**CE Delft**
**Solutions for environment, economy and technology**

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

# Estimating indirect land use impacts from by-products utilization

**Report**

**Delft, June 2008**

Author(s): Harry Croezen
Femke Brouwer

# Publication Data

Bibliographical data:
Harry Croezen, Femke Brouwer,
Estimating indirect land use impacts from by-products utilization

Delft, CE, June 2008

Land use / Fuels / Agriculture / Food / Effects / Analysis

Publication number: 08.4723.30

CE-publications are available from www.ce.nl.

Commissioned by: AEA Technology.
Further information on this study can be obtained from the contact person Harry Croezen.



**CE Delft**

**Solutions for environment, economy and technology**

CE Delft is an independent research and consultancy organisation specialised in developing structural and innovative solutions to environmental problems. CE Delfts solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

For the latest information on CE check out our website: www.ce.nl.

This report is printed on 100% recycled paper.

# Contents

# 1 Project Framework: scope and key aims

Aim of this project part is providing an indication of the effects utilization of by-products from biofuels production can have on global land use and on land use changes. Potential influences on land use changes may also influence net GHG emissions, in case deforestation or other forms of changing natural habitats into crop land are avoided. In order to demonstrate the relevance we broadly translated avoided land use in potential GHG emission avoidance due to avoiding land use change.

The analysis focuses on the utilization of by-products from so-called first generation biofuels production technologies as feed. This application avoids cultivation of primary feed crops such as soy, wheat and corn and thus reduces area requirement for cultivation of these crops and the GHG emissions related to crop cultivation and crop processing. Reduction in area requirement might also mean avoiding creation of extra agricultural area by transforming natural area's. This would avoid GHG emissions related to land use change.

The by-products could alternatively be utilized as fuel or – in the future – as feedstock for second generation biofuels. By-products utilization as fuel will avoid fossil fuel consumption and related GHG emissions.

The analysis is a follow up of the E4Tech scenario analysis. We used the amounts of crops applied as feedstocks in the E4Tech scenario's as starting point of our own analysis (see Appendix).

In the next chapter we estimate the amounts of by-products we have to consider. In chapter 3 we then estimate which amounts of primary feed crops are likely to be replaced by the considered amounts of by-products.

# 2 Future availability of DG's and meals

## 2.1 Amounts of by-products per unit of crop

Based on several authoritative LCA's and several other sources, following amounts of by-products per unit of crop utilized in biofuels production were estimated:

Table 1 Amounts of by-products per unit of crop feedstock for biofuels production

| | |
|---|---|
| Wheat | 0,323 |
| Soy | 0,83 |
| Corn | 0,30 |
| Palm | 0,02 |
| Sunflower | 0,6 |
| Rapeseed | 0,57 |
| Cassave | 0,02 |
| Sorghum | 0,02 |

For wheat and maize we took into account that for bioethanol production low protein crop species are and will be applied (see Ensus and GHGenius). For soy production of a separate hull fraction was ignored. The hulls are normally also applied as feed.

For sweet sorghum and cassava very little information is available concerning bioethanol production and by-products generation. Presented amounts are based on a very limited amount of sources.

## 2.2 Future availability of DG's and meals

For determining the amounts of by-products to consider we combined the amounts of crops that are to be applied in biofuels production (according to the E4tech scenario's) with the specific amounts of by-products per unit of consumed crop.
We estimated that in the scenario's developed by E4Tech the amounts of DDGS and meals from different crops given in Table 1 will become available. The shift from so-called first generation biofuels to second generation biofuels and the application of a GHG reduction target significantly reduces by-products generation.

Because oil palm trees and soy are less likely crops for cultivation in Europe we took the liberty of 'redistributing' the consumed amounts of crops in the different scenario's (see Figure 1). For palm oil we assumed that production will take place solely in 'other Asia'. For soy we assumed that the biodiesel consumed in the EU and Asian OECD countries is produced from crops cultivated in Latin America.

