Energy Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Food or fuel? What European farmers can contribute to Europe's transport energy requirements and the Doha Round

Jennifer Baka [a], David Roland-Holst [b,*]

[a] Yale School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA
[b] Department of Agricultural and Resource Economics, University of California Berkeley, Berkeley, CA, USA

ARTICLE INFO

Article history:
Received 19 September 2007
Accepted 1 September 2008

Keywords:
Doha
Biofuels
Trade

ABSTRACT

Farm support in higher income countries is a testament to the fundamental social and economic importance of agriculture, yet domestic efforts to support this sector can arouse multilateral discord in a world of global food markets. In this paper, we argue that the advent of biofuels offers a new opportunity for agriculture to contribute to society, and to do so in a way that reduces trade rivalry and improves energy security. Holding current agricultural production constant, we find that the EU has the potential to reduce oil imports between 6% and 28% by converting eligible agricultural crops into biofuels under two differing conversion scenarios. Further, 33% of food support could be removed with no net farm revenue loss, using the biofuel premia (compared with food value) of corn and rapeseed to compensate for subsidy reductions. These results can help overcome the current impasse in global trade negotiations by reconciling the needs of EU farmers with those who would gain from more liberal international trade.

1. Introduction

Two of the most momentous policy issues of modern times are climate change and globalization. Europe has shown consistent and remarkably unified leadership in the first context, yet the same cannot be said of its role in the latest round of WTO negotiations. The EU's path-breaking initiatives for carbon trading and affirmation of commitments beyond the Kyoto Protocol have given essential impetus to global greenhouse gas mitigation, and the European private sector has responded with alacrity to emerging green technologies and investment opportunities. In contrast, the EU (along with some other OECD economies) has consistently resisted the agricultural reforms necessary to facilitate competition in global food markets.

Because of seemingly intractable deadlocks over farm support policies, this round has been robbed of important momentum and progress in other European sectors (manufacturing and services) has been retarded. Agricultural trade protection inflates the exchange rate with respect to most trading partners, undermining EU export competitiveness across the board. While Europe is not the only obstacle to concluding the round, we believe a new perspective can reconcile the needs of EU farmers and those who gain from expanded international trade.

This paper poses a challenge to European farmers and policy makers to advance the EU's trade agenda by expanding production of biofuels. The farm support agenda has always been premised on the importance of agriculture to European society, until now defined primarily in terms of food security. The advent of biofuel offers a dramatic new contribution from agriculture, greater domestic energy self-sufficiency. Biofuels represent the remarkable option of substitution between two leading commodities, food and energy, within a single sector. Both are essential to Europe, one is in excess supply and the other largely imported and increasingly scarce. Until now, Europe has leaned toward self-sufficiency in the first commodity, while becoming ever more import dependent on the second. A one-sided approach like this is rarely optimal, yet agricultural support strongly biased the European food-energy portfolio in this direction because food was the primary source of farm livelihoods. Now that farmers can use their resources to earn income as energy producers, the EU has a wider range of food-energy portfolio choices.

Using detailed data on current EU production of potential biofuel feedstocks, our results indicate that Europe's existing crop potential could displace over 27% of its transportation fuel imports if all eligible feedstocks were converted to ethanol and biodiesel. This is far in excess of current EU targets for renewable transport fuels, and the same strategy would necessitate significant food imports (without, it should be emphasized, a corresponding loss of EU farm livelihoods). Whether such trade substitution is beneficial of course depends upon other factors,

* Corresponding author.
E-mail address: dwrh@are.berkeley.edu (D. Roland-Holst).

0301-4215/$ - see front matter © 2009 Published by Elsevier Ltd.
doi:10.1016/j.enpol.2008.09.050

including relative world prices and more complex institutional issues. On the other hand, if biofuel production were confined only to surplus production of eligible feedstocks, over 6% of oil imports would be displaced. To balance food and energy security interests, the optimum mix of imported and domestic food and energy probably lies somewhere in between. An essential feature of the biofuel option, however, is that these decisions can be made in a way that offsets revenue losses for domestic agricultural interests.

We also estimate that 33% of aggregate farm balance sheets would be revenue-neutral given current biofuel prices and existing farm support levels. An essential difference in this case, however, is that producer support for biofuel is not recognized as a trade distorting measure, enabling the removal of a significant portion of EU agriculture Doha negotiations. Ultimately, in the face of rising energy prices, there may be significant scope for unwinding support levels in these crop categories ($25.6 billion in 2004, about one-third of producer income) and redirecting the fiscal savings to other priorities.

Section 2 of the paper provides an overview of existing EU biofuel production and transportation energy demand. This is followed in Section 3 by a country and crop-specific overview current EU production of eligible feedstocks. Section 4 presents empirical estimates of opportunities for biofuel to displace imported oil in the transport sector. Section 5 evaluates the implications of these policy scenarios for Europe's position in the Doha Round, while Section 6 reviews additional global impacts that should be considered as result of this policy. Concluding remarks are offered in Section 7.

2. Current EU biofuel production and transportation energy demand

Demand for biofuels, fuels produced from biomass materials that can substitute for petroleum fuels, has increased rapidly in recent years as result of sustained high oil prices. The most common biofuels are ethanol and biodiesel, which can substitute for gasoline and diesel fuel, respectively. Ethanol can be produced from any biological material that contains sugar or substances that can be converted into sugar while biodiesel can be manufactured from any oil-bearing feedstock. Given current production technologies, so-called first-generation technology, the most common feedstocks are agricultural feedstocks such as sugar and corn for ethanol and soybean and rapeseed for biodiesel.

World production of biofuels reached nearly 20 million tonnes of oil equivalent (mtoe) in 2005, with ethanol accounting for 85% of this production total (IEA, 2006). Brazil was the world's largest producer, closely followed by the US. The EU was the third largest overall producer but was the world's leader of biodiesel production (IEA, 2006). In total worldwide biofuel production was equivalent to 1% of road-transportation energy use on an energy-equivalent basis (IEA, 2006).[1]

Within the EU, Germany and France were the largest biodiesel producers accounting for nearly 68% of total production while Spain and Sweden were the leading ethanol producers representing over 67% of total ethanol production between them. The primary biodiesel feedstocks in the EU are rapeseed and sunflower seed while the main ethanol feedstocks are wheat, sugarbeet, and barley (IEA, 2004). Biofuel production by country is presented below in Table 1.

