Boundless Biofuels? Between Environmental Sustainability and Vulnerability

Arthur P. J. Mol

Abstract

Biofuels currently appear to be one of the major controversies in the agriculture/environment nexus, not unlike genetically modified organisms. While some countries (such as Brazil) have for quite some time supported successful large-scale programmes to improve the production and consumption of biofuels, policy-makers and research institutions in most developed and developing countries have only recently turned their attention to biofuels. Threat of climate change, new markets for agricultural output, reduced dependencies on OPEC countries and high fossil fuel prices are driving this development. But opposition to biofuels is growing, pointing at the various vulnerabilities – not in the least for developing countries – that come along with large-scale 'energy' plantations. Against this background this article analyses the sustainability and vulnerability of biofuels, from the perspective of a sociology of networks and flows. Current biofuel developments should be understood in terms of the emergence of a global integrated biofuel network, where environmental sustainabilities are more easily accommodated than vulnerabilities for marginal and peripheral groups and countries, irrespective of what policy-makers and biofuel advocates tell us.

Introduction: emerging biofuels

Only 10 years ago Cadenas and Cabezudo (1998, p. 83) concluded that 'the future outlook of biofuels is beset by uncertainty'. But in 2007 little uncertainty remains: biofuels are booming. While for a long time – at least since the early 1970s until the mid 1990s – Brazil was the only country that had successfully entered into the significant production and use of liquid biofuels, hardly any country can now be found that is not engaged in, or planning to get engaged in, biofuel production. From highly developed countries such as the USA and most EU countries, to major transitional economies such as China and Russia and developing countries in Asia and sub-Saharan Africa, policies, projects and/or pre-tests are being formulated on biofuel production and/or consumption. In addition, most major players on the global energy markets and most environmental and development non-governmental organisations

Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK
Sociologia Ruralis, Vol 47, Number 4, October 2007 ISSN 0038–0199

(NGOs), already have or are currently formulating policies, strategies and opinions on the production, transmission and use of biofuels. This raises the question of the consequences of sharp increases of biofuel production and consumption, and especially their consequences for environmental sustainability and vulnerabilities for different geographies and groups.

This article focuses on liquid biofuels (biodiesel and bio-ethanol), as an alternative to fossil fuels. Other biofuels that are more common in developing countries (such as wood, dung and biogas) are not included. Biofuels are fuels that are directly derived from biological sources. Sources that lead to specific end products in biofuel production are usually classified into four groups. Of these, the first two are in common use while the latter two are still experimental:

- Cereals, grains, sugar crops and other starches that can fairly easily be fermented to produce bio-ethanol, and can be used in their pure state or blended with fuels.
- Oilseed crops, such as sunflower, rape seeds, soy, palm and jatropha, that can be converted into methyl esters (biodiesel) and blended with conventional diesel or burnt as pure biodiesel.
- Cellulosic materials, including grasses, trees and various waste products from crops and wood processing facilities as well as municipal solid waste, that can be converted into a newer generation of bio-ethanol (via enzymatic breakdown or acid hydrolysis, followed by fermentation).
- New biodiesel technologies, such as the Fischer–Tropsch process, that synthesise diesel fuels from different biomasses (such as organic waste material) via gasification.

Bio-ethanol is the most widely used biofuel, accounting for some 94 per cent of global biofuel production worldwide in 2006 (see Figure 1). Around 60 per cent of bio-ethanol comes from sugarcane and the remainder comes from other crops, mostly maize. Brazil was the world's largest bio-ethanol producer for a long period, but in 2006 the USA took over as leading bio-ethanol producer (Figure 1). Brazil still stands out as the most successful producer of biofuels due to its low production costs, advanced technology and management systems, hybrid sugar/ethanol complexes and favourable CO_2 reduction rate. China ranks third, but in contrast to Brazil and the USA Chinese national policies have been more restrictive in expanding ethanol production, mainly for food security reasons.[1] Bio-ethanol made from sugarcane is much more effective in reducing greenhouse gas emissions (producing around 80 per cent less CO_2 emission per energy unit than petrol) than maize-based bio-ethanol (that produces around 20–40 per cent less). It is also much cheaper to produce, both in Brazil and Australia, the two leading producing countries (International Energy Agency 2004). In Europe, Germany, France and Italy dominate biofuel production and were significantly ahead of other countries in 2006. In Southeast Asia biodiesel is mainly produced from palm oil, in the USA and Brazil mainly from soy. In the EU biodiesel (produced mainly from rapeseed and some sunflower seed) accounts for 80 per cent of biofuel production (Figure 2), while much less bio-ethanol is produced in this region than in the USA and Brazil.