Figure 1 Approximate by-products yields in the considered biofuels scenario's

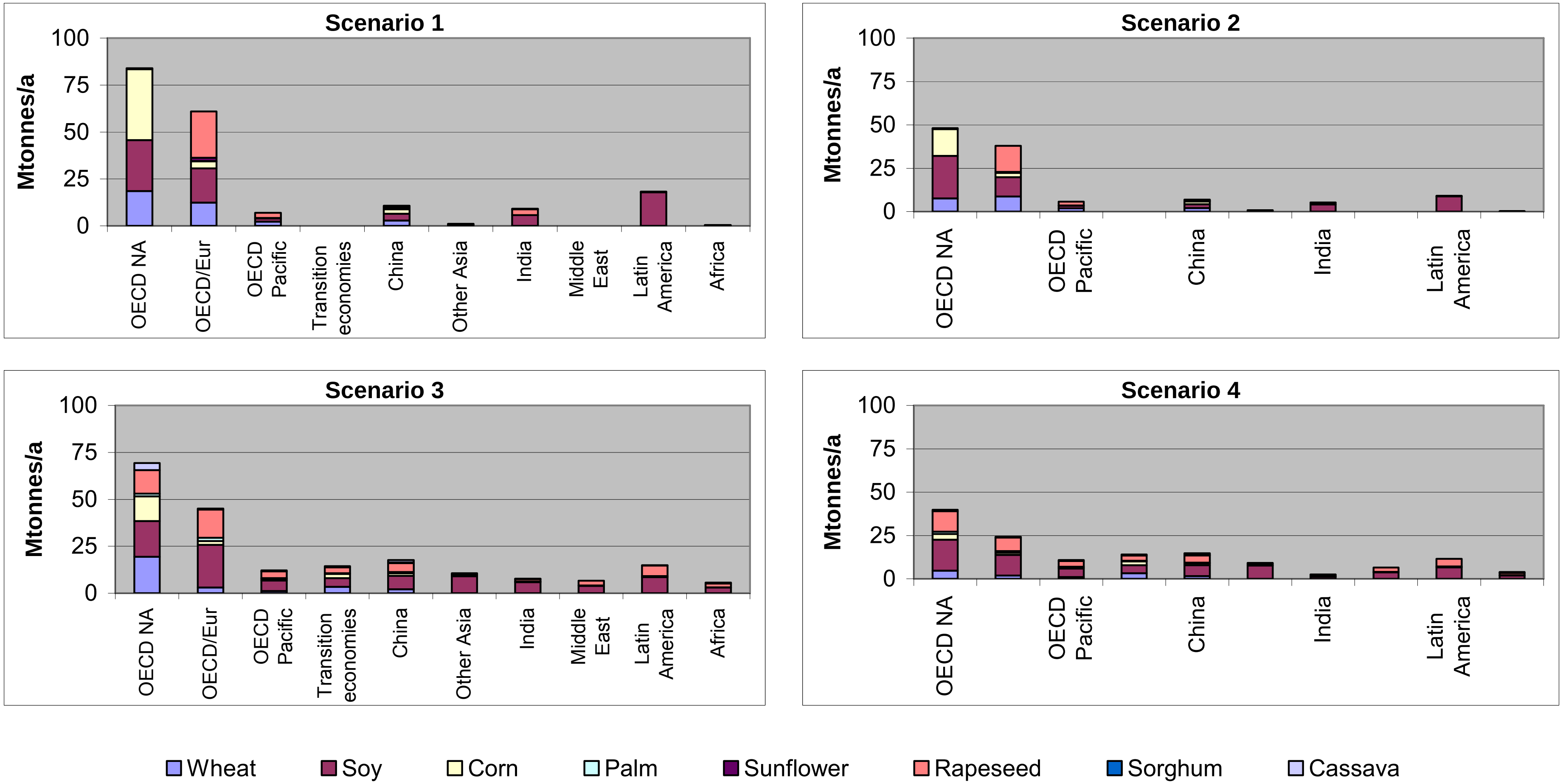
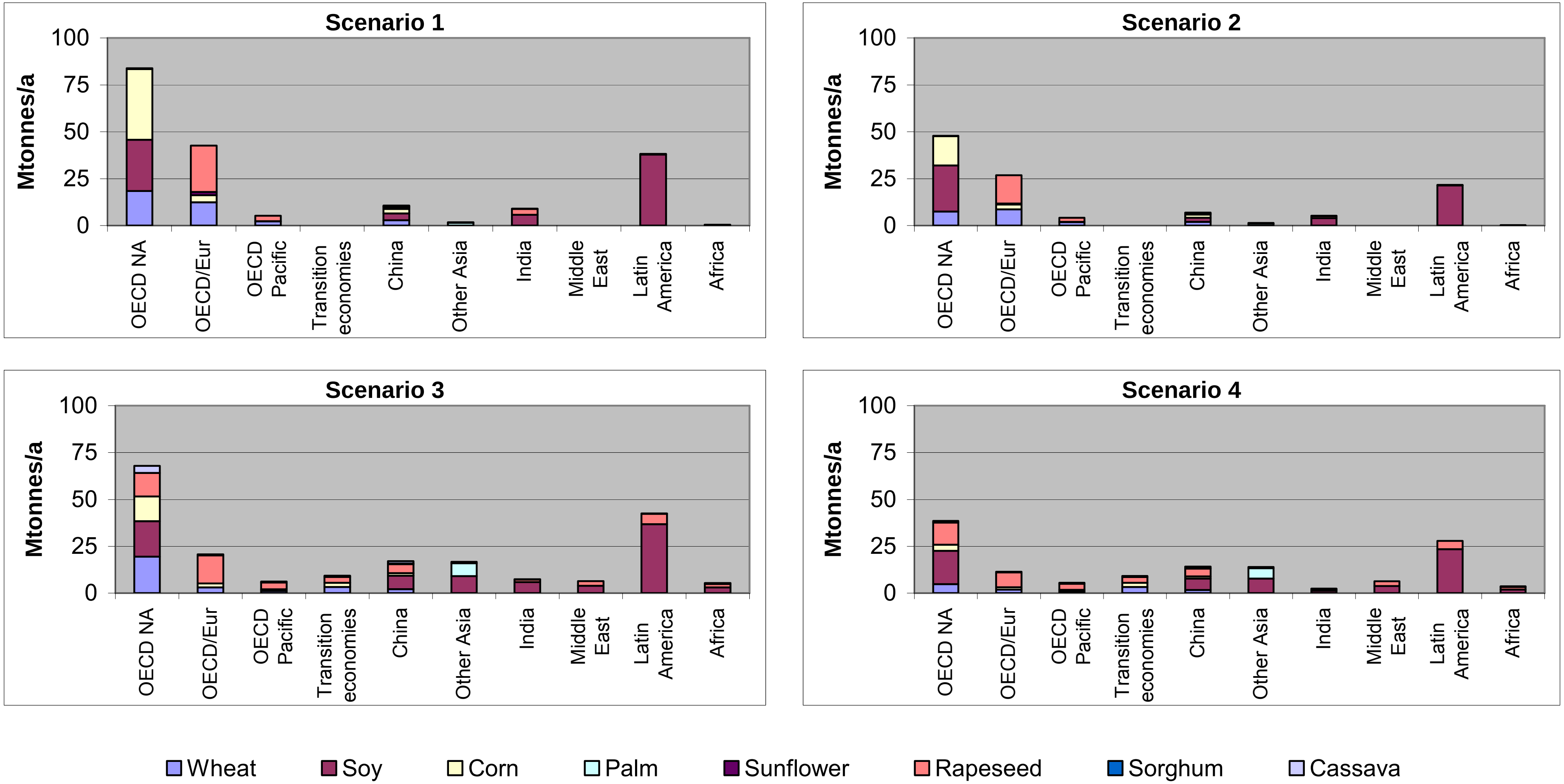


Figure 2 Estimated production of meals and DG's per region



The effect is illustrated by comparison between Figure 1 and Figure 2. The amount of soy meal given in Figure 1 as produced in the EU is assumed to be 'redistributed' to Latin America, giving a higher production of soy meal in Latin America in Figure 2 compared to Figure 2.
By-products and especially RSM and DG's are produced mainly in North America and the EU.

## 2.3 Applied focus

Of the different biofuel production routes considered in the E4tech scenario's following routes were considered as producing by-products readily applicable as feed and thus relevant for the analysis under consideration:

- Ethanol from wheat and corn.
- Biodiesel from rape.

Production based on sunflower and sugar beet were ignored because of the limited amount utilized for biofuels production. Production of palm oil biodiesel, sweet sorghum and cassave were ignored because of the limited amount of by-products applicable as feed produced.
Jatropha was ignored because the varieties currently considered for biodiesel production produce a press cake toxic for livestock. It is in practice often returned to the plantation for utilization as green manure.

Sugar cane was ignored as feed since in practice most bagasse by-product is utilized as a fuel in the ethanol production.

The potential for utilization of the glycerine by-product from biodiesels production was ignored because of lack of knowledge about the possibilities and time restrain during project execution[1].

Soy meal is not considered a 'by-product'. In fact soy will be cultivated primarily for meal production, since meal sales generate 60-70% of total gross income. It is more realistic to consider the oil as being a by-product. Because of the economic importance of soy meal and because soy meal is the main primary protein source in global feed consumption it does not seem logical to assume that soy meal utilization as feed will result in reduction of land use for feed crop cultivation.

---

[1] The glycerin by-product from biodiesels production may according to several studies potentially be utilized as feed. Competing and currently more common applications are chemical feedstock and feedstock for biogas production. However:

- Studies considering possibilities for utilization as feed have only started recently and still only consider one specific livestock specie (calves).
- Market prices for glycerin as chemical feedstock are still higher than the prices that can be expected for utilization as feed.

The focus in the analysis under consideration differs significantly from current feed market situation. In reality palm kernel cake for example is an important, though low quality component of feed concentrates of which millions of tonnes are applied in the EU feed industry. Sugar beet pulp is also an important feed component. However, in the E4Tech scenario's these by-products are produced in insignificant amounts and are therefore not considered further in this analysis.

# 3 Potential for application of DG's and meals as feed, avoided primary feed crops

Estimating how much land use and potentially associated GHG emissions can be avoided by applicating DG's and meals as feed requires generating an indication for the questions below:

- How much of these by-products could theoretically be applied as feed?
- With what products do or will these by-products probably compete?
- Given their quality, potential market price and the quality of competing feed components, what could be the amount of by-products actually utilized as feed?
- How much land use can possibly avoided by utilizing these amounts by-products as feed?

