the land use change emissions caused by growing those biofuels is a limitation of this work, as it could lead to a different scenario and indirect effects. Determining scenarios under a GHG reduction target could be an iterative process with the understanding of direct and indirect GHG impacts.

Another limitation to the scenario building is that the GHG target scenarios do not take into consideration the actual use of biofuels in different regions and their contribution to GHG reductions. This is not thought to be an issue in most regions where the contribution is small, but is an issue for Latin America where ethanol from sugarcane already makes a significant contribution. This means that under a blanket 7% GHG emissions reduction target, biofuel use in Brazil may be lower than at present and differently distributed between gasoline and diesel. However, at a global level the GHG reduction scenario implied a much increased use of biofuels, and reduces the effect of the limitation related to Latin America.

6. Key findings

6.1 Results of scenarios – feedstock quantities

The different scenarios model different situations in which either currently proposed biofuel volume targets are met or a 7% reduction in emissions from transport fuel is met using biofuels. It should be emphasised that these scenarios test how feedstock quantities (and therefore land take) are affected given different policy situations.

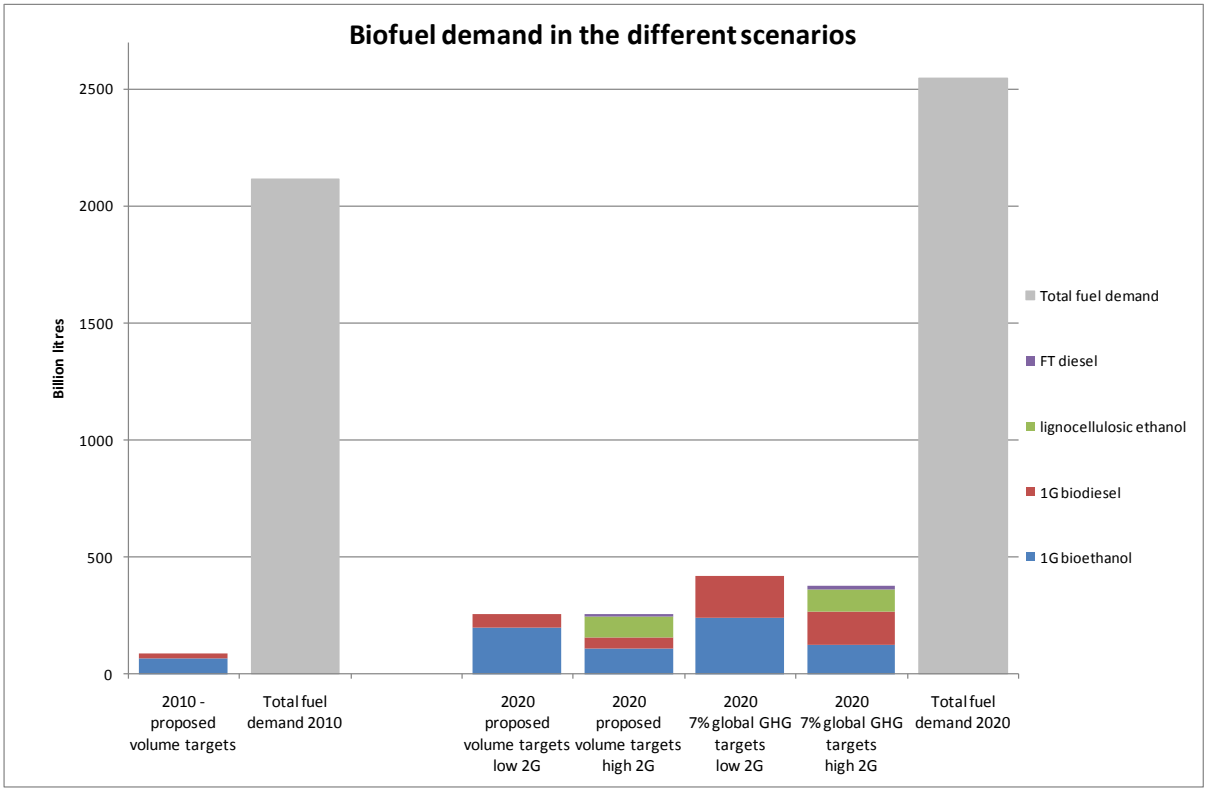

Figure 1: Biofuel demand in different scenarios

As noted from Figure 1 above, the inclusion of second generation biofuels in the GHG targets results in less biofuel demand. This is because the GHG intensity of the second generation biofuels is better and therefore less biofuel is required to meet the 7% GHG target.

The following graph summarises the demand for biofuels feedstock in each of the scenarios set out in section 2 of this report.