Total road-transportation energy use for the EU-27 countries in 2004 was nearly 297 mtoe (Eurostat). Fossil fuel consumption accounted for over 98% of this total (approximately 291 mtoe) with imports supplying over 80% of this demand, nearly 233 mtoe (EU DG Research, 2006; EU DG Energy & Transport, 2006). The Former Soviet Union, Norway, and Saudi Arabia were the largest import sources providing over 60% of total imports (EU DG Energy & Transport, 2006). Further, diesel fuel consumption represented over 68% of road-transportation energy use with gasoline consumption comprising the remainder (IEA, 2004).[2] Biofuel production accounted for roughly 1% of road-transportation energy use.

Table 1
EU biofuel production in 2005.

	Biodiesel		Ethanol	
	Mtoe	%	Mtoe	%
Austria	0.09	2.7	–	0.0
Belgium	0.00	0.0	–	0.0
Cyprus	0.00	0.0	–	0.0
Czech Republic	0.13	4.2	–	0.0
Denmark	0.07	2.2	–	0.0
Estonia	0.01	0.2	–	0.0
France	0.49	15.5	0.10	18.3
Germany	1.67	52.4	–	0.0
Greece	0.00	0.1	–	0.0
Italy	0.40	12.4	–	0.0
Latvia	0.01	0.2	0.00	0.2
Lithuania	0.01	0.2	0.01	1.2
Malta	0.00	0.1	–	0.0
Poland	0.10	3.1	0.07	12.5
Portugal	0.00	0.0	–	0.0
Slovakia	0.08	2.4	–	0.0
Slovenia	0.01	0.3	–	0.0
Spain	0.07	2.3	0.24	44.0
Sweden	0.00	0.0	0.13	23.9
United Kingdom	0.05	1.6	–	0.0
Total	3.18	100	0.55	100

Source: EurObserv'ER (2006).

3. European production of potential biofuel feedstocks

Although the EU biofuel sector is only just emerging, a substantial amount of European agriculture is already dedicated to crops that are eligible as biofuel feed stocks. Specifically, for our analysis we consider wheat, barley, corn, potatoes, and sugarbeet as potential ethanol feedstocks and rapeseed, sunflower seed and soybeans as eligible biodiesel feedstocks.[3] Fig. 1 shows the 2004 production portfolios of these crops for the EU-27 economies. The percentages listed in the figure are the shares of total production by member state. Crop allocation is quite diverse across countries, with traditional staples like wheat, barley, and potatoes dominant. As one might expect from their land area, Germany and France are by far the largest producers of biofuel eligible crops, with approximately 17% and 21% percent, respectively, of all European production.

The results in Fig. 2 embed eligible biofuel feedstock production in the larger setting of European agriculture, indicating land

[1] Both ethanol and biodiesel have lower energy contents than their fossil fuel counterparts. Ethanol has two-thirds the energy content of a unit of gasoline while biodiesel has 87% the energy content of a unit of biodiesel (IEA, 2004).

[2] Diesel and gasoline percentages were calculated using consumption data presented in Table 3.5 of the Energy Information Administration's (EIA) International Energy Annual 2005.

[3] We defined eligible feedstocks as crops currently produced in the EU that could be used to produce biofuels and for which imports of similar quality exist or could be manufactured. A notable exclusion from our analysis is grapes, which could be used as an ethanol feedstock but for which similar quality substitutes would be difficult to find.

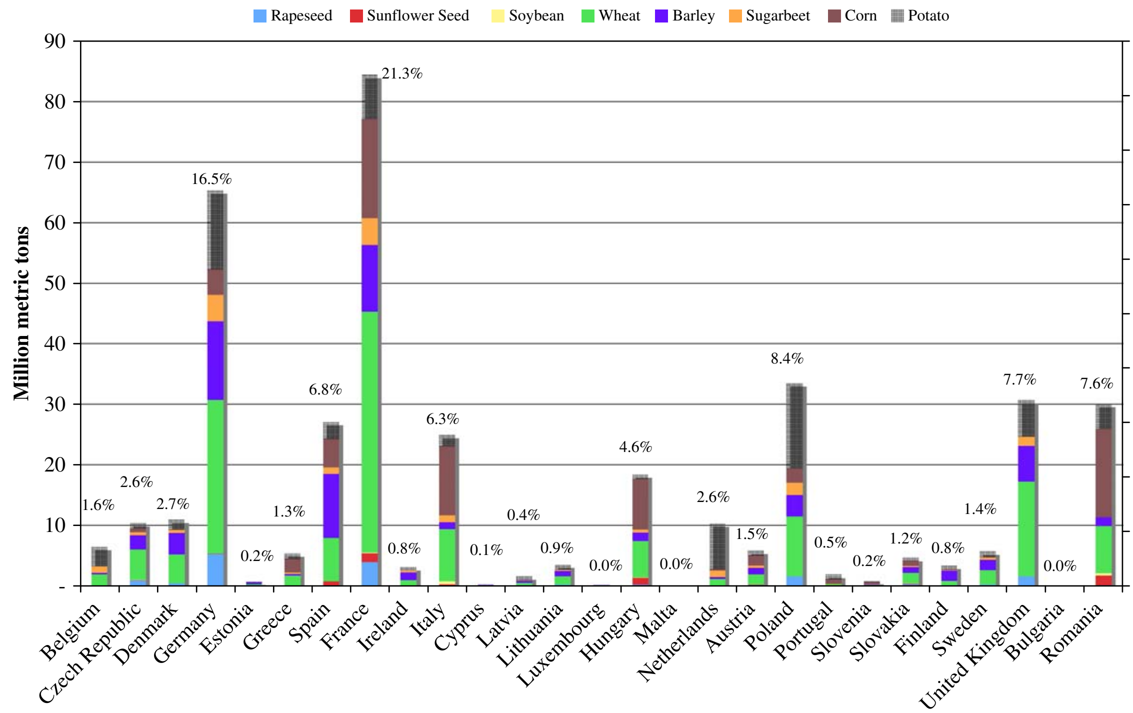

Fig. 1. 2004 Production of potential biofuel feedstocks (percentages are country percentages of total EU potential biofuel feedstock production). *Sources*: Eurostat agriculture database.