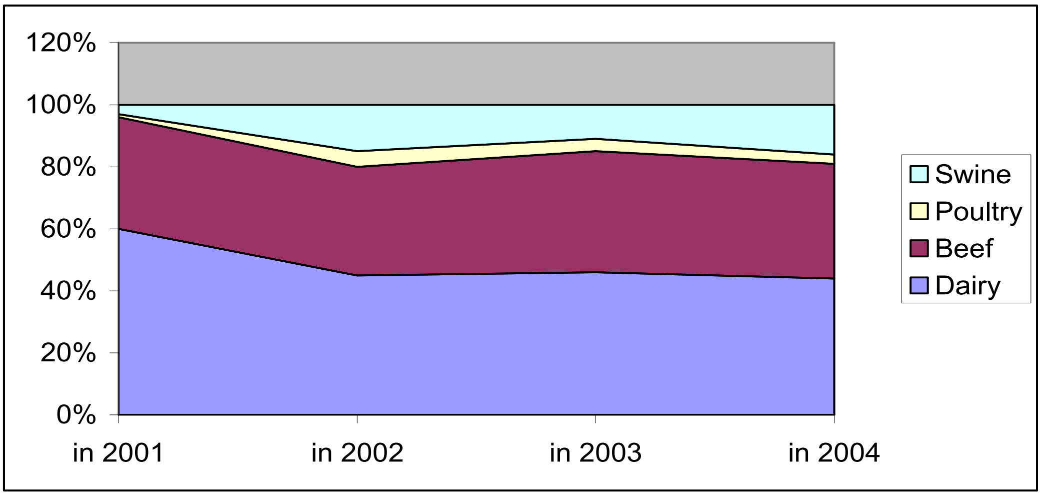
The issues mentioned above are considered in the subparagraphs below

## 3.1 Quality of DG's and RSM as feed

As mentioned in several sources Distiller Grains (DG's) contain higher levels of digestible fibre and higher levels of bypass protein, making it a an ideal feed for ruminants and especially dairy livestock. In dairy livestock DG's seem to enhance milk production per unit of feed. The suitability for ruminants is mirrored in outlet markets. In the USA 80-85% of DG's produced in 2005 was utilized in cattle and dairy farming (see Figure 3). Of it approximately 80% was wet, undried distiller grains (WDG) and approximately 20% dried distiller grains (DDG)[2]. WDG can be kept for approximately a week and can be supplied only to nearby consumers because of the extra water content. DDG (90% d.s.) has a far longer shelf live and transportation is cheaper.

[2] See http://www.iowafarmbureau.com/programs/commodity/information/ddgs.pdf.

Figure 3 Current application of DG's in the USA




Source: USB, 2007.

DG's were until recently viewed as a less suitable feed for non-ruminants. However, new dry milling ethanol plants seem to produce a (far?) more digestible product that yields comparable digestive energy compared with corn.
DG's in poultry diets is probably limited due to the high content of fibres and because of the risk of colour change of egg shells. In pigs an inclusion rate of more than 20% results in soft fat due to the oil content and oil quality of DG's.

Rape seed meal (RSM) is an established protein source in dairy and beef cattle diets and finds more and more application in pig diets (see e.g. OECD-FAO, 2007). Incorporation ratios in pig diet are however limited due to the presence of toxic substances and because RSM can give a fishy taste to pig fat.

Current advised levels and potential levels of incorporation are given in Table 2.

Table 2 Current advised levels and potential levels of incorporation for Distiller's Grains (DG's) and Rape Seed Meal (RSM)

| | DDGS | | RSM | |
|---|---|---|---|---|
| | Advised | Potential | Advised | Potential |
| Ruminants | | | | |
| - Dairy | 40% | 40% | 25% | 25% |
| - Other cattle | 40% | 40% | 40% | 25%-30% |
| Pigs | | | | |
| - Piglets | | 30% | 3% | 15%-25% |
| - Growers | 2,50% | 30% | 3% | 25% |
| - Finishers | 5% | 20% | 3% | 10%-30% |
| - Sows | | | | |
| a) Gestating | 5% | 50% | 5% | Unknown |
| b) Lactating | 5% | 20% | 5% | Unknown |
| Poultry | | | | |
| - Broilers | 5% | 15% | 5% | 10%-15% |
| - Layers | 5% | 15% | 3% | 10%-15% |

With respect to digestability, following specifications were found for DG’s and RSM. For comparison the specifications of SBM and cereals are also given.

Table 3 Digestibility specifications of by-products and primary feed components

| | Wheat DDGS | Corn DDGS | RSM | SBM | Wheat | Corn |
|---|---|---|---|---|---|---|
| d.s.% | 90% | 90% | 90% | 90% | 85% | 85% |
| ME[3]: | | | | | | |
| Ruminants | 13,5 | 14 | 12,1 | 13,6 | 13,5 | 13,8 |
| Pork | 14,1 | 14,1 | 10,5 | 12 | 10,2 | 11 |
| Poultry | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown |
| Crude protein | 34% | 31% | 40% | 49% | 9,50% | 8,40% |
| Protein digestability | | | | | | |
| Ruminants | 68% | 68% | 50% | 60% | 77% | 95% |
| Pork | 58% | 58% | 78% | 85% | 80% | 75% |
| Poultry | 58% | 58% | 82% | 89% | | |

In comparison with other protein sources, not mentioned in the table the protein content of RSM is comparable to that of sunflower meal and cottonseed meal (both 40%) and is higher than that of palm kernel meal (approx. 20%). DG’s have a lower protein content compared to sunflower and palm kernel meals but a higher protein content compared to palm kernel meal.

The table does not cover all relevant aspects. Essential amino acid composition and availability and content of digestible phosphorous for example are not given. The data can however be applied for estimating the ratio’s at which the by-products can substitute soy meal and other primary feed components.

Table 4 Estimated substitution ratio’s

| | SBM | Wheat | Maize |
|---|---|---|---|
| RSM | | | |
| In pork | 0,72 | | 0,23 |
| In cattle feed | 0,60 | | 0,28 |
| Corn DG's | | | |
| In pork | 0,28 | | 0,97 |
| In cattle feed | 0,61 | | 0,41 |
| Wheat DG's | | | |
| In pork | 0,28 | 1,05 | |
| In cattle feed | 0,72 | 0,27 | |

This can be done by determining a combination of SBM and wheat or corn that matches both digestible protein content and ME for a certain kind of life stock (see also GHGenius, 2005).

3 ME = Methabolic Energy, the amount of energy applied by the animal for movement and maintaining body temperature.

For comparison:

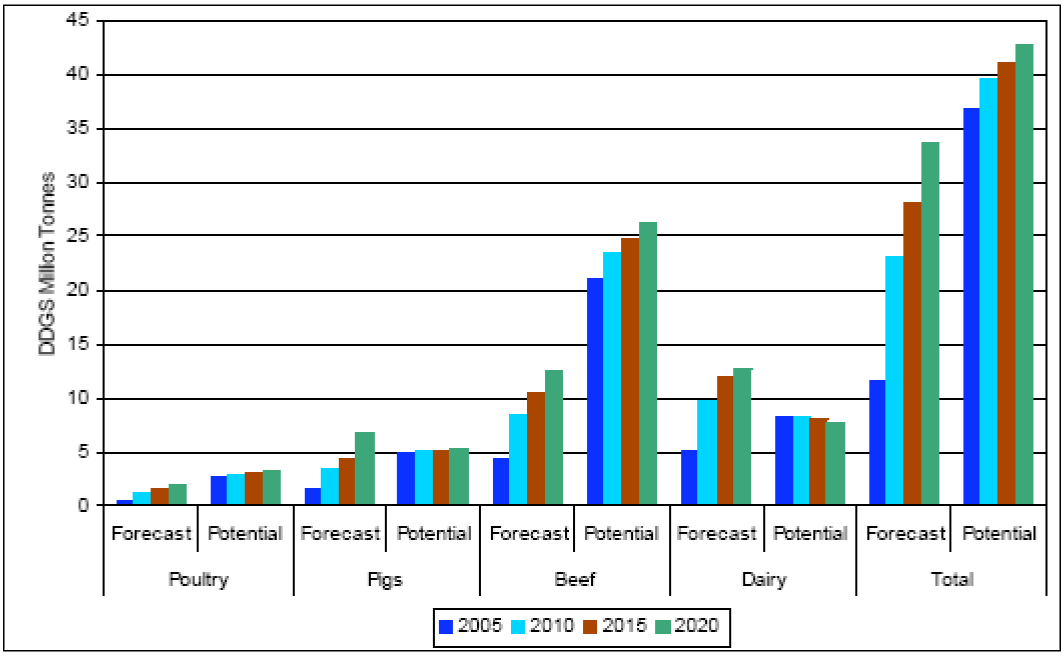
- In GHGenius ratio's at which corn DG's substitute soy meal and corn in cattle feed are estimated at 0,60 and 0,68 tonne/tonne DG's.
- According to USB (2007) a tonne of RSM replaces 0,65 ± 0,05 tonnes of SBM in cattle feed.