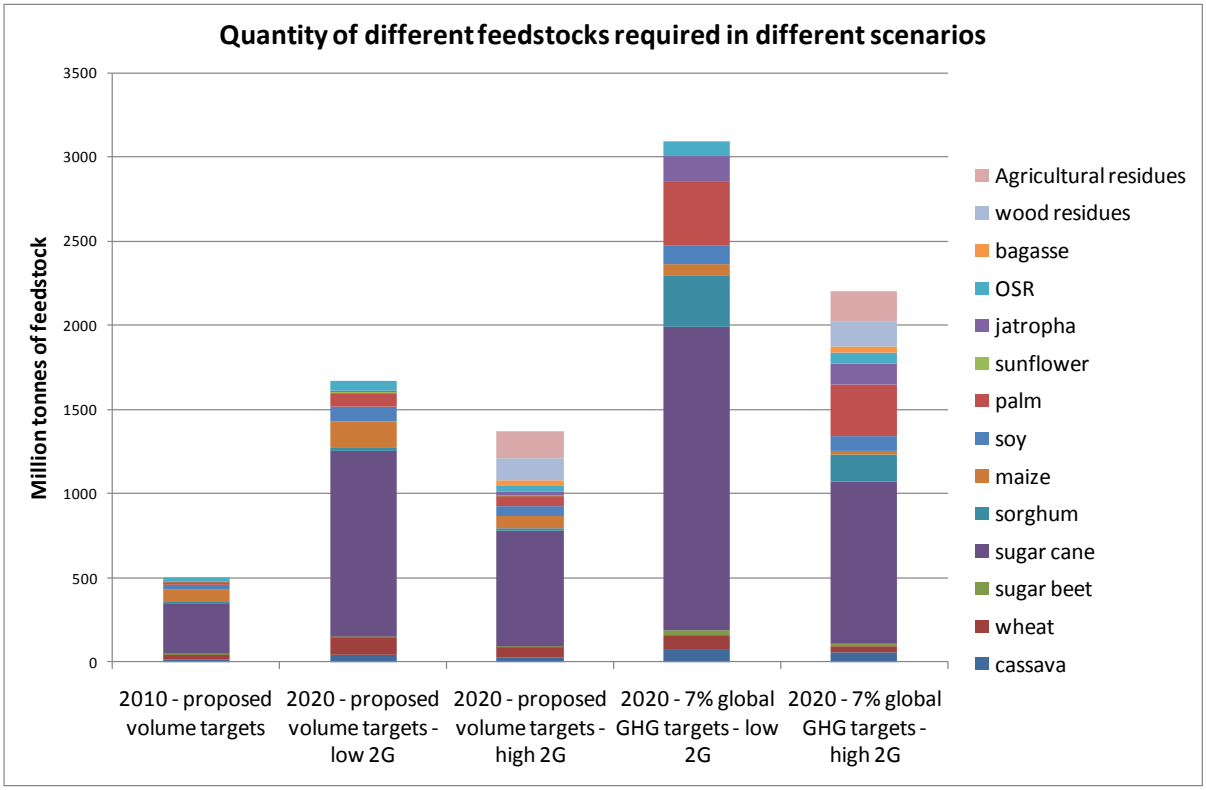

Figure 2: Quantity of feedstocks required in the different scenarios.

The following table shows estimates of the relative percentage of current global feedstock production that would be required to meet demand for biofuel produced from that feedstock in each of the different scenarios. These shares are based on the current crop production statistics available from FAO (2006).

	% of current global production required to meet world demand				
	2010	Scenario 1 – 2020	Scenario 2 – 2020	Scenario 3 – 2020	Scenario 4 – 2020
Cassava	6	18	14	32	24
Wheat	6	18	10	15	6
Sugarbeet	1	1	1	12	7
Sugar cane	21	79	49	129	69
Sorghum	8	43	30	536	274
Maize	10	21	10	10	4
Soy	7	21	15	25	19
Palm	10	36	27	167	133
Sunflower	5	10	3	0	0
Jatropha	n/a	n/a	n/a	n/a	n/a
OSR	24	63	37	99	78
Bagasse	0	0	16	0	17
Wood residues	0	0	36	0	40
Agricultural residues	0	0	24	0	26

Figure 3: Proportion of current global production required to meet demand for the different scenarios

6.2 Results of scenarios – land area required

The following graph shows the land area required in each of these scenarios, using BAU yields. Sensitivity of these results to the yields used is addressed by other accompanying reports.