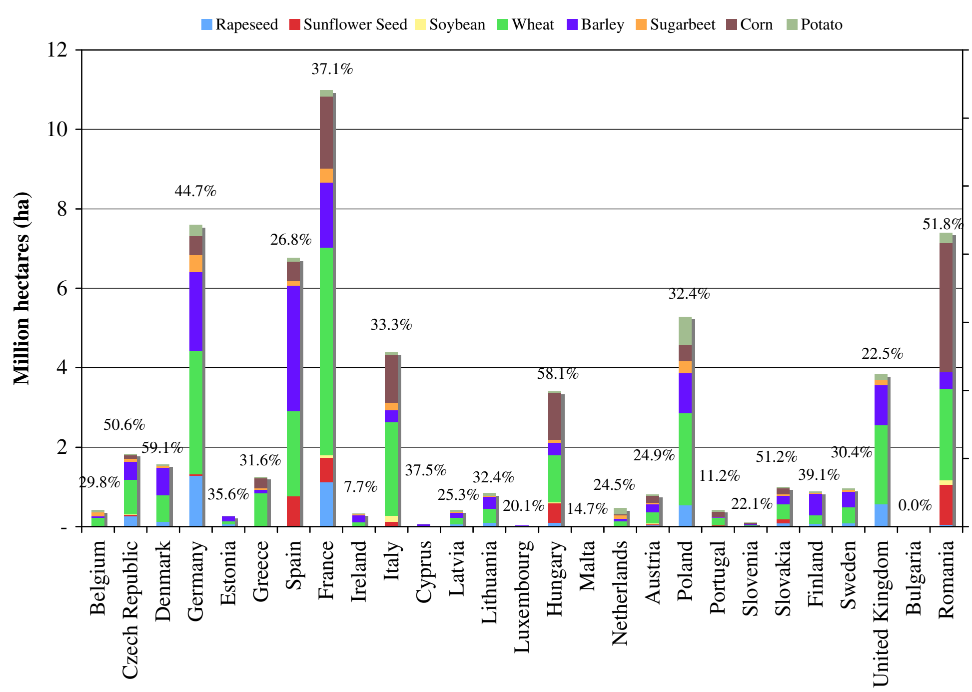

Fig. 2. 2004 Potential biofuel feedstock land utilization (percentages are biofuel feedstock landuse percentages of the country's total utilizable agricultural area (UAA)). *Sources*: Eurostat agriculture database.

area committed to each crop and the percent of total utilized agricultural area (UAA) currently committed to biofuel eligible crops.[4] Land use results resemble those of output in Fig. 1, but can differ because of varying yield per hectare in different countries. Also interesting is the percent of UAA in potential feedstock crops. This varies significantly across the EU-27, from highs of over 50% to well below 10%. As the value of biofuel rises with energy prices generally, there will likely be a re-examination of existing cropping patterns.

Food security must be a primary consideration for biofuel crop conversion, so it is reasonable to ask how self-sufficient EU

[4] UAA includes total arable land, permanent meadow and pasture, and land devoted to permanent crop production and kitchen gardens (European Environmental Agency website).

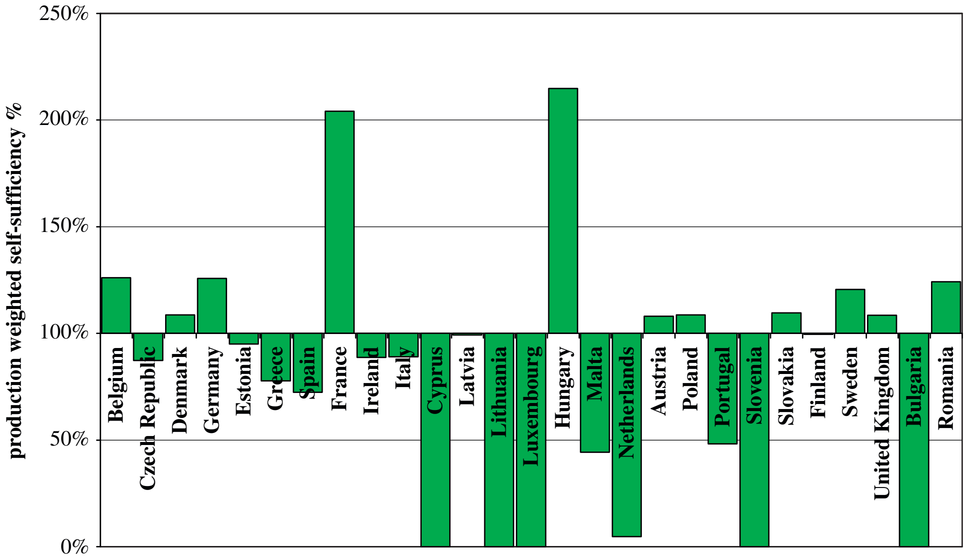

Fig. 3. 2004 Production-weighted average self-sufficiency levels for biofuel crops (production weights assigned based on country-level production percentages. 2003 Self-sufficiency levels were used in instances where 2004 levels were not available). *Sources*: Eurostat agriculture database.

economies are in these crops. Using country-level crop self-sufficiency data reported by Eurostat and the crop production data used to generate Fig. 1, Fig. 3 shows that about half the EU-27 are self-sufficient in aggregate biofuel crop production on a production weighted average basis (individual crop self-sufficiency levels by country are presented in Appendix A). Both France and Hungary, for example, are producing more than double their food requirements in biofuel eligible crops. Clearly, there is significant potential within Europe to explore alternative uses.[5]

4. Opportunities to increase biofuel production and mitigate energy import dependence

Given the substantial existing production eligible for biofuel conversion, it is reasonable to ask how much Europe could increase biofuel production and reduce its current dependence on fossil fuels. Conversion of existing agriculture to biofuel raises issues of food security, but these have a compelling analogy in energy security. Food may be a more elemental human need, but energy is essential to modern society. Biofuel offers EU farmers an opportunity to defend basic living standards in both ways.