## 3.2 Theoretical applicable amount

Given the projected production of meat and milk, application of the amounts of DDGS and meals produced in the different E4Tech scenario's as feed according to the above seems theoretically possible:

1 According to USB (2006) potential for application of DG's in beef and dairy sectors in 2015 amounts to approximately 33,5 Mtonnes, 25 Mtonnes in beef production and approximately 8,5 Mtonnes in milk production (see Figure 4). US production of beef and milk in 2015 is estimated by USDA at respectively 12,6 Mtonnes and 88 Mtonnes (USDA, 2007). Assuming that the potential for DG's utilization in the USA can be extrapolated to global beef and milk production in 2015 the global potential for DG's utilization in cattle diets amounts to approximately 156 Mtonnes (see Table 5).

Figure 4 Forecast and potential utilization of DG's in the USA




Source: USB, 2006.

Table 5 Estimation of available market volume for DG's in dairy and beef diets

| | 2015 production (Mtonnes) | 2015 DG's utilization potential (Mtonnes) | Specific utilization potential (kg DG's/kg) | Global production in 2015 (Mtonnes) | Approximate DG's potential (Mtonnes) |
|---|---|---|---|---|---|
| Beef | 13 | 25 | 1,99 | 75 | 150 |
| Milk | 88 | 0,8 | 0,01 | 599 | 6 |

A potential market of 156 Mtonnes/a is more than the maximum amount of 80 Mtonnes of DG's produced in scenario 1.

2 According to scientific assessments rape seed meal (RSM) may be incorporated into pig and poultry diets up to levels of at least 10-15% (Table 2).
The amount of feed for pigs and poultry currently consumed amounts to about 630 Mtonnes/a[4] at a production level of pig meat and poultry meat of respectively 107 Mtonnes/a and 80 Mtonnes/a (OECD-FAO, 2007).
Considering the forecast production level of pig meat and poultry meat of approximately 130 Mtonnes respectively 100 Mtonnes in 2016, feed consumption for pigs and poultry may rise to approximately 750 Mtonnes in 2016.
At 10-15% incorporation, the utilizable amount of RSM amounts to 75-105 Mtonnes annually. Maximum amount of rape seed meal produced in the E4Tech scenario's is 50 Mtonnes/a (scenario 3).

Another way of checking whether the amounts of DG's and RSM could theoretically be utilized as feed is comparing current amount of protein meals with the amounts of DG's and RSM assumed to be produced.

Table 6 Current consumption of protein meals for feed

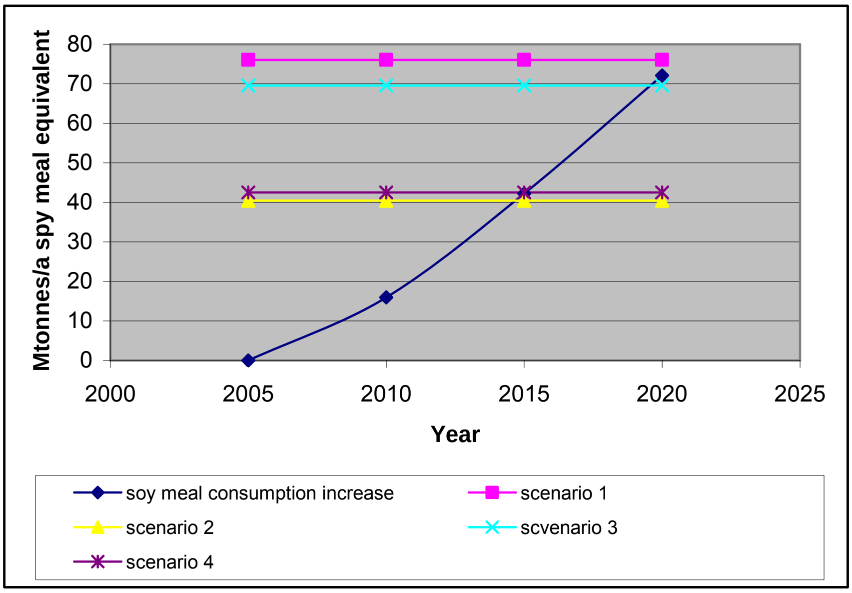
| | Protein meals in Mtonnes/a of soymeal equivalents | Amounts of by-products (Mtonnes/a of soymeal equivalents | | | |
|---|---|---|---|---|---|
| | | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
| Soy (dehulled) | 144,9 | | | | |
| - Biodiesel related | 1,4 | | | | |
| - Otherwise produced | 143,5 | | | | |
| Rape | 21,1 | 23 | 14 | 36 | 28 |
| Sunflower | 8,4 | | | | |
| Palm kernel | 1,9 | | | | |
| Coconut | 0,9 | | | | |
| Cottonseed | 5,6 | | | | |
| DG's | | 53 | 27 | 33 | 14 |
| *Total* | *182,8* | *76* | *40* | *70* | *43* |

Source: USB, 2007.

4 According to USB (2007) approximately 25% of the total US soy production is utilized in pig diets and approximately 45% in poultry diets. According to FAO (2006) soy makes up approximately 10% of pork diet and approximately 20% in poultry diets. Extrapolating to global level gives a feed input of 145 x [(25% ÷ 10%) + (45% ÷ 20%)] ≈ 630 Mtonnes/a.

This comparison illustrates that in all E4Tech scenario's the amounts of by-products is significant compared to protein demand for livestock but that the total amount of by-products is still less than 50% of total protein demand.
The amounts of by-products are also more or less comparable with the forecasted increase in global soy meal consumption (see USB, 2007).

Figure 5 Comparison of prognosed increase in global soy meal consumption and produced amounts of by-products




This implies that theoretically the by-products produced in the four considered E4Tech scenario's *might* substitute global increase in soy meal consumption.

## 3.3 Competition with alternative feed components

Predicting what kind and amounts of feed components are being or will be substituted by DG's and RSM requires a more detailed analysis. These aspects will probably differ per region.
However, given:

- The amounts of by-products produced according to the E4Tech scenario's.
- Current and prognosed amounts of different protein sources applied in feed.

there is actually little other possibility than that the larger part of the by-products volumes compete with soy meal. All other protein sources are much smaller in volume than the considered volumes of by-products. Substituting these will not cover the entire volume of by-products considered in any of the different scenario's.

However, the claim that DG's in dairy and beef cattle diets will substitute soy bean meal is somewhat questionable for some E4Tech scenario's.
Of total current US soy meal production of 67 Mtonnes only 7-15% seems applied in cattle diets (both exports and domestic consumption, see USB, 2007).

Extrapolating to a global level of 145 Mtonnes gives a current total soy meal consumption of approximately 10-22 Mtonnes/a and a future consumption of 12-26 Mtonnes of soy bean meal[5].

Assuming a substitution ratio of 0,6-0,7 kg SBM per kg of DG's (100% d.s.) the amounts of DG's produced in several scenario's will substitute more than only soy bean meal. In the USA urea (USDA, 2006) and cottonseed meal may be substituted and in the EU other secondary protein rich by-products such as palm kernel meal may be substituted. Palm kernel meal may then be applied as green manure, as is common practice in Africa (CE, 2006b).