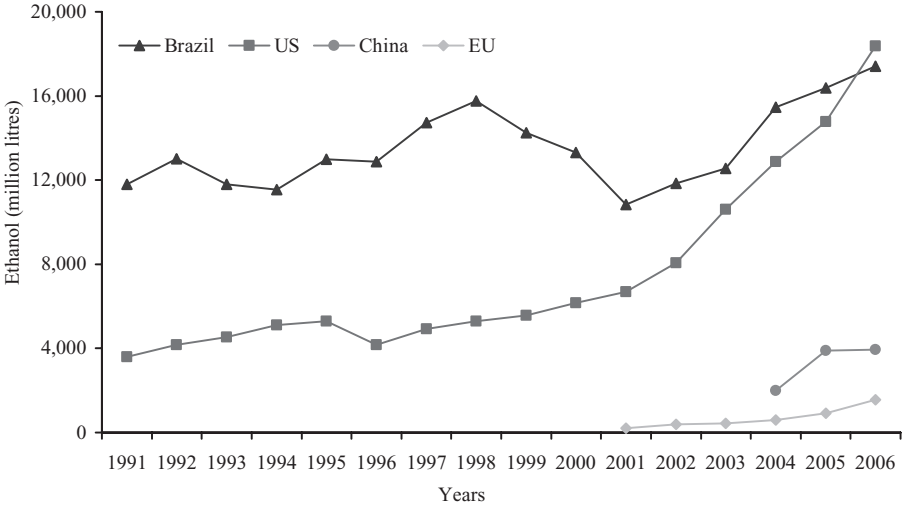

Figure 1: Production of ethanol in Brazil, USA and China, 1991–2006 (million litres)
Source: Renewable Fuels Association data; China Statistical Yearbook; European Bioethanol Fuel Association data) Available online at http://www.ebio.org/home.php

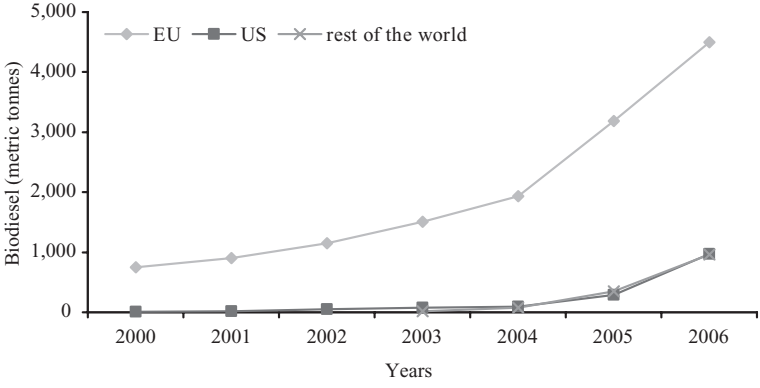

Figure 2: Production of biodiesel in the EU, UAS and the rest of the world, 2000–2006 (1,000 metric tonnes)
Source: National Biodiesel Board. Available online at http://www.biodiesel.org and European Biodiesel Board. Available online at http://www.ebb-eu.org/

There are four main reasons behind this recent remarkable increase in the attention attracted by biofuels and the correspondingly related increase in biofuel production, R&D programmes, policy initiatives and debates, although not all reasons for this are the same in every country and region (Munckhof 2006). Firstly, the continuing concern about the role of fossil fuels in climate change via the release

of greenhouse gasses during their exploitation, transport and, especially, their use, has created favourable conditions for increased attention into all kinds of renewable energy alternatives. The recent enforcement of the Kyoto protocol, the implementation of national targets for biofuels in various countries[2] and Al Gore's campaign around his Oscar-winning movie *An Inconvenient Truth* (2006) has intensified that interest.