In this section, we present two scenarios for increasing biofuel production in the EU holding existing agricultural production constant. Although the scenarios are relatively extreme, they identify a large potential for the EU to increase biofuel production beyond today's levels. This could both improve energy security and facilitate liberalised trade agreements, and could also reduce GHG emissions, depending on the life-cycle impacts of required feedstocks and displacement effects.

Our analysis holds existing agricultural production levels and land use constant in order to examine the EU's ability to increase biofuel production given current eligible feedstock production levels. Using the underlying data from Figs. 1 and 2 above, we analyzed the following scenarios:

Scenario 1: potential biofuel production from complete conversion of eligible feedstocks (Fig. 1);
Scenario 2: potential biofuel production from conversion of surplus production of eligible feedstocks (Fig. 2).

We determined potential biofuel production levels by applying appropriate crop-specific conversion factors obtained from various biofuel life-cycle analyses. These conversion factors are included in Appendix B. We also adjusted our results to account for the difference in energy balances between biofuel and fossil fuels as described earlier. Our results are shown in Table 2 below.

European agricultural potential to reduce transportation fossil fuel use is substantial. Under Scenario 1, we estimate the EU could produce over 64 mtoe of biofuels (column 5), well exceeding current production levels of 3.6 mtoe (Table 1). This figure would be sufficient to displace over 22% of total road-transportation fossil fuel use or nearly 28% of road-transportation fossil fuel imports (columns 6 and 7, respectively). This figure is far higher than the EU's current biofuel production target of 5.75% to be achieved by 2010,[6] indicating that it might be appropriate to reconsider the food-fuel tradeoff.

When biofuel conversion is limited only to the proportion of eligible crop output that exceeds national self-sufficiency (Scenario 2), nearly 15 mtoe of biofuels could be produced (column 5). At this production level, it is still possible to displace over 5% of total EU road-transport fossil fuel use or 6% of EU road-transport fuel imports (columns 6 and 7). This number also exceeds current biofuel development targets, and suggests strongly that the latter may be too conservative.

Biofuel production levels by country under these scenarios are illustrated in Figs. 4 and 5. Residual road-transport demand (fossil fuel consumption minus potential biofuel production) is also shown in these figures. Finally, these figures also present the road-

[5] Fig. 3 shows country-level self-sufficiency percentages. Presumably, some of the country-level surpluses would be used for intra-EU trading. According to our derivation of EU-27 aggregate consumption of these eligible biofuel feedstocks (production divided by self-sufficiency percentage), the EU would be approximately 118% self-sufficient in these feedstocks if surpluses were primarily used for intra-EU trading. This finding helps legitimize Scenario 2 as overall, there is surplus production of these feedstocks in the EU.

[6] The Biofuels Directive, passed in 2003, established a biofuel market share targets of 2% and 5.75% for 2005 and 2010, respectively (Directive 2003/30/EC, 2003). The 2005 target was not met (European Commission, 2006).

Table 2
Summary of potential biofuel production and oil displacement.

Scenario	Current road-transportation energy use		Energy-equivalent biofuel production[a]			Fossil fuel displacement potential[b]	
	Fossil fuels	Fossil fuel imports	Biodiesel	Ethanol	Total	Total fossil fuel use	Fossil fuel imports
	[1] (mtoe)	[2] (mtoe)	[3] (mtoe)	[4] (mtoe)	[5] (mtoe)	[6] (%)	[7] (%)
1	290.87	233.17	6.16	58.39	64.54	−22.19	−27.68
2	290.87	233.17	1.23	13.57	14.80	−5.09	−6.35

Sources: Transportation energy use and import data from EU DG Energy & Transport (2006).
Feedstock production values from EU DG Agriculture and Rural Development (2005). Agriculture in the European Union—Statistical and Economic Information—2005.
Biofuel conversion factors from Argonne National Laboratory (2006). (Corn).
Edwards et al. (2006). (Sugarbeet).
Elsayed et al. (2003). (Sugarbeet and rapeseed).
Punter et al. (2002). (Wheat).
Sheehan et al. (1998). (Soybean).
IEA (2000). (Barley).
Pimentel and Patzek (2005). (Sunflower seed).
Smeets et al. (2006). (Potato).

[a] Adjusts for lower biofuel energy contents compared to fossil fuels.

[b] Displacement potentials shown in columns 6 and 7 are the reductions in total fossil fuel use and fossil fuel imports (columns 1 and 2) that would result from biofuel production shown in column 5.