Next to this, soy meal as a protein source has superior specifications in terms of digestability – especially for pigs and poultry – and essential amino acid composition (see e.g. USB, 2007). Contrary, most other protein sources such as cottonseed, palm kernel meal and urea seem[6] comparable or inferior to DG's and RSM in terms of digestability, palatability and/or presence of toxic substances. As a result application of urea and cottonseed meal seems limited to ruminants. Cottonseed[7] and palm kernel meal (CE, 2006b) are already applied partly as green manure, indicating their limited value as feed component.

On the other hand, DG's can also be applied in poultry and pig diets, in which it can also substitute soy meal. In fact, most DG's export is applied in poultry and pig feed.

Considering above aspects it seems reasonable to assume that DG's and RSM will primarily substitute soy meal.

According to several sources[8] the most likely applications of Distiller's Grains (DG's) and Rape Seed Meal (RSM) are as followed:
- Distiller's Grains – likely supplied mainly in the wet form – will be applied primarily in dairy and beef cattle menu's. In these applications it is said to replace soybean meal (SBM), RSM and (in the USA) urea as protein source and corn as energy source.
- Rape seed meal will probably be applied preferentially in diary and beef cattle diets but may be increasingly applied in pig diets. In these applications it will substitute SBM.
- Distiller's Grains (DG's) may also be an interesting protein source for poultry, although the rate of inclusion seems limited to a maximum of 15% by weight (see Table 2).

---

5 Global beef and milk production are expected to increase with approximately 20% up to 2016.
6 As far as can be deducted in this limited study.
7 See e.g. http://www.cottonseed.com/publications/beautifulgardens.asp.
8 See USDA (2007), USB (2006), Feed tech (2007).

The applications in which the by-products are utilized will probably also depend on national policies of by-products producing countries. The French government for example is actively involved in stimulation of RSM as a SBM substitute within the own country (USDA, 2005), not only in ruminants diets, but also in pig and poultry diets. USDA is actively supporting incentives for DG's exports to Mexico, Asia and Europe for application primarily in poultry and pig diets.

# 4 Estimating avoided land use for primary crop cultivation and avoided concurrent GHG emissions

## 4.1 Avoided land use for crop cultivation

Assuming that both RSM and DG’s will replace soy as protein source in cattle, pig and poultry diets (see previous chapter), reduction in land requirement for cultivation of the potentially substituted amounts of wheat, corn and soy are given in Table 7 and Table 8.

The estimations are based on following assumptions:

- DG's and rape seed meal produced in USA substitute US wheat, corn and soy bean meal. No land use change is avoided.
  DG's and rape seed meal produced in Europe and R.O.W.[9] substitute locally produced corn and wheat. They also substitute Latin American soy.

It was assumed local cereal production will be substituted, because both the EU and North America – the two area’s where the bulk of the considered amounts by-products would be produced – are (almost) self supporting in terms of cereal cultivation for feed application (see USDA, 2006 and ENSUS, 2007).
Because the amounts of DG’s and RSM are too large to be applied solely in ruminants diets, a 50% : 50% application in ruminant and pig diets was assumed.

The approach that in the EU and R.O.W. imports of Latin American cultivated soy and soy meal will be substituted by by-products can be motivated with the forecasts for soy bean and soy meal export. Latin America will supply approximately 70% of global exports in 2015 and 2020. According to (USB, 2006) there is very little opportunity for area expansion for soy cultivation in the USA. USB and USDA on the contrary expect shrinkage of soy area as more area will be applied for corn cultivation. This implies that importing countries can get their imports primarily from Latin American producers.
This is especially true for the EU, which actually imports little US soy and soy meal because of the widespread cultivation of GM soy in the USA.

It is assumed that the by-products are applied to substitute the prognosed increase in soy meal cultivation. Subsequently, the substituted exported soy from Latin America would probably have been cultivated on recently deforested land.
Soy production on existing area will increase with approximately 20% compared to current level and can therefore not cover the expected increase in soy bean production in Latin America (see Table 8).

---

9 R.O.W. = rest of the World.

Table 7 Potential reduction in primary feed crop

Byproducts amounts (Mtonnes/a)

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Replaces: |
|---|---|---|---|---|---|
| Wheat DG's | | | | | |
| - North America | 18 | 8 | 19 | 5 | a) |
| - Europe | 12 | 9 | 3 | 2 | b) |
| - R.O.W. | 5 | 4 | 7 | 6 | b) |
| Corn DG's | | | | | |
| - North America | 38 | 15 | 13 | 3 | c) |
| - Europe | 4 | 3 | 2 | 1 | d) |
| - R.O.W. | 2 | 2 | 4 | 4 | d) |
| Rapeseed meal | | | | | |
| - North America | 0,3 | 0,3 | 13 | 12 | c) |
| - Europe | 25 | 15 | 15 | 8 | d) |
| - R.O.W. | 7 | 4 | 23 | 19 | d) |

X

Substitution ratio's (50% : 50% cattle and pig diets) tonne/tonne

| | SBM | Wheat | Maize |
|---|---|---|---|
| Wheat DG's | | | |
| - North America | 0,50 | 0,66 | |
| - Europe | 0,50 | 0,66 | |
| - R.O.W. | 0,50 | 0,66 | |
| Corn DG's | | | |
| - North America | 0,45 | | 0,69 |
| - Europe | 0,45 | | 0,69 |
| - R.O.W. | 0,45 | | 0,69 |
| Rapeseed meal | | | |
| - North America | 0,66 | | 0,26 |
| - Europe | 0,66 | | 0,26 |
| - R.O.W. | 0,66 | | 0,26 |

***Avoided crop production (Mtonne/a)***

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Wheat DG's | | | | |
| - North America | 12 | 5 | 13 | 3 |
| - Europe | 8 | 6 | 2 | 1 |
| - R.O.W. | 3 | 3 | 4 | 4 |
| Corn DG's | | | | |
| - North America | 26 | 11 | 12 | 5 |
| - Europe | 9 | 6 | 5 | 3 |
| - R.O.W. | 3 | 2 | 9 | 8 |
| Soy bean (corrected for meal : bean ratio) | | | | |
| - North America | 32 | 13 | 29 | 14 |
| - Europe | 29 | 19 | 15 | 8 |
| - R.O.W. | 10 | 6 | 25 | 21 |

Figures in the lower table result from multiplication of amounts of by-products with substition ratio's. Substitution ratio's are for application of by-products in a 50% : 50% ratio in pig and cattle diets. For soy bean figures have been corrected for the fact that 1 tonne of bean yields approximately 0,83 tonne of meal (and hull).

a = Replaces local produced wheat and soy.
b = Replaces local produced wheat and from Latin America imported soy.
c = Replaces local produced maize and soy.
d = Replaces local produced maize and from Latin America imported soy.