Secondly, the dependence of a number of major fossil-fuel-importing countries (most notably the USA and the EU) on unstable fossil-fuel-producing and exporting regions (notably Russia, the Middle East and Venezuela) has triggered these former countries into launching programmes to lower their dependence on fossil fuel and thus increase their national energy security. A number of events in 2005 and 2006 sensitised oil and gas importing OECD countries to this feature of their dependence on fossil fuel.[3]

Thirdly, and partly related to the former consideration, the oil price increases that started in 2004 gave a further boost to biofuel interests, especially since many projections of oil price decreases had not been met up to mid-2007, thus making biofuels increasingly cost-effective.[4] This comes together with the fact that biofuel can to a significant extent use existing the infrastructure of conventional petroleum fuels (such as distribution and retailing systems, cars and combustion systems [Doering 2004]), making it far more competitive than, for example, hydrogen.

Lastly, an ongoing crisis in the rural areas of many OECD countries following the over-production of agricultural commodities, low prices, land continually taken out of production (set asides) and low income levels for farmers has provided fertile ground for a new market for agricultural commodities, especially – but not only – in large-scale, capital-intensive agricultural areas (such as the USA). In the USA, the EU and Brazil governments have heavily subsidised farmers and agribusiness to get involved in biofuel production. In addition, although one can also witness various drivers for biofuel expansion in the developing countries (including reduced oil imports, rural development and export opportunities), these countries have generally not been driving the recent biofuel expansion.

Consequently, from the early 2000s we have witnessed sharp increases and spatial proliferation in the production of biofuel, almost quadrupling between 2002–2006, according to OECD estimates.[5] While most biofuel production is still consumed domestically (90 per cent in 2005, with Brazil as the largest exporter), global trade is expanding rapidly, triggered by biofuel targets set in various countries in combination with uneven conditions for feedstock and biofuel production.[6] This increase and globalisation of biofuels has led to sharp debates on the proclaimed environmental sustainability of biofuels and the social vulnerability for notable two groups: the poor in developing countries and small farmers. But the common understanding among economic and political elites is that if biofuels are going to make a significant contribution to climate change mitigation, energy security and rural development, then biofuel production and consumption needs to globalise further, to become part of the global space of (energy) flows. This might, however, further endanger specific localities, interests and sustainabilities: most notably, the interests of small farmers and the poor in developing countries and specific local environmental sustainabilities (rather than global climate change).

In analysing in this article the emergence of a global biofuels system and the accompanying environmental sustainabilities and vulnerabilities, I use a sociology of networks and flows perspective. The objectives of this article are then twofold. Firstly, to bring biofuel developments into sociology, as the subject has remained up till now the privileged domain of natural scientists, economists and environmental scholars. Secondly, to illustrate what a sociology of networks and flows – that up till now has mainly focused on economic, bodily and information flows and mobility – has to offer for interpreting material and environmental flows (following upon the work of Spaargaren *et al.* 2006; see also Marvin and Medd 2006, and Mol and Spaargaren 2005). Using the sociology of networks and flows (section 2) I analyse the current biofuel debate and developments (section 3), paying special attention to questions of globalisation and governance (section 4). The last section draws conclusions on the future sustainability and vulnerability of an increasingly globalising biofuel system.

Biofuels networks and flows

The sociology of networks and flows is not so much one clearly formulated consistent theory, but rather a new perspective, or even a new 'rules of sociological method', for understanding the contemporary globalised world. While Castells was not first in using such new concepts and perspectives, his trilogy *The information age: economy, society and culture* (Castells 1996, 1997a, 1997b) made a significant impact in the social science community and triggered further work that perceived flows and networks – instead of states and societies – as the new architects of global modernity.

