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Non Food Uses of Crops

Biofuels: Their impact on crop production world wide

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Summary

Bioethanol and biodiesel produced from conventional processes and crops will have the most impact on agriculture globally over the period up to 2013. Brazil is projected to remain a leading producer. An estimated additional 2–3 Mha of sugar cane will need to be planted by 2013. In the USA the rush to grow corn (maize) as a bioethanol feedstock was a major factor in promoting the "food *vs* fuel" debate internationally. By 2013 as much as 40% of the crop could be for biofuel use. Biodiesel is, and is likely to remain, the major biofuel produced in the EU. Around 50% of vehicles are diesel powered and the high biofuel consumption targets set for the EU will require biodiesel requirements to be met from a combination of domestic production, mainly from oil seed rape and imports from markets such as Argentina and Brazil, based on soya bean oil. Currently, the agronomic management of crops grown for biofuels differs little from where they are grown for food. This could change if greenhouse gas savings are to be factored into production methods.

Key words: Bioethanol, biodiesel, first generation biofuels, fully flexible vehicles, dry distillers grains (DDG), feedstock

Introduction

The objective of the review was to project, up to 2013, what crops will be grown, on what areas and in which country, for the production of liquid biofuels for transport. The study was specific to first generation biofuels, bioethanol or biodiesel, produced from conventional crops. The impact of second generation biofuels, produced by advanced processes or from new crops, was covered briefly but it is not expected that they will have a significant impact on crop production within the time frame of this study. This paper concentrates on the situation in Brazil, USA and the EU, the main biofuel producers, and predictions of land use by 2013 are based on biofuel production capacity already in place, under construction or planned. Although most Governments have set out indicated or mandatory targets for biofuel consumption, relying on national consumption targets is not on its own, a reliable basis for predicting biofuel crop production in a particular country. There is already significant movement of liquid biofuels between continents, for example from Latin America to the EU. Furthermore, as a consequence of pressures from NGOs and, through the media, the public, Government policies towards biofuels are in some cases quite fragile.

The projections are limited to bioethanol produced from grain, sugar crops or starchy tuber crops and biodiesel from oilseed crops. The main crops considered are sugar cane, corn and wheat for bioethanol production and oilseed rape, soya beans, sunflower and palm for biodiesel production. Some opportunities for developments in new varieties, crop protection methods and nutrition have been identified. While references are made to the energy balance of biofuels compared to fossil fuels, and to their environmental impact, these are not topics covered in depth.

Materials and Methods

Information was based on the findings for a literature survey executed in 2008 and updated in 2009. Sources included Government policy statements on biofuels, including indicated or mandatory targets for inclusion rates in transport fuels, company statements on existing or planned biofuel production capacities and international survey data on biofuel production volumes (e.g. US Renewable Fuels Association statistics, 2009, European Biodiesel Board statistics, 2009). National crop areas and yields, used as the basis for forward projections, were taken from Food and Agriculture Organisation statistics (FAOStat, 2007 and 2008 crop production data). Except where quoted, no account has been taken of yield increases over the forecast period. Bioethanol production from agricultural waste material such as grape residues, was not included in the study. In calculating the quantity of feedstock required per 1000 litres (L) of biofuel the typical outputs recorded in the relevant countries were used. As published data is sometimes in tonnes (t) the following specific gravities used were: Bioethanol: 0.79 kg L^{-1}, Biodiesel: 0.88 kg L^{-1}.

Results

Production of conventional biofuels

Bioethanol can be derived from: (i) Crops primarily grown for sugar, of which the main crops of importance are sugar beet and sugar cane. Sweet sorghum is another sugar crop with potential as a feedstock for ethanol production. The sugar is converted enzymatically to ethanol. For use as a biofuel, bioethanol is blended with conventional petrol at levels of up to 80%; (ii) Crops primarily grown as a source of carbohydrate or protein, for food or feed. Use of these crops and conversion of the carbohydrate to starch or to ethanol is a well established industrial process: corn (maize), wheat, rice. Other crops used as sources of ethanol include cassava and sweet potato.