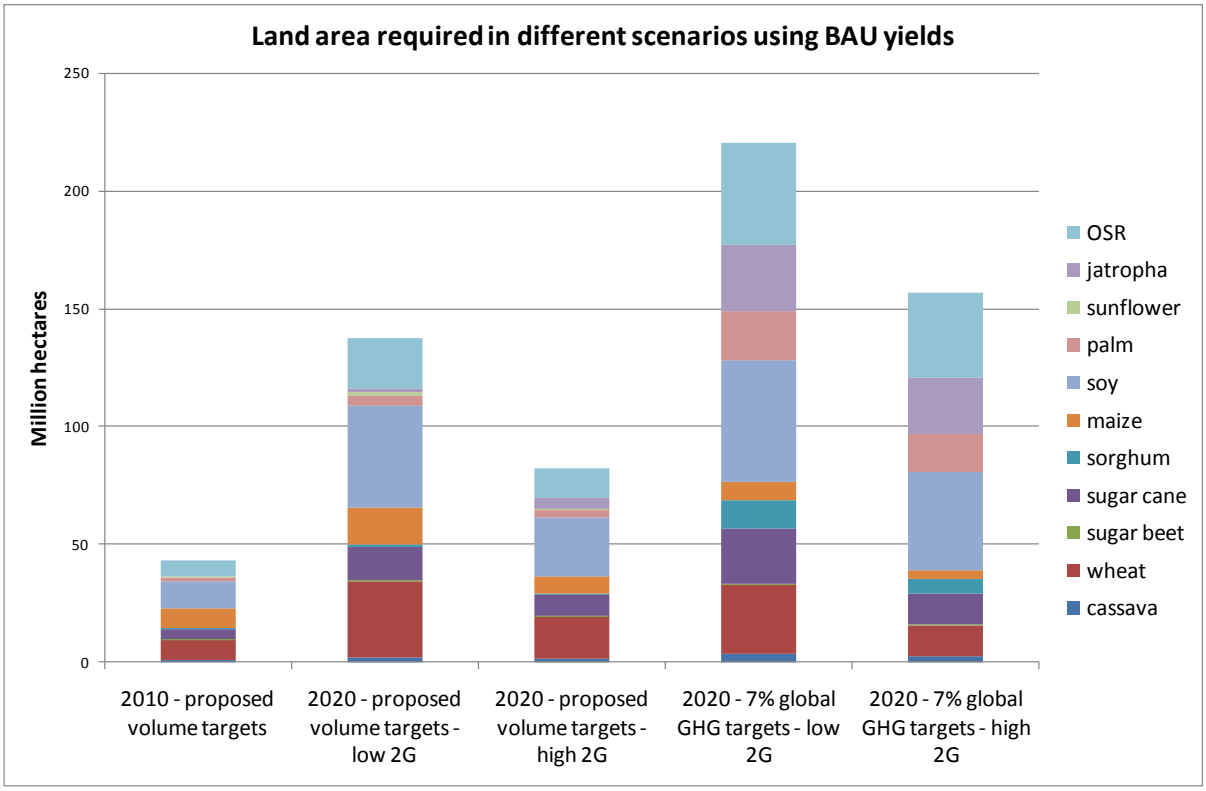

Figure 4: Land area required in different scenarios, if BAU yields for crops are used

6.3 Analysis

Key points to note from the scenario development, with respect to the feedstock quantities required, are:

- Moving from likely 2010 volume targets to proposed 2020 volume targets without 2G biofuels is likely to result in a considerable increase in crop production for biofuels. For example, the required quantity of sugarcane could increase nearly four-fold over the baseline demand for biofuels in 2010, the quantity of wheat, soy and palm could triple and maize could double.

- If 2G biofuels can be used at the scale currently under discussion by governments (i.e. 30% penetration in the EU by 2020), this considerably reduces the increase in demand for non-food crops. The use of approximately 25% of the world's current estimated exploitable agricultural and wood residues for 2G biofuel feedstocks results in sugarcane demand increase by about two-fold rather than four-fold, the demand increase in soy, palm and wheat also being reduced, and maize demand staying constant.

- In the EU, the introduction of a 7% reduction in GHG emissions from transport through the use of biofuels could lead to a very different feedstock mix than a target of 10% biofuels by energy in the fossil fuel mix. Policies which focus on reducing GHG emissions from transport and which support an effort to have significant penetration of 2G biofuels by 2020 could lead

to a reduced requirement for wheat, OSR and maize in the EU, but potentially significant demand increases for sugarcane and palm.

- As can be shown from the summary table (Figure 3), meeting any of these targets would result in a significant expansion of production of a number of crops, particularly sugarcane, palm, wheat and OSR, especially without the introduction of 2G biofuels. These scenarios also assume an expansion of crops that are not currently grown particularly widely, such as sweet sorghum, cassava and jatropha. A global 7% reduction target of global GHG emissions from transport through biofuels would be particularly challenging, especially without significant penetration of 2G biofuels, as it would require large expansion in crop production.