The new institutional makeup of the network society is understood to be directly related to a new layer or dimension emerging within and in between contemporary societies. This new layer, the 'space of flows', should not be understood as a new layer in the geographical meaning of the word, but rather in terms of a new kind of time–space organisation of social practices. The space of flows refers to new social dynamics – to new concepts of time, space and power. But the notion of space of flows has also a substantial connotation in Castells' work. The dominance of the space of flows here refers to the power elites that operate at the most crucial nodes of global networks, knowing best how to handle the switches, codes and programmes (Castells 2004) that govern global flows of money, capital and information, at the expense of the mass of ordinary people living their lives in the space of place. With the notion of the space of place Castells (1996, pp. 378, 423–428) refers to the place-based spatial organisation of social life, as commonly perceived and experienced by the most citizens in advanced and developing societies. The only option left to the locals in the space of place is protest and resistance against the disturbing, exploitative and uncontrollable logics of markets, genes and technology that characterise the space of flows.

While Castells mainly concentrates on economic and information flows, others have expanded such perspectives to mobility and bodily flows. Building upon conceptual work of Mol and Law (1994), recent work by John Urry (2003) and Sheller and Urry (2006) on mobile sociology used a slightly different conceptualisation by doing away with the 'zombie' concepts of states and societies and moving beyond sedentarist theories that focus only on place and stability. Urry reworks Castells' dichotomy of 'space of place' and 'space of flows' by suggesting that networks and flows operate in

three spatial patterns or modalities, that are regions, global integrated networks (GINs), and global fluids. Regions consist of objects, actors and relations (networks) that are primarily clustered together geographically, often within one country. They are characterised by fixed and solid relations in a nation–state container, showing 'directional' mobility of flows and constrained by the fixed boundaries of that region. This is the typical modality that dominated the pre-globalisation era.

GINs consist of more or less stable, enduring and predictable relations between nodes or hubs stretching across different regions with relatively walled routes for flows. GINs cross regional boundaries and thus become deterritorialised, although place-based moorings ensure that they do not become footloose. They deliver the same kind of outcome at all nodes, with limited adaptation to local circumstances and their 'products are predictable, calculable, routinised and standardised' (Urry 2003, pp. 56–57). Large multinational corporations like Coca Cola, agro-food networks and civil society network organisations such as Friend of the Earth are typical examples.

Global fluids are spatial patterns structured neither by boundaries nor by more or less stable relations, but by large flexibility, liquidity, gel-like movement and permeable boundaries. Fluids demonstrate no clear point of departure or arrival and no clear sequential dependency, just deterritorialised movement with no necessary end state or goal. Migrating people, financial capital, the Internet and social movements are typical examples. The unpredictability of global modernity that is so central in Urry's notion of complex modernity is especially related to this latter modality. More recently, however, Urry and colleagues (Hannam *et al.* 2006; Sheller and Urry 2006) seem to be placing global fluids less centrally in their paradigm for mobile sociology and mobilities.

In the sociology of networks and flows the notion of 'scapes' refers to socio-technical infrastructures that structure and govern these spatial patterns of flows. Scapes are 'networks of machines, technologies, organisations, texts and actors that constitute various interconnected nodes along which flows can be relayed' (Urry 2000, p. 35). Unlike Castells'work, Urry gives a less deterministic ring to these 'spaces of flows' but his notions of power are more or less similar. Power in networks is related to access, inclusion and exclusion and control over flows, both through being on and off the network and through power relations inside the network. The scapes, the socio-material networks that structure the mobility of flows, are shaped by these power relations but they also structure power positions around these flows, access rights and the material bypassed by the flows (Graham and Marvin 2001, p. 167), together with the degrees of strictness of boundaries of different kinds of flows.

The ability of nation–states, as one of the power containers, to regulate mobilities and ensure conditions for favourable interaction processes and flows differ for all three modalities. With respect to regions, states are still major governing actors, although under globalisation they can no longer structure in detail the patterns and regularities of societies. They can do so even less for global integrated networks, where states have become less and less able to act purposefully in regulating mobilities, ensuring favourable conditions and structuring scapes, that is, influencing the direction, speed, form, contents and outcomes of mobile flows. The relevance of state and governance decreases still further with respect to global fluids. Global fluids are hardly touched by the activities of nation–states, nor do the socio-material

infrastructures or scapes seem to have any specific relation to nation–states. Governability belongs no longer to the vocabulary of this modality.