The traditional route for bioethanol production from corn, and increasingly in North America for wheat, is the Dry Milling Process. Marketable by-products from dry milling include dry distillers grains (DDG, used as animal feed), flakes, grits, and captured CO_2. Wet milling is used where other co-products, such as fibre, gluten and starch are to be produced and marketed. Wet corn mills are more expensive to build, but generally require less energy to operate. Bioethanol production from sugar crops is simpler. Production plants in Brazil generally operate alongside the sugar mills and waste bagasse can be used as a source of more ethanol and to generate the heat necessary for the distillation.

The main vegetable oil crops used as feedstock for biodiesel production are oilseed rape, soya bean, sunflower, oil palm. Other potential crops are Olives, Castor bean (*Ricinus communis*), and an arid zone tree crop, still being developed, *Jatropha curcas*.

Chemically, biodiesel is the product of esterification of fatty acid triglycerides, the basis of vegetable oils. The process is a simple one step chemical reaction, trans-esterification, using dry caustic soda (sodium hydroxide), as a catalyst and methanol as the methylating agent. Biodiesel production, from oilseed crops, is invariably sited alongside oilseed crushing facilities.

Second generation biofuels

A major R&D effort is underway, particularly in the USA towards the commercial introduction of cellulosic ethanol. Production would be from straw, corn stover or wood. The Canadian company, Iogen Corporation, have developed a system. That makes it economically feasible to convert biomass into cellulose ethanol using a combination of thermal, chemical and biochemical techniques. Intensive research efforts are also underway examining the feasibility of the use of enzymes instead of acids for the hydrolysis process to convert lignocellulose to sugars. The US Department of Energy has indicated that this route will offer good prospects for cost-effective ethanol production (Sheridan, 2008).

For biodiesel production there are two main research routes which are being followed, introduction of new crops with high vegetable oil yield content. The main effort is directed at *Jatropha*, and production of biodiesel from algae. The interest in algae is due to the high potential yield of oil with up to 50% of the weight of the organism as oil with some species. In terms of yield per hectare, per year, it potentially exceeds that from arable crops. Pilot scale production facilities are underway, however the capital cost for full scale production is a barrier (Sheehan *et al.*, 1998). Algae is not expected to be a major source of feedstock before 2013.

Biofuel production world wide

Bioethanol

Total bioethanol produced for use in fuels in 2008 was 65 billion L. 85% was produced from the USA and Brazil.

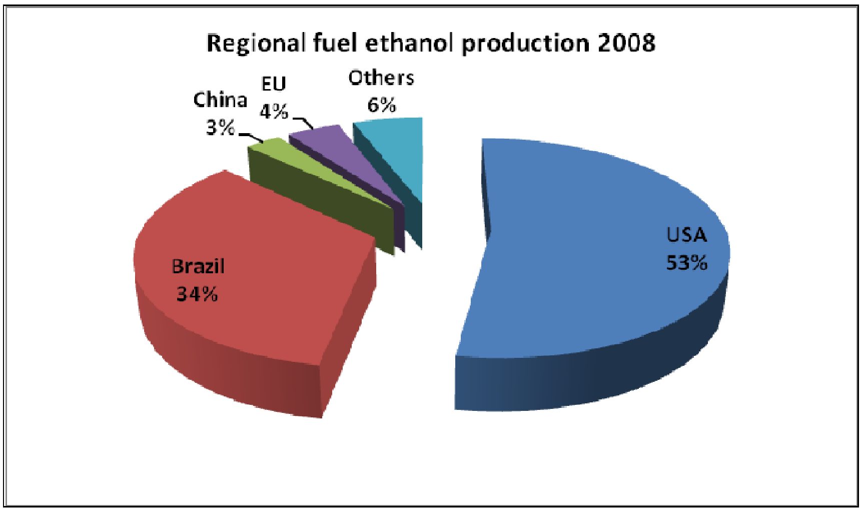

Fig. 1. Regional bioethanol production (US Renewable Fuels Agency statistics, 2009).

Global bioethanol production doubled between 2005 and 2008, but in 2009 there was expected to be a levelling off of the quantity produced due to over capacity particularly in the USA.