Table 8 Estimation of reduced land requirement for feed crop cultivation

***Avoided crop production (Mtonne/a) (see* Table 7*)***

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Wheat DG's | | | | |
| - North America | 12 | 5 | 13 | 3 |
| - Europe | 8 | 6 | 2 | 1 |
| - R.O.W. | 3 | 3 | 4 | 4 |
| Corn DG's | | | | |
| - North America | 26 | 11 | 12 | 5 |
| - Europe | 9 | 6 | 5 | 3 |
| - R.O.W. | 3 | 2 | 9 | 8 |
| Soy bean (corrected for meal : bean ratio) | | | | |
| - North America | 32 | 13 | 29 | 14 |
| - Europe | 29 | 19 | 15 | 8 |
| - R.O.W. | 10 | 6 | 25 | 21 |

X

Yield (tonne/ha in 2020)

| | |
|---|---|
| Wheat DG's | |
| - North America | 3,5 |
| - Europe | 5,2 |
| - R.O.W. | 3,4 |
| Corn DG's | |
| - North America | 12,5 |
| - Europe | 7,6 |
| - R.O.W. | 5,1 |
| Soy bean | |
| - North America | 3,5 |
| - Europe | 3,3 |
| - R.O.W. | 3,3 |

***Reduction in required agricultural area (million ha)***

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Wheat DG's | | | | |
| - North America | 3,5 | 1,4 | 3,7 | 0,9 |
| - Europe | 1,6 | 1,1 | 0,4 | 0,2 |
| - R.O.W. | 1,0 | 0,8 | 1,3 | 1,1 |
| Corn DG's | | | | |
| - North America | 2,1 | 0,9 | 1,0 | 0,4 |
| - Europe | 1,2 | 0,7 | 0,7 | 0,4 |
| - R.O.W. | 0,7 | 0,4 | 1,8 | 1,5 |
| US soy | 9,0 | 3,7 | 8,1 | 4,0 |
| Latin American soy | 12,0 | 7,6 | 12,1 | 9,0 |
| | 31,0 | 16,7 | 29,1 | 17,5 |

The left upper corner table is the result from Table 7. Yields per hectare are adopted from E4Tech and ADAS. For R.O.W. a mathematically averaged value for the other regions than North America and EU has been applied.

Table 9 2008 USDA BASELINE forecast for soy area and production in Latin America (see USDA site)

| | ARGENTINA | BRAZIL | OTHER SOUTH AMERICA | ARGENTINA | BRAZIL | OTHER SOUTH AMERICA |
|---|---|---|---|---|---|---|
| | Production (ktonnes/a) | | | Area (million ha) | | |
| Year | | | | | | |
| 06/07 | 47 | 59 | 9 | 16 | 21 | 4 |
| 07/08 | 47 | 62 | 10 | 17 | 22 | 4 |
| 08/09 | 46 | 68 | 10 | 17 | 23 | 4 |
| 09/10 | 51 | 71 | 10 | 18 | 24 | 4 |
| 10/11 | 53 | 77 | 10 | 18 | 26 | 4 |
| 11/12 | 54 | 83 | 10 | 19 | 28 | 4 |
| 12/13 | 55 | 87 | 11 | 19 | 29 | 4 |
| 13/14 | 57 | 91 | 11 | 19 | 30 | 4 |
| 14/15 | 58 | 96 | 11 | 20 | 31 | 4 |
| 15/16 | 59 | 100 | 11 | 20 | 32 | 4 |
| 16/17 | 60 | 104 | 12 | 20 | 33 | 5 |
| 17/18 | 61 | 108 | 12 | 20 | 34 | 5 |

## 4.2 Substitution and GHG emissions

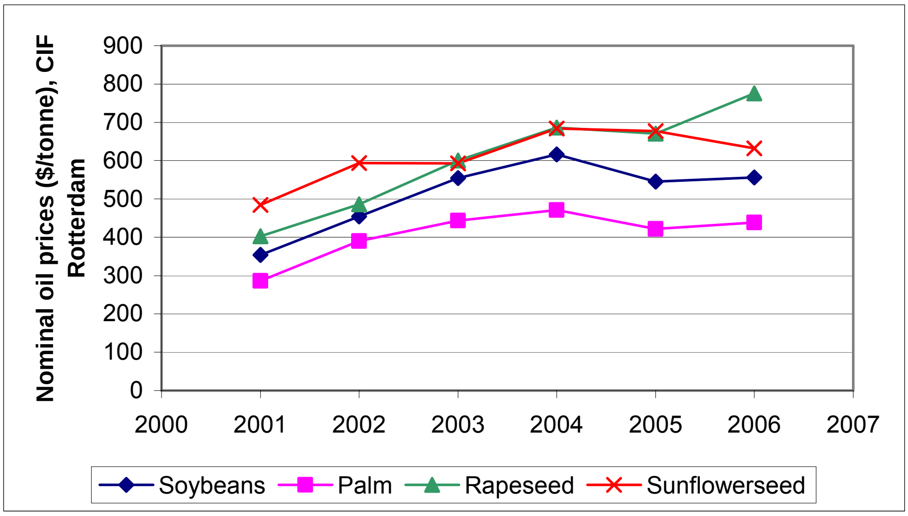
For estimating GHG emissions related to DG's and rape seed meal application as feed following emissions were taken into account:

- Emissions for drying of DG's (as far as required).
- Emissions avoided due to avoiding cultivation of substituted wheat, corn and soy beans and due to avoiding processing (crushing) of soy beans and processing of oil.
- Extra emissions related to the production of extra palm oil, required to fill up the cap between demand and supply in vegetable oils created by substitution of soy beans in feed applications.
- Avoided land use change emissions in case of avoided soy cultivation in Latin America.

Decrease in production of soy oil due to substitution of soy bean meal by DG's and rape seed meal is assumed to be compensated by extra palm oil production. The assumption is based on the fact that palm oil is the cheapest oil in terms of production costs (Parkhomenko, 2004) and has the lowest market price (see Figure 6).

Default emission factors applied for crop cultivation are given in Table 9. Green painted cells refer to $CO_2$-tool NL as information source, yellow painted cells to JRC (2007).

Figure 6 Development of vegetable oil prices




Source: http://www.oilworld.biz/home.

Table 10 Default GHG emission factors for crop cultivation and processing

| | Soy bean (USA) | Soy bean (Argentina) | Corn USA | Palm oil, Asia | Rapeseed EU | Wheat EU | Theoretical extra emission from extra palm oil production (kg $CO_2$-eq/tonne soy bean) |
|---|---|---|---|---|---|---|---|
| Cultivation | 112 | 125 | 275 | 62 | 727 | 260 | 64 |
| Possible land use change emissions | | 8.088 | | | | | |
| Processing | 156 | 156 | | 339 | | | 351 |

Land use change related emissions related to (avoided) soy bean cultivation in Latin America were estimated assuming conversion of 20% grassland, 20% rain forest and 60% Cerrado (see Ensin, 2008). Emissions are based on IPCC (2006 methodology report).

GHG emissions are calculated by combining the default emission factors with the estimated substituted amounts of wheat, corn and soy given in Table 7. Resulting emissions are given in Table 10.

Table 11 Estimated reduction in global GHG emissions due to utilizing biofuels by-products as feed

***Wheat, avoided emissions***

| | | | | |
|---|---|---|---|---|
| Cultivation | 2,5 | 1,4 | 2,0 | 0,9 |
| Possible land use change emissions | | | | |
| Processing | | | | |
| | 2,5 | 1,4 | 2,0 | 0,9 |

***Corn, avoided emissions***

| | | | | |
|---|---|---|---|---|
| Cultivation | 6,5 | 3,1 | 4,5 | 2,7 |
| Possible land use change emissions | | | | |
| Processing | | | | |
| | 6,5 | 3,1 | 4,5 | 2,7 |

***US soy, avoided emissions***

| | | | | |
|---|---|---|---|---|
| Cultivation | 2,1 | 0,9 | 1,8 | 0,8 |
| Possible land use change emissions | | | | |
| Processing | -8,6 | -3,5 | -7,3 | -3,3 |
| | -6,5 | -2,7 | -5,5 | -2,5 |

***Latin American soy, avoided emissions***

| | | | | |
|---|---|---|---|---|
| Cultivation | 2,9 | 1,8 | 2,8 | 2,1 |
| Possible land use change emissions | 384,1 | 246,4 | 374,1 | 278,3 |
| Processing | -9,2 | -5,9 | -9,0 | -6,7 |
| | 377,7 | 242,3 | 367,9 | 273,7 |

The negative figures given for processing for soy indicate that palm oil cultivation and production would yield higher GHG emissions per unit of oil. This is largely due to methane emissions from POME digestion.