I apply this conceptualisation to investigating current developments and tensions in the emerging biofuels system and in relation to the prevailing fossil-fuel system. Currently, we can identify two of the spatial modalities in biofuels, although one of them these needs further differentiation.

Firstly, the region modality of biofuel flows and networks is dominant, where objects, actors and relations are primarily clustered together in localities with fixed relations and boundaries and limited global integration. But there are two versions of these biofuel regions that are largely independent of each other. In the poorer developing countries biofuel systems are locally organised, with limited differentiation among actors, limited nation–state involvement, a poorly articulated socio-material infrastructure (with simple technologies, limited differentiation among actors and non-codified rules). In the more advanced developing countries (such as Brazil and Malaysia) and in various OECD countries biofuels regions are nationally organised, with a well-articulated socio-material infrastructure (including advanced technologies, piped networks, legally codified rules and the differentiation of tasks and responsibilities), strong state involvement, further differentiation among actors and a larger mobility and wider spatiality of biofuel flows. But they also display limited global integration, poor homogenisation across countries, a nation-state container that is still dominant and socio-technical infrastructures that are defined, organised and governed locally. These can be called national biofuel regions.

Secondly, we can witness the emergence of a global integrated biofuel network (GIBN), characterised by less concentration of objects, actors and relations in specific locations/regions, increasing transboundary flows of biofuels, an increasingly globally defined scape, the decreasing dominance of states and governability and a homogenisation and standardisation of products and processes; but still with reasonably stable and predictable patterns of biofuel exchange and relations and walled routes for biofuel flows. Increasingly this GIBN integrates with the GIN of fossil fuels.

I use this framing in the next two sections to (1) investigate the nature of the current biofuels controversy where biofuel regions are confronted with an emerging GIBN, especially with respect to sustainability and vulnerability, and (2) assess the governance outlooks of these GIBN in the making. In the final chapter I turn to the logical question of whether the category of a biofuel global fluid makes any sense.

Biofuel controversies

Arguably, Brazil's biofuels network was the first that could be understood as a full-fledged national biofuel region, with an active governmental policy towards sugarcane cropping and rural development, an elaborated infrastructure of hybrid ethanol/sugar plants, a flex-fuel car[7] development and production programme, the integration of petrol companies and a policy mandating the mixing of bio-ethanol with petrol. There has always been debate on the Brazilian biofuel programme in the 1970s and 1980s (Dufey 2006), but that was largely an internal debate on its environmental, economic and social dimensions. Currently, with the major growth and ambitions of biofuel production and consumption under conditions of globalisation, criticism of the

national biofuel regions in various countries has become more widespread, vivid, pointed and global in nature. The debate encompasses several frontiers (such as its impact on the environment, development, economics, trade and power relations) and an increasing number of participants. We will not review the entire debate with respect to biofuels, but focus on sustainability claims and the vulnerability of particular groups in this respect, leaving partly aside technical discussions on economics and climate change gains.

While initially biofuels were celebrated as an alternative to fossil fuels for their contribution to combating climate change (and a range of other air pollution problems such as particulates, hydrocarbons and carbon monoxide; although biofuels often increase nitric oxide [NO_x] emissions), more recently critics started to question the environmental profile of biofuels on various points.

There is considerable diversity in greenhouse gas savings from biofuel use, depending on the type of feedstock, its cultivation methods, conversion technologies used and energy efficiency assumptions made. While the Brazilian sugarcane-based bio-ethanol and Malaysian oil-palm-based biodiesel indeed contribute significantly to lowering carbon dioxide emissions, this is either not the case or only partly the case (depending on which analyst is speaking, for US maize-based biofuels (for example, Pimentel and Patzek 2005; McElroy 2006). It is also questioned whether biofuels are a cost-effective carbon dioxide emission abatement strategy, as other investments towards a low carbon economy are more cost-efficient (Worldwatch Institute 2006a, p. 19; Frondel and Peters 2007).