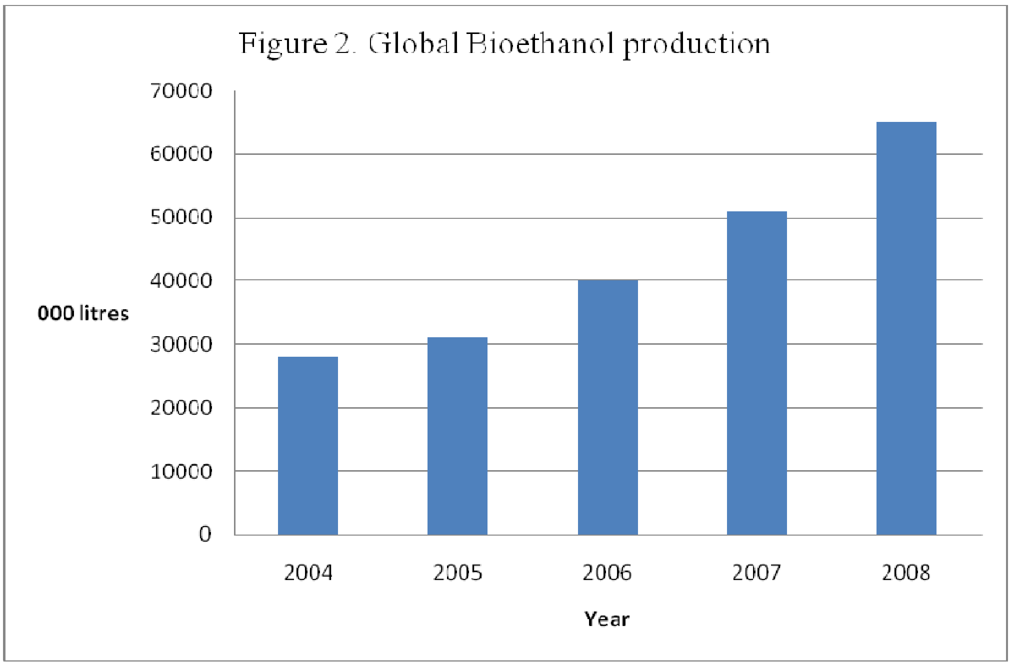

Fig. 2. Global bioethanol production 2004–2008 (US Renewable fuels agency statistics, 2009).

Global biodiesel production in 2008 was of the order of 13 billion L, this was up from 10 billion L in 2007 (European Biodiesel Board statistics , 2009).

Table 1. *Regional biodiesel production, 2008*

Region	Total biodiesel production) M L)
EU	9,000
USA	1,700
Argentina	900
Brazil	1,100
Others	800
Total	13,500

The EU is by far the most important producer. Production in the EU rose by some 35% in 2008 compared with 2007.

Regional characteristics and trends

The drivers behind the adoption of biofuels vary in different regions of the world and have changed over the years. Energy security has always been the main driver in the Americas, while at least initially, in the EU the adoption of biofuels has been led by climate change policies, environmental policies and particularly reduction of Greenhouse Gas (GHG) emissions. Energy security is gaining in importance as a policy driver.