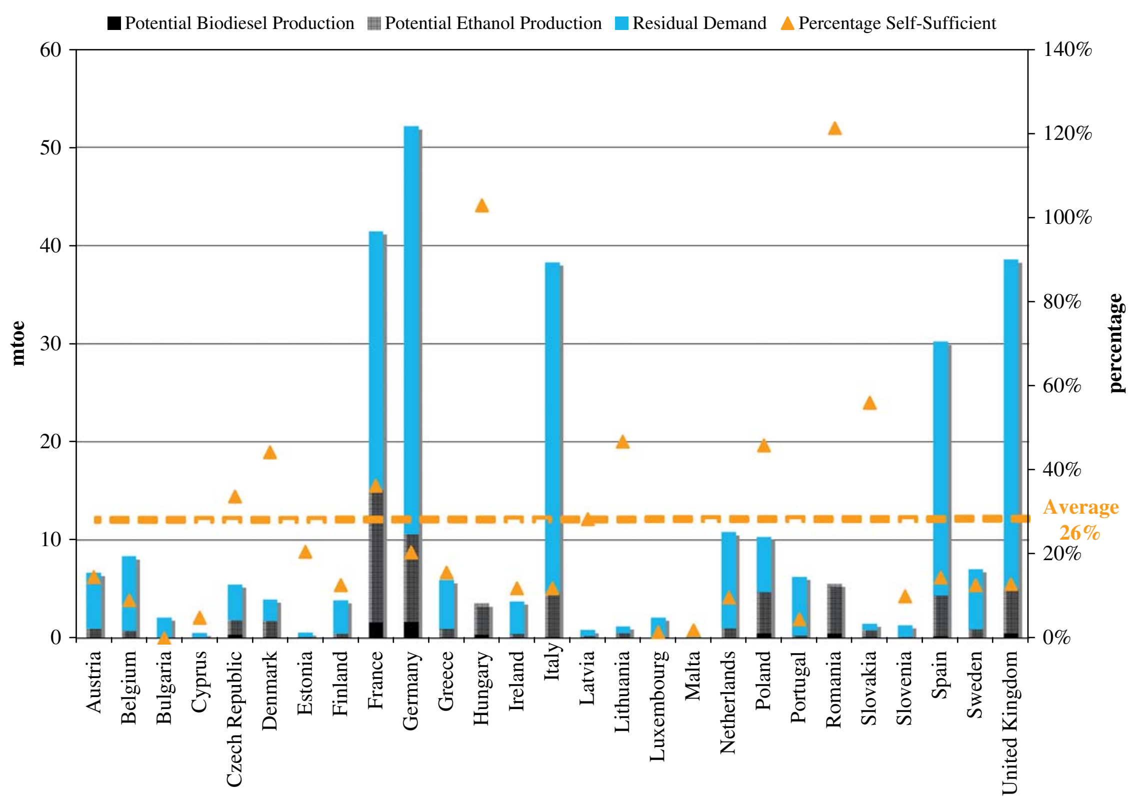

Fig. 4. Scenario 1—Road-transport fossil fuel displacement potential by country and resultant self-sufficiency levels. *Notes*: Scenario 1 converts all current biofuel feedstock production to biofuels. *Methodology*: Biofuel production amounts calculated from conversion factors listed in Appendix B. Residual demand is the difference between total road-transportation fossil fuel use and total biofuel production. Self-sufficiency percentage is the ratio of biofuel production potential to total road-transportation fossil fuel use. *Sources*: Eurostat agriculture and energy databases (road-transportation fossil fuel demand and current agricultural production), biofuel conversion factors listed in Appendix B.

transportation self-sufficiency levels that would result if biofuel production were domestically consumed. On average, the EU-27 countries would achieve self-sufficiency levels of approximately 26% and 5%, respectively, under Scenarios 1 and 2. Some countries have much higher levels of displacement potential, including Hungary, Romania, and Poland, who could in theory become self-sufficient (or very nearly so) in transport fuels under Scenario 1.

By its nature, biofuel conversion under both scenarios is dominated by ethanol production (Table 2), yet by global standards the EU has a relatively large share of diesel in transport fuel demand. This mismatch of fuel composition is relatively

Please cite this article as: Baka, J., Roland-Holst, D., Food or fuel? What European farmers can contribute to Europe's transport energy requirements and the Doha Round. Energy Policy (2009), doi:10.1016/j.enpol.2008.09.050

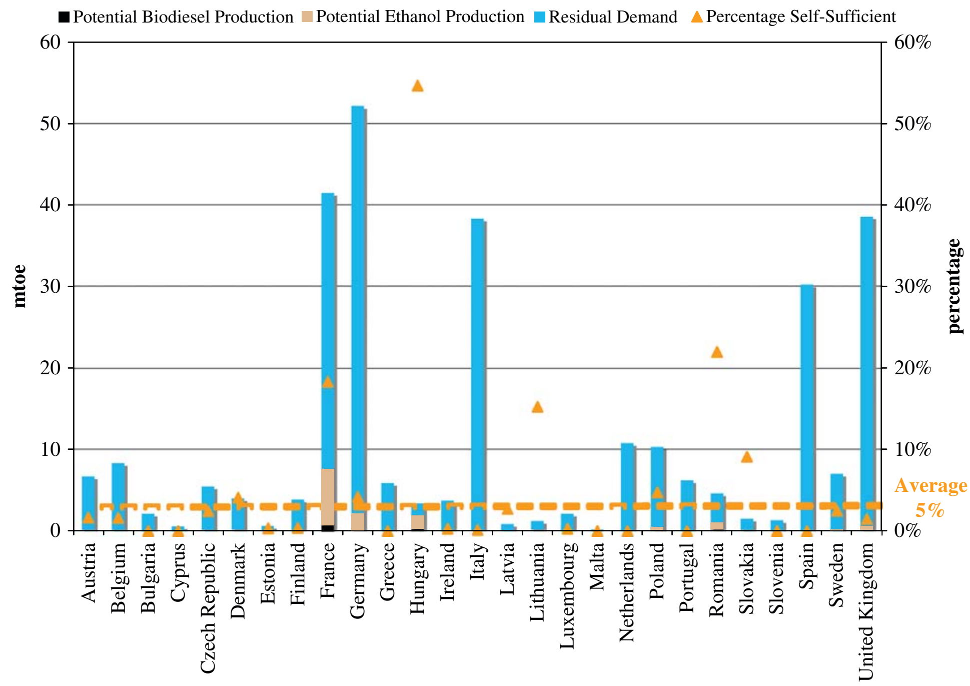

Fig. 5. Scenario 2—Petroleum displacement potential for conversion of surplus biofuel crops. *Notes*: Scenario 1 converts all current biofuel feedstock production to biofuels. *Methodology*: Biofuel production amounts calculated from conversion factors listed in Appendix B. Residual demand is the difference between total road-transportation fossil fuel use and total biofuel production. Self-sufficiency percentage is the ratio of biofuel production potential to total road-transportation fossil fuel use. *Sources*: Eurostat agriculture and energy databases (road-transportation fossil fuel demand and current agricultural production), biofuel conversion factors listed in Appendix B.

unimportant in the present case, since road-transportation energy self-sufficiency levels remain near 25%, on average, under the most aggressive scenario (see Fig. 4). In any case, energy markets can reconcile these differences, so Europe can get the fuel it wants while its farmers reap the rewards of producing valuable energy crops.