- It is not appropriate to calculate the GHG emissions for the different scenarios as these scenarios have not been designed for this purpose. The purpose of these scenarios was to give *estimates* of the quantities of feedstocks that might be required. There are also uncertainties associated with the future GHG savings of the different routes. The concern is that by calculating exact figures for GHG savings for the different scenarios, these may be taken as means of comparing the consequences of the different policy mechanisms employed in the different scenarios, without taking into consideration the extra uncertainties associated with the feedstock estimates and the GHG savings of the routes.

As shown in the results section of this report, we have used the scenarios for biofuel and feedstock demand to calculate the land area required to grow the crops, under a BAU crop yield scenario

7. Considerations

Both volume and GHG targets lead to significant increases in crop production required to meet biofuel demand, and consequently potentially significant increases in land required to produce the crops. Therefore, the direct and indirect implications need to be considered and managed carefully. However, there are a number of factors that mitigate the requirement for land.

The likely expansion required for most crops implies that global yield improvement will be an important factor in limiting land requirements for biofuel production.

The deployment of 2nd generation biofuels could be essential to limiting the significant expansion in crop production that may be required under different scenarios, especially if substantially based on residue and waste feedstocks.

GHG oriented targets are likely to lead to lower land requirements because of the increased uptake of existing and new high yielding (sub)tropical crops and a possible accelerated deployment of 2nd generation routes. Also note that a volume based target within which emphasis is given to low GHG fuels, could lead to lower land requirements than a pure volume based target.

8. Further work

There are obviously other scenarios that could be investigated, and with more time it would be possible to look at different GHG targets and different volume targets for different world regions and observe the effects on global feedstock demand, as well as examine in more detail the implications of 2nd generation biofuels deployment.

It will be important to look at how the priority of different biofuels changes when the direct and indirect land use change associated with the different biofuel routes are taken into consideration. It will therefore be important to revisit these scenarios once data is available regarding the net GHG intensity of the fuel including possible land use change impacts.

It would also be important to consider in more detail crop yields and their improvements.

These scenarios presented here are meant to inform other work strands to draw conclusions and recommendations on the potential direct and indirect effects of biofuel demand.

Bibliography

The following documents were used to inform the assumptions made in our scenarios:

Walter et al. (2007) Task 40: Sustainable Bioenergy Trade; Securing supply and demand. Deliverable 8. Market Evaluation: Fuel Ethanol

OECD (2006) Agricultural market impacts of future growth in the production of biofuels.

USDA (2007) GAIN report: Paraguay – Annual report on biofuels

USDA (2007) GAIN report: South Africa – Biofuels situation update

USDA (2007) GAIN report: Brazil – Biodiesel situation update

USDA (2007) GAIN report: Israeli Renewable Energy Markets – Biofuels

USDA (2007) GAIN report: Canada Biofuels report

USDA (2007) GAIN report: EU-27: Commission publishes impact assessment of the 10% biofuel obligation

USDA (2007) GAIN report: Uruguay biofuels report

USDA (2007) GAIN report: Columbia – Annual report on biofuels

USDA (2007) GAIN report: Indonesia – Annual report on biofuels

USDA (2007) GAIN report: Mexico – Annual report on biofuels

USDA (2007) GAIN report: Pakistan – Biofuels

USDA (2007) GAIN report: China – Biofuels

USDA (2007) GAIN report: Russian Federation – Biofuels

USDA (2007) GAIN report: India – Biofuels

USDA (2007) GAIN report: Policy, production and market potential

USDA (2006) GAIN report: Australia – Annual report on biofuels

Walter et al. (in press) Perspectives on fuel ethanol consumption and trade

AEA (2008) Review of the work on the environmental sustainability of international biofuels production and use

EU Commission (2008) The impact of a minimum 10% obligation for biofuel use in the EU-27 in 2020 on agricultural markets

Renewable Fuels Agency (2008) Technical Guidance for the RTFO – Parts 1 and 2

Viewls (2005) Biofuel and Bioenergy implementation scenarios. Final report of Viewls WP5, Modelling studies.

Annex: World regions - definition

OECD North America: USA, Canada, Mexico

OECD Europe: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom

Latin America: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, the Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands, Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay and Venezuela

Middle East: Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, UAE and Yemen

Africa: all countries on the continent of Africa

OECD Pacific: Australia, Japan, (South) Korea and New Zealand

China

India

Transition economies: Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, FYR Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus, Gibraltar and Malta.

Other Asia: Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macau, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, the Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Tonga, Vietnam and Vanuatu