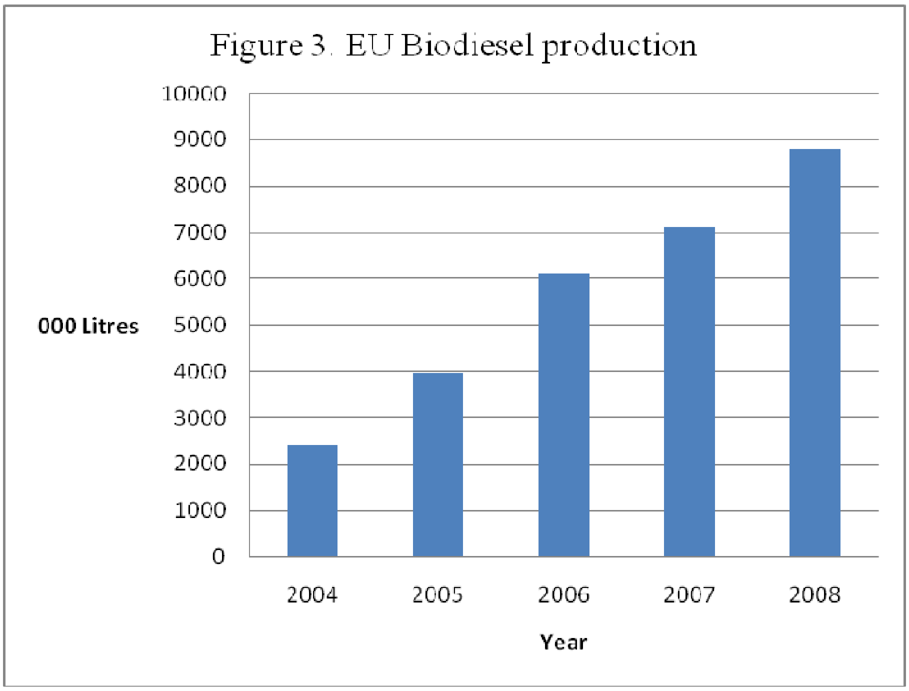

Fig. 3. EU Biodiesel production 2004-2008, 000 L (European Biodiesel Board statistics, 2009).

Brazil

Brazil has been the world pioneer in the large scale commercial production of bioethanol for many years. Production based on sugar cane first started in 1931, however policies and the level of biofuel consumption have varied considerably over the decades. Today 46% of all forms of Brazil's energy, is generated from renewables. Furthermore 16% of the nation's energy needs comes from sugar cane used for both biofuels and electricity generation. Bioethanol is offered as a pure fuel: E100, for use in dedicated engines. It is also blended with traditional petrol at a proportion of 20 to 25% (E20 to E25). Around 85% of the new vehicle registrations in Brazil are now flexible fuel vehicles, which means they can run either on regular petrol or on bioethanol or with a blend of both.

Bioethanol fuels account for nearly 50% of the total petrol market (Dornelles, 2008). In 2008/09 (1 May–30 April 30) production had reached a record 26.7 billion L, up from 22.4 billion L for the same period in 2007/08. The total harvested cane area reached 7.74 M ha in 2009 and about 55% of the crop, 349 M t (from 4.3 M ha) was expected to be used for bioethanol production. The most important region for sugar cane and therefore bioethanol production is the South - Centre region, with Sao Paulo as its centre. The north east around Recife is the other important region.

In September 2008, the state-owned Energy Research Corporation (EPE) (The Bioenergy Site, 2008) published a report indicating that the demand for bioethanol as a fuel will grow at an annual rate of 11.3% between 2008 and 2017. Demand by the end of this period was projected to be over 53 billion L annually. On the basis of an average yield of 80 tonnes ha^{-1} (FAOStat, 2008) the area of cane grown would need to be 6–7 Mha by 2012/13. Brazil is well placed in having large areas of land, over 90 M ha, which has potential for arable cropping. For the most part this would mean converting pasture land in the south. There is no direct impact on Amazon forests which are mainly 2000 km away from the southern pasture areas. However some studies (Lapola *et al*., 2009) suggest that there could eventually be indirect impact due to the migration of cattle ranchers to other regions and possible increased deforestation.

Production of biodiesel in Brazil commenced relatively recently. In 2004 a national biodiesel law came in to force which mandated that biodiesel would be blended in all fossil fuel diesel sold at the pump by 2008. For the period from January to July 2008 the blend mandated was 2% biodiesel, B2, then B3 and B5 by 2013. B4 came into effect in July 2009. The objective of the law is to reduce imports of diesel and to support agriculture in less productive areas. Brazil is also exporting biodiesel. At least 80% of the biodiesel is sourced from soya bean oil, which will be the dominant feedstock certainly up to 2013. However new production is also intended to come from castor bean oil and from small farm operations, particularly in the north and north east regions. Palm oil has potential also, due to its high yield per hectare (Lapola *et al*., 2009).

USA

Bioethanol production, mainly from corn, has been underway in the USA for many years; however, as recently as 2004 it was only equivalent to 2% of gasoline consumption. The 2005 Energy Policy Act, set an annual consumption target of 28 billion L by 2012. A new target of 130 billion L by 2017 came from the Energy Independence and Security Act of 2007. If achieved biofuels would displace 15% of the projected annual gasoline consumption. The Obama Government policy is heavily committed to the use of renewable transport fuels but particularly through the development of second generation biofuels.

By August 2008 there were 168 facilities in operation and a further 36 being built, mainly in corn belt States. Production had risen from 13 billion L in 2004 to 35 billion L by 2008. E10 has been available from gasoline stations all over the country. Some E85 is available mainly in corn producing states, but E85 can only be used as a substitute for gasoline in vehicles that have been modified.