5. European biofuel and the Doha Round

The analysis in the previous sections demonstrates the EU's large capacity to increase biofuel production above today's levels holding existing agricultural production constant. In addition to offering energy and environmental benefits, such a strategy also presents the EU an opportunity to advance the current Doha Round of WTO mediated trade negotiations in which agriculture support policies have been a stumbling block. Within this category, farm support in higher income countries is seen as trade distorting, putting taxpayer subsidized downward pressure on global food prices and, by extension, the livelihoods of farmers in lower income countries. While the degree of such price–income transmission is an independent empirical question, there is no doubt that existing patterns of farm support, particularly in Europe, are a highly contentious negotiating point. In this section, we examine the possibility of supporting farmers in a different way, one that recognizes their contribution to energy self-sufficiency rather than food self-sufficiency.

Specifically, we examine the possibility for the EU to support biofuel production rather than food production by comparing the market food and fuel prices of eligible biofuel feedstock crops. Total farm support for the eligible feedstocks amounted to over $25 billion in 2004, with wheat receiving the largest individual share, nearly $17 billion. The total market value of these crops was approximately $82 billion in 2004, with wheat comprising nearly half this value ($40 billion).

Table 3 summarizes the authors' estimates of the food and fuel values of these crops, including estimates of support and tax levels.

The market food price for the crops, the value at producer price, is shown in column 1. Total subsidies and taxes are presented in columns 2 and 3 and net support, subsidies minus taxes, is listed in column 4. The distribution of net support across crops is shown in column 5 while the biofuel market value for the crops is presented in column 6. Note, this reflects the market value of potential biofuel production under Scenario 1. The food crop premium, food value minus biofuel value, is calculated in column 7.

As farmers and policy makers may be more interested in a per hectare revenue comparison, the per hectare revenue for food and biofuel are calculated in columns 8–11. Column 8 shows the total area planted for each crop, column 9 displays the food revenue per hectare (or column 1 divided by column 8) and column 10 presents the biofuel revenue per hectare (column 6 divided by column 8). The food premium per hectare (column 10 minus column 9) is calculated in column 11.

The two most arresting aspects of these results are somewhat contradictory. There is a significant aggregate value disadvantage for biofuel eligible crops, but also apparent are highly diverse returns to crops between the two markets. The former helps explain the slow uptake of biofuel conversion, but the latter identifies important opportunities for Europe to pursue energy price risk management while reducing the scope of Doha actionable food support. Both corn and rapeseed crops have a negative food premium on both an aggregate and per hectare basis, indicating that biofuel values exceed support inclusive food value. In these cases energy markets not only offer alternative demand for farm products, but may also bear part of the cost of producer support.

Alternatively, these savings could be used to step up support for crops with low food premia, making them revenue-neutral to

Table 3
Food, fuel, support, and taxation levels for biofuel eligible European crops (millions of 2004 USD and percentage).

Crop	Value at producer price[a] [1] 2004 $millions	Subsidies on products [2] 2004 $millions	Taxes on products [3] 2004 $millions	Net support [4] = [2]–[3] 2004 $millions	Percent of total net support [5] %	Biofuel value[b] [6] 2004 $millions	Food premium [7] = [1]–[6] 2004 $millions	Area Planted [8] 1000 ha	Food revenue/ha [9] = [1]/[8] 2004 $/ha	Biofuel revenue/ha [10] = [6]/[8] 2004 $/ha	Food premium/ha [11] = [9]–[10] 2004 $/ha
Wheat	39,938	16,901	116	18,244	66	22,908	17,030	25,578	1561	896	666
Barley	8265	3807	4	4133	15	7571	694	13,357	619	567	52
Sugarbeet	7241	10	209	(216)		855	6386	2159	3354	396	2958
Corn	10,982	2575	46	2749	10	11,742	(760)	9676	1135	1213	(78)
Potato	10,072	103	2	110	0	5003	5069	2440	4129	2051	2078
Rapeseed	3701	1414	0	1537	6	4766	(1065)	4542	815	1049	(234)
Sunflower Seed	1685	566	1	614	2	1312	373	3212	524	408	116
Soybean	278	140	10	142	1	158	120	397	700	398	302
Total	82,162	25,517	389	27,529	100	54,314	27,848	61,361	1339	885	454

Sources: Eurostat (producer price value and support levels), DOE EERE (2007), Global Financial Data (exchange rate data).
[a] Value at producer price is equivalent to the market price for the crop and is our estimate of the food value of the crop. We assume an exchange rate of $1.24/€, the 2004 average exchange rate.
[b] Biofuel value calculated using biofuel production quantities from Scenario 1 in our analysis. We use prices of $111.73 and $137.40 for ethanol and biodiesel, the current US biofuel market prices deflated to 2004$. We assume EU prices are roughly equivalent.

farmers in fuel production. If barely, sunflower, and soybeans were brought in this way, fully 33% of net support would be removed from food-marketed commodities (sum of net support percentages for corn, rapeseed, barley, sunflower, and soybeans in column 5).

The magnitude of this kind of product diversion is of course very ambitious, and in all societies there are non-market reasons for domestic food production. The potential to influence Doha also depends how negotiators treat biofuels in comparison to food. Furthermore, many assumptions have gone into the present estimates, since support levels themselves are imprecise and we have for convenience assumed food and fuel-processing costs are comparable.[7]

Additionally, we do not estimate the impact on consumer welfare in this analysis because it is outside the scope of this paper. This would require larger modeling efforts to compare the household-level costs of food to fuel under a more liberalized international agricultural trading scheme with increased domestic fuel production.

Despite the need for more rigorous empirical work on this issue, we believe these preliminary results show the important role the food–fuel conversion issue and play an important role in European agricultural, energy, and trade policy.

6. Potential global impacts

There are additional global impacts to be considered when evaluating the policy analyzed in this paper. This section discusses a few of the salient issues. Recently, for example, concern has arisen about the impact of increased biofuel production on food security. Echoing this, the most recent OECD/FAO Agricultural Outlook warned of sustained high food prices throughout the next decade as growing shares of food supplies are diverted to or displaced by biofuel production (OECD/FAO, 2007). These effects would be particularly harmful for developing countries, many of which are net food importers.