Emissions related to drying of DG's to DDGS have not been included in Table 11. Drying of DG's requires approximately 5,4 GJ/tonne DDGS and would give a specific emission of 295 kg $CO_2$-eq./tonne DDGS – assuming natural gas is applied as fuel. The net emission in case all DG's are supplied as DDGS is given in Table 12.

Table 12 Net greenhouse gas emissions in case DG's are dried

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| Total DG's (d.m.) | 80 | 40 | 49 | 21 |
| Total global GHG emission (Mtonne) | 23,6 | 11,8 | 14,4 | 6,2 |
| Avoided | -385,0 | -246,5 | -372,0 | -276,5 |
| Net emission | -361,4 | -234,7 | -357,6 | -270,3 |

## 4.3 GHG emission savings when applying by-products as fuel

An alternative application of both DG's and RSM would be anaerobic digestion. This seems a more realistic conversion process than combustion. Both types of by-products contain high amounts of sulfur, nitrogen and may be expected to generate high emissions (in raw off gases) during combustion. Next to this, both types of by-products also contain low melting ashes, making combustion technically difficult.

In the Netherlands at least two ethanol producers are installing anaerobic digestion installations for DG's. Co digestion of rape seed meal is conducted in Germany.

In general approximately 75% of the energy content of DG's and RSM can be converted into biogas. This biogas can be applied as natural gas substituent or can be upgraded to natural gas quality. In the first case – taking into account 1% leakage of methane from the digester – net GHG[10] emission reduction would amount to the figures presented in Table 13.

Table 13 Estimation of GHG savings achievable by conversion of by-products into directly utilized biogas

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | LHV |
|---|---|---|---|---|---|
| Produced (Mtonne): | | | | | |
| Wheat DG's | 36 | 20 | 29 | 13 | 16 |
| Corn DG's | 44 | 20 | 20 | 8 | 16 |
| Rapeseed meal | 32 | 19 | 50 | 39 | 17 |
| PJ biogas produced | 1.368 | 721 | 1.228 | 750 | |
| GHG saving potential (Mtonnes) | 68 | 36 | 61 | 37 | |

In this broad estimation potential GHG saving from digestate application as green manure or from stripped and isolated $NH_3$ as fertilizer substituent are not taken into account. This also applies to carbon storage in soil related to application of digestate as manure[11].

GHG savings achievable with anaerobic digestion may be further enhanced by separating $CO_2$ from the gas and sequestrate it geologically.

GHG reductions achievable by utilization of by-products as feed are only higher than reductions achievable with anaerobic digestion if by-products utilization as feed can help prevent deforestation in Latin America.

---

10 These generally amount to 1% of produced biogas.

11 The digestate will decompose slowly because of the high residual level of lignine.

# References

**ADAS, 2007**
B. Cottril, …(et al.)
Opportunities and implications of using the co-products from biofuel production as feeds for livestock
Woodthorne : ADAS UK Ltd and Nottingham University, 2007

**Argonne, 2008**
H. Huo, M. Wang, C. Bloyd, V. Putsche
Life-Cycle Assessment of Energy and Greenhouse Gas Effects of Soybean-Derived Biodiesel and Renewable Fuels
Argonne : Argonne National Laboratory, 2008

**CE, 2005**
J.T.W. Vroonhof, H.J. Croezen
Milieuevaluatie van inzet alternatieve (bio-)brandstoffen in de Gelderland 13 energiecentrale
Delft : CE Delft, 2005

**CE, 2006a**
M.N. Sevenster, D. Hueting
Energiegebruik in de veevoerketen
Delft : CE Delft, 2007

**CE, 2006b**
J.T.W. (Jan) Vroonhof H.J. (Harry) Croezen M.N. (Maartje) Sevenster M. (Kiek) Singels
Milieuanalyse 4 alternatieve (bio-) brandstoffen voor de Gelderland 13
Delft : CE Delft, 2006

**EC, 2008**
Prospects for Agricultural markets and incomes in the EU 2007-2014
Brussels : European Commission, DG for Agriculture and Rural Development, 2008

**Ensus, 2007**
Tackling Climate Change
Ensus, December 2007

**Ensus, 2008**
Indirect effects of biofuels
Ensus, April 2008

**FAO, 2006**
H. Steinfeld, …(et al.)
Livestock's long shadow, environmental issues and options
Rome : FAO, 2006

**GHGenius, 2005**
Ethanol GHG Emissions Using GHGenius, an update
Delta : $(S\&T)^2$ Consultants Inc., 2005

**Grassi, 2002**
G. Grassi, D. Chiaramonti, A. Agterberg, H.-P. Grimm, B. Coda
European Biomass Industry Association (EUBIA)
Large bio-ethanol project from sweet sorghum in China and Italy: description of site, process schemes and main products ; Presented at 12th European Conference on Biomass for Energy, Industry and Climate Protection, 17-21 June 2002, Amsterdam, The Netherlands

**Hermans, 2006**
J.L. Hermans. …(et al.)
Integrating bio-fuel production with Wisconsin dairy feed requirements
2006 ASABE Annual International Meeting, Portland, July 2006

**McKinnon, [2007]**
J.J. McKinnon, A. Walker
Comparison of wheat-based DDGS to barley as an energy source for backgrounding cattle
Saskatchewan : University of Saskatchewan, [2007]

**NPC, 2007**
Th.P. Binder, … [et al.]
Biomass – Topic paper 8 : Potential Biomass Energy Supply in 2030 to 2050 Time Frame
S.I. : Petroleum Council (NPC), Biomass Subgroup of the Supply Task Group of the NPC Committee on global oil and gas, 2007

**LBST, 2002**
Raj Choudhury, Trudy Weber [GM], Jörg Schindler, Werner Weindorf, Reinhold Wurster [LBST]
GM well-to-wheel analysis of energy use and greenhouse gas emissions of advanced fuel/vehicle systems – A European study
Ottobrunn : Ludwig-Bölkow-Systemtechnik GmbH (LBST), 2002

**JRC, 2007**
WELL-to-WHEELS Report : Well-to-Wheels analysis of future automotive fuels and powertrains in the European context, Version 2c
S.I. : EUCAR ; CONCAWE ; the Joint Research Centre of the EU Commission (JRC), 2007

**Shurson, 2004**
J. Shurson
Feeding value of DDGS for swine, dairy and beef
University of Minnesota

**OECD-FAO, 2007**
L. Boonekamp
OECD-FAO Agricultural Outlook 2007-2016
Paris : OECD/FAO, 2007

**Parkhomenko, 2004**
S. Parkhomenko
International competitiveness of soybean, rapeseed and palm oil production in major producing regions (Sonderheft 267)
Braunschweig : Federal Agricultural Research Centre, 2004

**Searchinger, 2008**
T.D. Searchinger, R. Heimlich
How much can demand-induced increases in yields replace crops or cropland diverted to ethanol (advanced discussion draft)
Princeton : Princeton University, 2008

**SenterNovem, 2008**
C. Hamelinck, …[ et al.]
Technical specifications: GHG calculator for biofuels
Utrecht : SenterNovem, 2008

**Themba Technology, 2006**
Jeremy Woods, Richard Tipper, Gareth Brown, Rocio Diaz-Chavez, Jessica Lovell and Peter de Groot
Evaluating the Sustainability of Co-firing in the UK, final
London : Themba Technology Ltd., 2006

**USB, 2006**
G. Martin, … (et al.)
Soybean meal evaluation to 2020
Chesterfield : United Soybean Board (USB), 2006

**USB, 2008**
M. Fitzpatrick, C. Ratajczyk
Soybean use and trends 2001 - 2006
Chesterfield : United Soybean Board, 2008

**USDA, 2005**
M.-C. Hénard, K. Seifarth
France Explores Substituting Soybean Meal with Rapeseed Meal
Washington DC : United States  Department of Agriculture (USDA), 2005