Dry mills account for 75% of all current US bioethanol production and nearly all of the most recent growth. Many of them are owned by small co-operatives of independent farmers, while wet corn mills are owned almost exclusively by large corn processing companies. Wet mill production may expand as more investment from large enterprises takes off. Investments into bioethanol production were based on the high oil prices applying in 2007 and were generally made before the global recession. There is now considerable over capacity which resulted in a downturn in prices and according to the Renewable Fuels Association, 24 plants closed in 2009. Production in 2009 was estimated to be only slightly up on the 2008 figure of 35 billion L. Nonetheless, in 2009 according to the USDA (USDA, June 2009 report) one third of the corn crop was used for bioethanol production. This represented 11–12 Mha, considerably higher than previous forecasts.

There is clearly competition for land with corn grown for feed. In 2008, biofuels were largely blamed by NGOs and much of the media for the dramatic rise in grain prices. The International

Food Policy Research Institute attributed biofuels to a 26% increase in corn prices (von Braun, 2008). The National Corn Growers Association (National Corn Growers Association, 2007) had, however, argued that the bioethanol production will have less effect on feed markets than many claim. They argue that corn yields will increase and that corn exports are in any case lower due partly to rejection of GM corn in the EU and Japan and most significantly the protein content of corn used for bioethanol production is still available as a feed in the form of distillers grains, DDGS. Increasing production from more land is now limited. Assuming a further 10% increase, in average yields by 2013, and the USDA ERS predict considerably higher yield increases (USDA, June 2009 report), around 12.5 Mha would be needed to produce 40% of the corn crop for bioethanol.

There has been a major investment in biodiesel production capacity in the USA since 2005, mainly from large companies. The 2005 Energy Policy Act, set a target for biodiesel at 1.9 billion L by 2009 and 3.8 billion L by 2012. Soya bean oil is the main feedstock, supplemented by canola and waste oils. In fact production had already reached 2.65 billion L by 2008. However, the economic downturn and the surplus capacity has created major instability in the market with a number of insolvencies and plant closures resulting. On the basis that 80% of biodiesel originates from soya beans, 1.2 Mha were needed in 2008, representing about 4% of the total crop. By 2013 it is estimated that the area devoted to biodiesel could be doubled, i.e. 2.0–2.5 Mha, 8% of the total crop. There is however considerable uncertainty regarding such projections.

The European Union

The EU has led the way in biodiesel production (Table 1), largely due to the fact that diesel powered vehicles are popular and the fact production mainly from oil seed rape oil, and to a lesser extent sunflower oil, was given major support from Governments in Germany and France in the mid 1990s. Today Germany produces the most biodiesel of any country in the world, 3.3 billion L in 2008 (EBB statistics, 2009). The European Directive 2003/30/EC laid the foundation for the promotion of alternative fuels in the EU. The initial target set was 5.75% of transport fuels to be from renewables by 2010, this has led to the installation of over 270 plants across the region. By 2006 it was clear that the 5.75% target by 2010 was not going to be met, consequently since February 2007 the EU has been working to a target of 10% by 2020. Quite different approaches have been adopted by Member States in terms of how the targets will be met. In the UK, where large scale production of biodiesel only started after 2003, the Renewable Transport Fuel Order, RTFO, was introduced in 2008. This places an obligation on fuel suppliers to ensure that, by 2010, all UK fuel sold into the transport sector shall include a renewable source. Renewable Fuel Certificates are issued, which can be traded by companies. Biofuel producers have to report on the green-house gas balance, and environmental impact of their biofuels.

Total installation capacity is reported at 24 billion L (EBB statistics, 2009). But low price imports from the USA meant that many plants were no longer economically viable. Anti dumping legislation introduced by the EU in 2009 has curtailed imports from the USA, but imports from Argentina and Brazil continue to increase. 2007 biodiesel accounted for 75% of the total biofuels used for transport in the EU and 26% of the biodiesel was imported (Communication from the Commission, 24 April 2009). Domestic production of biodiesel largely comes from oil seed rape, although less so in the UK, and the demand has contributed to an increase the crop area from 4.2 Mha in 2003 to 6.1 Mha in 2008 (FAOStat). Much of the biodiesel is sourced from rapeseed oil that was previously used for other markets, including edible oils. This shift has had an effect on the international vegetable oil trade particularly from sources such as palm, with its negative biodiversity implications. Expansion of oilseed production areas in the EU for biodiesel production is not necessarily at the expense of food cops, as meal for the animal feed market is still available whatever use the oil is put to.