We believe a policy of supporting energy security in developed economies offers a way to alleviate such tensions as it presents a parallel opportunity to liberalize agricultural markets and expand domestic agriculture worldwide. Growth would likely be most significant in developing economies because of their lower land and labor costs, as well as advantageous climatic conditions. In fact, it has been estimated that reducing domestic agricultural support would improve global welfare by over $2.8 billion (2001$) (Hertel, Keeney, 2006), mainly by stimulating incomes of farmers in poor countries. As this figure does not account for induced increases in demand for agricultural products, our welfare measurement can be viewed as a conservative estimate of the potential gains.

However, expanding agricultural production to produce either food or fuel may pose environmental and ecological threats, primarily by expanding cultivated land areas, which could cause the release of carbon stored in soils or increasing utilitization of existing agricultural areas, which could step up the use of chemical fertilizers. At the moment, the precise environmental impacts of producing biofuels are somewhat controversial (Doornbosch and Steenblik, 2007), with some researchers conjecturing that biofuels could actually increase emissions of certain green-

[7] Feedstock production of first-generation biofuels currently accounts for approximately 50% of biofuel production costs with plant operating costs accounting for the remainder (IEA, 2004). Because biofuel markets are still in their infancy, operating costs can be expected to fall as markets mature. Further, co-product credits from selling biofuel by-products will also help modulate biofuel production costs. This will help to better equate food and fuel-processing costs.

Please cite this article as: Baka, J., Roland-Holst, D., Food or fuel? What European farmers can contribute to Europe's transport energy requirements and the Doha Round. Energy Policy (2009), doi:10.1016/j.enpol.2008.09.050

house gases or potentially create large carbon debts as new lands are brought under cultivation (Crutzen et al., 2007; Searchinger et al., 2008; Fargione et al., 2008).

We recognize this is an important area for further research and believe measures can be taken to incorporate concepts of sustainability into the production of food or biofuels. As a first step, optimising food and biofuel cropping patterns could alleviate pressure to expand agricultural land, and minimise the environmental impact of production. Further data analyses could indicate the type of cropping patterns likely to result from increased biofuel production. Additionally, the EU can allow biofuel feedstock cultivation on additional set aside lands as these lands have already been utilized for agricultural production and could thus have a lower environmental impact than bringing new lands under cultivation. Certification measures are another option, but measures should be taken to ensure such programs are uniform and encourage multilateral participation. Another option would be to develop sustainable production guidelines. The Roundtable on Sustainable Biofuels represents one possible venue to develop such concepts (Roundtable on Sustainable Biofuels website).

Finally, there is momentum to develop so-called second-generation biofuels utilizing lignocellulosic materials such as agricultural residues and forest trimmings as feedstocks. While second-generation biofuels may be more environmentally benign than first-generation biofuels (Farrell et al., 2006), at the present time, production costs for lignocellulosic biofuels are nearly double those of conventional biofuels (IEA, 2006). However, continued use of first-generation biofuels helps to support a biofuels market, which will aid in developing more sustainable and cost-effective second-generation biofuels.

7. Conclusions

In this paper, we examine how biofuels might enable agriculture to contribute to European society, while mitigating two important multilateral risks, trade rivalry and climate change. Biofuels give farmers a new source of income while they help reduce external energy dependence. European farm support is also an impediment to global trade negotiations, and we believe a new food–fuel perspective can help overcome this by reconciling the needs of EU farmers and other stakeholders in Europe and elsewhere who gain from more liberal international trade.

Using data from the 27-EU economies, we find that Europe has biofuel capacity that could contribute substantially reduce dependence on imported transport fuels, nationally and regionally, while expanding use of renewable fuels that can mitigate global warming potential. Europe's existing biofuel crops embody the equivalent of over 27% of current transport fuel imports, while crops in excess of food self-sufficiency could still displace over 6% of EU-27 imports. As a renewable substitute for imported fossil fuels, these benefits would compound over time against rising world oil prices.

Critics of agricultural support generally, and agricultural trade protection in particular, often argue that domestic farming is being overly rewarded for its economic and environmental contributions. We argue that farming's promise is even greater now, and that its economic value is destined to rise substantially with the cost of oil, risks of global warming, and the rising energy yields from biofuel. Perhaps just as importantly, we believe that rising private valuations of renewable energy products can shift the burden of securing farm livelihoods from governments to markets, freeing public resources for other uses and removing significant distortions from global food markets.

Extensions of the present work would include a more detailed examination of the potential for energy trading to distribute biofuel benefits, both within Europe and with respect to the rest of the world. The EU's biofuel capacity is currently dominated by ethanol, yet it consumes a relatively high proportion of diesel by global standards. Trading systems can reconcile this as well as other national disparities in biofuel capacity. It is also reasonable

Table A1
2004 Self-sufficiency levels in biofuel crops.

Country	Wheat	Barley	Corn	Potato	Sugarbeet	Rapeseed	Sunflower seed	Soybean
Austria	150	98	86	91	100	52	81	103
Belgium	55	61	25	172	135	3	0	0
Bulgaria	91	81	90	85	100	183	180	100
Cyprus	0	0	0	0	0	0	0	0
Czech Republic	79	161	103	87	0	0	0	0
Denmark	107	110	0	98	100	162	0	0
Estonia	88	105	0	86	0	96	0	0
Finland	101	105	0	88	100	55	0	0
France	215	266	223	108	100	172	136	22
Germany	152	128	80	110	100	93	36	0
Greece	81	41	79	71	100	0	12	0
Hungary	250	156	210	91	103	505	218	99
Ireland	76	106	45	66	100	100	0	0
Italy	100	50	102	63	0	13	47	26
Latvia	129	94	0	94	101	0	0	0
Lithuania	156	119	6	98	100	2000	0	0
Luxembourg	105	92	27	56	0	16,526	0	0
Malta	0	0	0	44	0	0	0	0
Netherlands	31	27	12	0	0	0	0	0
Poland	120	103	103	102	100	131	14	0
Portugal	39	7	38	72	0	0	0	0
Romania	143	167	114	99	95	710	125	116
Slovakia	68	127	145	87	100	140	269	49
Slovenia	0	0	0	0	0	0	0	0
Spain	76	87	54	68	0	13	62	0
Sweden	125	149	0	81	100	69	0	0
United Kingdom	113	126	0	82	100	112	0	0

Sources: (1) EU DG Agriculture & Rural Development (2005). Agriculture in the European Union—Statistical and Economic Information 2005. (2) Eurostat.