**USDA, 2007**
USDA, Economic Research Service
USDA Agricultural projections to 2016
Washington DC : United States  Department of Agriculture (USDA), 2007

**CE Delft**
**Solutions for environment, economy and technology**

Oude Delft 180
2611 HH Delft
The Netherlands
tel: +31 15 2 150 150
fax: +31 15 2 150 151
e-mail: ce@ce.nl
website: www.ce.nl
KvK 27251086

# Estimating indirect land use impacts from by-products utilization

Annexes

**Report**

**Delft, June 2008**
Author(s): Harry Croezen
Femke Brouwer

# A E4tech crop input figures

| Scenario | Crop | Unit | OECD NA | OECD/Eur | OECD Pacific | Transition ec. | China | | India | Middle East | Latin America | Africa | World |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *EtOH* | *bil.lit.* | *105,2* | *21,7* | *10,0* | *0,0* | *11,7* | *6,6* | *4,4* | *0,0* | *36,5* | *1,6* | *197,7* |
| | *Biodiesel* | *bil.lit.* | *8,5* | *27,4* | *3,1* | *0,0* | *2,4* | *9,0* | *5,2* | *0,0* | *4,7* | *0,5* | *61,0* |
| Scenario 1 | Wheat | Mton | 57,2 | 38,4 | 6,8 | 0,0 | 9,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 111,4 |
| | Soy | Mton | 32,8 | 22,0 | 2,2 | 0,0 | 4,3 | 0,0 | 7,0 | 0,0 | 21,5 | 0,4 | 90,1 |
| | Corn | Mton | 128,1 | 12,7 | 0,0 | 0,0 | 8,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 148,9 |
| | Palm | Mton | 12,1 | 7,8 | 1,2 | 0,0 | 4,6 | 51,3 | 0,0 | 0,0 | 4,0 | 1,4 | 82,4 |
| | Sunflower | Mton | 0,0 | 2,9 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 3,2 |
| | Rapeseed | Mton | 0,5 | 43,4 | 4,9 | 0,0 | 1,7 | 0,0 | 5,5 | 0,0 | 0,0 | 0,2 | 56,2 |
| | Cassave | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 8,6 | 9,6 | 6,4 | 0,0 | 13,3 | 2,4 | 40,3 |
| | Sorghum | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 24,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 24,5 |

| Scenario | Crop | Unit | OECD NA | OECD/Eur | OECD Pacific | Transition ec. | China | | India | Middle East | Latin America | Africa | World |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *EtOH* | *bil.lit.* | *43,1* | *15,2* | *8,5* | *0,0* | *8,2* | *5,9* | *3,1* | *0,0* | *25,6* | *1,5* | *111,0* |
| | *Biodiesel* | *bil.lit.* | *7,7* | *19,2* | *2,7* | *0,0* | *1,7* | *8,1* | *3,7* | *0,0* | *3,3* | *0,4* | *46,7* |
| Scenario 2 | Wheat | Mton | 23,5 | 26,9 | 5,8 | 0,0 | 6,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 62,4 |
| | Soy | Mton | 29,5 | 13,3 | 1,8 | 0,0 | 2,6 | 0,0 | 4,9 | 0,0 | 10,6 | 0,2 | 63,0 |
| | Corn | Mton | 52,5 | 8,9 | 0,0 | 0,0 | 5,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 67,1 |
| | Palm | Mton | 10,9 | 5,4 | 0,3 | 0,0 | 3,2 | 36,9 | 0,0 | 0,0 | 3,8 | 1,0 | 61,5 |
| | Sunflower | Mton | 0,0 | 0,8 | 0,3 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 1,1 |
| | Rapeseed | Mton | 0,5 | 26,3 | 3,6 | 0,0 | 0,8 | 0,0 | 1,9 | 0,0 | 0,0 | 0,1 | 33,3 |
| | Cassave | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 6,0 | 8,6 | 4,5 | 0,0 | 9,3 | 2,1 | 30,6 |
| | Sorghum | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 17,1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 17,1 |

| Scenario | Crop | Unit | OECD NA | OECD/Eur | OECD Pacific | Transition ec. | China | | India | Middle East | Latin America | Africa | World |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *EtOH* | *bil.lit.* | *110,8* | *23,4* | *14,8* | *18,9* | *19,5* | *14,3* | *6,7* | *9,0* | *14,9* | *9,2* | *241,4* |
| | *Biodiesel* | *bil.lit.* | *38,7* | *46,2* | *11,4* | *9,6* | *14,6* | *14,9* | *12,0* | *7,8* | *17,3* | *6,0* | *178,5* |
| Scenario 3 | Wheat | Mton | 60,2 | 9,5 | 3,6 | 10,3 | 6,5 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 90,1 |
| | Soy | Mton | 22,8 | 27,3 | 6,7 | 5,7 | 8,6 | 10,8 | 7,0 | 4,6 | 10,2 | 3,6 | 107,4 |
| | Corn | Mton | 44,7 | 7,0 | 2,7 | 7,6 | 4,8 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 66,8 |
| | Palm | Mton | 79,8 | 95,5 | 23,4 | 19,8 | 30,2 | 52,9 | 19,7 | 16,2 | 35,7 | 12,5 | 385,7 |
| | Sunflower | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| | Rapeseed | Mton | 22,0 | 26,3 | 6,4 | 5,4 | 8,3 | 0,0 | 2,3 | 4,4 | 9,8 | 3,4 | 88,4 |
| | Cassave | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 18,4 | 27,9 | 13,1 | 0,0 | 7,8 | 4,8 | 72,0 |
| | Sorghum | Mton | 159,4 | 25,1 | 23,2 | 27,2 | 50,3 | 0,0 | 0,0 | 0,0 | 0,0 | 16,8 | 302,1 |

| Scenario | Crop | Unit | OECD NA | OECD/Eur | OECD Pacific | Transition ec. | China | | India | Middle East | Latin America | Africa | World |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *EtOH* | *bil.lit.* | *27,1* | *14,5* | *12,9* | *18,5* | *14,9* | *13,4* | *5,0* | *8,8* | *1,8* | *9,0* | *126,1* |
| | *Biodiesel* | *bil.lit.* | *36,4* | *24,3* | *10,1* | *9,4* | *12,7* | *12,9* | *8,2* | *7,7* | *13,5* | *6,2* | *141,3* |
| Scenario 4 | Wheat | Mton | 14,7 | 5,9 | 3,2 | 10,1 | 5,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 38,8 |
| | Soy | Mton | 21,5 | 14,3 | 6,0 | 5,5 | 7,5 | 9,4 | 1,5 | 4,5 | 8,0 | 2,3 | 80,5 |
| | Corn | Mton | 11,0 | 4,4 | 2,3 | 7,5 | 3,7 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 28,8 |
| | Palm | Mton | 75,1 | 50,1 | 20,9 | 19,3 | 26,2 | 45,9 | 12,8 | 15,9 | 27,9 | 9,8 | 303,8 |
| | Sunflower | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| | Rapeseed | Mton | 20,7 | 13,8 | 5,7 | 5,3 | 7,2 | 0,0 | 1,5 | 4,4 | 7,7 | 2,2 | 68,4 |
| | Cassave | Mton | 0,0 | 0,0 | 0,0 | 0,0 | 14,0 | 26,3 | 9,8 | 0,0 | 0,9 | 4,7 | 55,8 |
| | Sorghum | Mton | 39,1 | 15,6 | 20,3 | 26,7 | 38,3 | 0,0 | 0,0 | 0,0 | 0,0 | 16,5 | 156,5 |