The extent to which the biodiesel demand can continue to be met from domestic production is open to question. Oil seed rape accounts for over 70% of the vegetable oil seed produced in the EU, grown on around 60% of the oil seed area, and is increasing. Because of its health properties sunflower oil is still predominantly used for edible markets. The European Biodiesel Board do not publish data on the proportion of feedstocks used but it can be realistically estimated that 75% of the current oil seed rape area, ie 4.6 Mha, is used for biodiesel production.

The official view in the European Commission is that the biofuel target of 10% by 2020 can be met without a serious conflict between land requirements for biofuels or food, although it is anticipated that there will need to be an investment in technology to widen the choice of feedstocks and to continue to partially rely on imports (Summa H, DG Agriculture, 2008). However, the UK, potentially a major biodiesel consumer, only sourced 24% of biodiesel from domestic oil seed rape in 2008 (RTFO,2010). By 2013 the EU target requirement for biodiesel is nearly double the 2008 quantity at 17 billion L. Clearly a substantial part of this requirement will have to be met from imports. A modelling study carried out by the REA (Wenner & Knibbs, 2009) indicates that by 2020 the EU will need to import the majority of its biodiesel demand, 24–27 billion L, unless significant progress can be made in advanced biodiesel from other feedstocks. By 2013 an increase to 5–7 Mha of EU grown oil seed rape is an estimated maximum area.

The EU is now the fourth producer of fuel bioethanol in the world behind the USA, Brazil and China. In 2008 about 2.8 billion L were produced with around 1 billion L in France. Wheat and sugar beet are the main feedstocks. The wheat area for bioethanol is estimated to rise from around 0.5 Mha in 2008 to 1.5 M ha by 2013. As with biodiesel, much of the EU's demand will be met from imports.

Other regions

Other regions which will contribute to world bioethanol markets by 2013 are China, initially producing from corn but then from cassava and Canada producing from wheat and corn. The main emerging biodiesel suppliers will be Argentina, from soya beans and Canada from canola.

Agronomic implications

Maximum yield output of crops grown for biofuels is just as important as with food or feed crops. In this respect there is little evidence that crops grown for biofuel markets need be managed differently from food or feed crops. Some opportunities for improved varieties are already being addressed and include the development of high sugar content, hybrid sugar cane; high starch content, corn and wheat and high oil content oil seed rape. There may be trends in pest and disease incidence where crop rotations are altered, e.g. increased fungal disease incidence and clubroot in oil seed rape in Europe. There is however a need to minimise the GHG emissions associated with biofuel crop production, and research effort in the UK is ongoing aiming to produce biofuel crops under a low nitrogen fertiliser regime (Kindred *et al*., 2008; Weightman & Kindred, 2009).

Discussion

Investment in some form of biofuel production is a global phenomenon with few parts of the world not involved. Mandatory consumption levels for biofuels have been set in most of the major economies. Consequently the production of conventional biofuels on newly cultivated land, or land substituted from food or feed crop production is projected to continue to 2013 and beyond. With in excess of 80% of bioethanol production in Brazil and the USA it is these markets and the policies adopted which will have the most impact on the international trade in bioethanol and technical developments. Similarly with the EU accounting for around two thirds of global biodiesel production, and challenging consumption targets it will be this region that influences the future development of biodiesel most.

The crops and regions that will be most positively affected will be (i) sugar cane in Brazil, due to the fact that land is available and production costs are low. (ii) Soya beans in Brazil, and Argentina, with opportunities to meet local demand for biodiesel and exports particularly to the EU. (iii) Wheat and corn in Canada for bioethanol. The fuel versus food issue will be most acute in the USA, with little spare land for corn production, yield increases will be important. The timing of the introduction of second generation biofuels will be important. To date the fuel *vs* food issue is not affecting production within the EU but it is already having an indirect on the international vegetable oil market, such as palm oil, with potential threats to biodiversity through deforestation. R & D effort to improve yields and where possible to enhance quality of biofuel crop grain or oil is clearly important.

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