Please cite this article as: Baka, J., Roland-Holst, D., Food or fuel? What European farmers can contribute to Europe's transport energy requirements and the Doha Round. Energy Policy (2009), doi:10.1016/j.enpol.2008.09.050

Table B1
Scenarios for biofuel production and oil import substitution.

Crop	Fuel	Conversion factor [ton fuel/ton dry stock]	Sources
Corn	Ethanol	0.31	A
Sugarbeet	Ethanol	0.08	B
Barley	Ethanol	0.22	C
Wheat	Ethanol	0.29	D
Potato	Ethanol	0.13	E
Rapeseed	Biodiesel	0.35	F
Soybean	Biodiesel	0.16	G
Sunflower seed	Biodiesel	0.26	H

Sources: A—Argonne National Laboratory (2006) Greenhouse gases, regulated emissions, and energy use in transportation (GREET) model. Version 1.7(beta), http://www.transportation.anl.gov/software/GREET/. B—Edwards et al. (2006). C—IEA (2000). D—Punter et al. (2002). E—Smeets et al. (2006). F—Elsayed et al. (2003). G—Sheehan et al. (1998). H—Pimentel and Patzek (2005).

to expect trading to animate a far-reaching re-examination of existing cropping patterns, another important subject only alluded to in this paper. As biofuel potential is examined more actively, and particularly as carbon fuel prices continue their historical ascent, it is reasonable to expect adjustments in agricultural land use, both for conventional crops and more innovative alternatives (switchgrass, miscanthus, etc.).

Appendix A. 2004 Self-sufficiency levels in biofuel crops

See Table A1.

Appendix B. Biofuel conversion factors

See Table B1.

References

Argonne National Laboratory, 2006. Greenhouse gases, regulated emissions, and energy use in transportation (GREET) model. Version 1.7 (beta) 〈http://www.transportation.anl.gov/software/GREET〉.

Crutzen, P.J., Mosier, A.R., Smith, K.A., Winiwarter, W., 2007. N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. Atmospheric Chemistry and Physics Discussions 7, 11191–11205.

Doornbosch, R., Steenblik, R., 2007. Biofuels: Is The Cure Worse Than The Disease? SG/SD/RT(2007)3. OECD Publications, Paris.

EC, 2006. An EU Strategy for Biofuels. {SEC(2006) 142}, COM(2006) 34 final.

Edwards, R., Larivé, J.-F., Mahieu, V., Rouveirolles, P., 2006. Well-to-wheels analysis of future automotive fuels and powertrains in the European context. Well-to-Tank Report. CONCAWE, EUCAR and JRC.

Elsayed, M.A., Mathews, R., Mortimer, N.D., 2003. Carbon and energy balances for a range of biofuel options. DTI Sustainable Energy Programme.

EU DG Agriculture and Rural Development, 2005. Agriculture in the European Union—Statistical and economic information 2005. Agriculture and Rural Development DG, Brussels.

EU DG Energy & Transport, 2006. The annual energy and transport review for 2004 〈http://ec.europa.eu/dgs/energy_transport/figures/pocketbook/2006_en.htm〉.

EU DG Research, 2006. Biofuels in the European Union: a vision for 2030 and beyond 〈ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf〉.

EurObserv'ER, 2006. Biofuels Barometer, May 2006.

European Union (EU), 2003. Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the Promotion of the use of biofuels or other renewable fuels for transport (OJ L 123, 17.5.2003).

Fargione, J., Hill, J., Tilman, D., Polasky, S., Hawthorne, P., 2008. Land Clearing and the Biofuel Carbon Debt. Science, doi:10.1126/science.1152747.

Farrell, A.E., Plevin, R.J., Turner, B.T., Jones, A.D., O'Hare, M., Kammen, D.M., 2006. Ethanol can contribute to energy and environmental goals. Science 311.

Hertel, T.W., Keeney, R., 2006. What is at stake: the relative importance of import barriers, export subsidies, and domestic support. In: Anderson, K., Martin, W. (Eds.), Agricultural Trade Reform & The Doha Development Agenda. Palgrave Macmillan, New York, pp. 37–62.

IEA, 2000. Assistance of the "IEA bioenergy task 27" on biofuels implementation issues: bioethanol in France and Spain. Task 27 Appendix 2.

IEA, 2004. Biofuels for Transport: An International Perspective. OECD Publications, Paris.

International Energy Agency (IEA), 2006. 2006 World Energy Outlook. OECD Publications, Paris.

OECD/FAO, 2007. OECD–FAO Agricultural Outlook 2007–2016. OECD Publications, Paris, Rome.

Pimentel, D., Patzek, T., 2005. Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. Natural Resources Research 14 (1), 65–76.

Punter, G., Rickeard, D., Larivé, J.-F., Edwards, R., Mortimer, N., Horne, R., Bauen, A., Woods, J., 2002. Well-to-Wheel Evaluation for Production of Ethanol from Wheat. Low Carbon Vehicle Partnership Fuels Working Group.

Roundtable on Sustainable Biofuels 〈http://cgse.epfl.ch/page65660-en.html〉.

Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Yu, T., 2008. Use of US croplands for biofuels increases greenhouse gases through emissions from land use change. Science.

Sheehan, J., Camobreco, V., Duffield, J., Graboski, M., Shapouri, H., 1998. Life Cycle Inventory of Biodiesel and Petroleum Diesel. National Renewable Energy Laboratory (NREL).

Smeets, E.M.W., Junginger, M., Faaij, A.P.C., 2006. Supportive study for the OECD on alternative developments in biofuel production across the world, report commissioned by: OECD, Unit Science, Technology and Society, Copernicus Institute, Utrecht University, Utrecht, the Netherlands, NWS-E-2004-109, December 2005.

US Department of Energy, Energy Efficiency and Renewable Energy (DOE EERE), 2007. Clean cities alternative fuels price report, March, 2007.

Please cite this article as: Baka, J., Roland-Holst, D., Food or fuel? What European farmers can contribute to Europe's transport energy requirements and the Doha Round. Energy Policy (2009), doi:10.1016/j.enpol.2008.09.050