In addition, several other environmental problems have recently been associated with biofuels: deforestation and a decrease in biodiversity, monocropping, land degradation and water pollution. Oil palm plantations in Malaysia and Indonesia were the target of environmentalists in recent years (with the orang-utan as symbol mobiliser; see also Painter, [2007]), but soy production also faces criticism for threatening the savannah and tropical forests in north-east Brazil, and soil and water conservation are endangered in the corn belt states of the USA. It is for these reasons that the NGO network Biofuelwatch has called on the EU to abandon their targets on biofuel use in petrol and diesel. New generation (Fischer–Tropsch) biofuels are received more favourably, especially when they are based on waste biomass or cellulose.

These debates have been directed mainly at national biofuel regions and hardly at all at local biofuel regions, where small-scale oilseed production is converted by farmer co-operatives in biofuels, to be consumed within the same locality. Production of low-input biofuels crops such as jatropha on marginal land is perceived to be a positive contribution to local soil improvements, providing biofuels (and farmer income) through simple processing methods (Dufey 2006). But energy balances and cost structures show remarkable inefficiencies of these local biofuel regions in developing countries (van Eijck and Romijn 2006), making them attractive only in peripheral localities that are not well served by conventional fossil-fuel infrastructure.[8]

Secondly, various impacts of biofuel systems on developing countries and poverty have met with criticism. Arguably the most criticised of these, by well-known spokespersons such as Noam Chomsky and Lester Brown, is the potential impact of large-scale biofuel production on food supplies, food prices and food scarcity. With the development of local biofuel regions to national biofuel regions and the expansion of

national biofuel regions in an increasing number of countries, these impacts are spreading globally. US large-scale biofuel production in particular is believed to increase food prices (such as that of maize in Mexico,[9] sugarcane in Brazil and even of beer in Europe[10]) as well as the availability of food to the poor (Runge and Senauer 2007a, 2007b).

With growing demand for biofuels on the world market, and thus the development of a GIBN, cropping patterns in developing countries, as well as the exports of food crops from them, will change, further jeopardising the availability of food crops in developing countries. For instance, Jank *et al*. (2007, p. 25) estimate that the EU will have to import 40 per cent of its biodiesel needs by 2012 to fulfill its targets, as insufficient cropping areas are available within the EU. For ethanol the need for imports is less clear until 2012, but it might still be substantial.

Currently, we also see major commitments of Malaysia and Indonesia (and to a lesser extent, Thailand) towards the expansion of oil palm, and of India and Indonesia towards jatropha. This might all interfere with the local biofuel regions in developing and developed countries, disturbing and transforming small-scale biofuel networks by integrating them into national biofuel regions. Proponents of free trade and large-scale biofuel programmes make contrasting evaluations of such developments. Such scholars celebrate the potential for developing countries to enter into new export markets, to provide local farmers with better opportunities and incomes and the boosting of national economies via a model of both import substitution (of fossil fuels) and export growth (of biomass/biofuels).[11] The favourable natural conditions, widespread availability of land and low labour costs in tropical countries, and the fact that sugarcane and oil palm (the most cost-efficient and greenhouse gas-saving crops, according to Worldwatch [2006b, p. 8]) grow best in tropical conditions should provide developing countries in tropical regions a comparative advantage in growing biofuel feedstock. IFPRI (von Braun and Pachauri 2006) and to a lesser extent the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) seem to take a middle position in celebrating biofuels for their potential to serve the environment and the poor, but acknowledging at that same time that careful management and governance of biofuel production and trading is needed in order to develop pro-poor biofuel programmes. Policies and measures on feedstock, geographies, increasing productivity, waste reuse and scale optimisation in processing such fuels should allow win–win situations to be created and require public–private partnerships in biofuel development (von Braun and Pachauri 2006).

This win–win goal appears to be easier to attain if the value-added stages of biofuel production, notably processing and refining, take place in the developing regions themselves. But the Brazil case teaches that to achieve this end a well-developed scape is needed. This is certainly not available in many sub-Saharan and other less developed countries (Kojima and Johnson 2005). This would result in developing countries becoming biomass – rather than biofuel – exporting regions, or in large foreign companies investing in biofuel production facilities, preferably in developing countries with better infrastructure (such as South Africa). Second-generation biofuels from cellulose-rich organic material interferes less with the food economy and might have less negative consequences for the environment, but these require even more

advanced technical processes, higher capital investments and large facilities, thus diminishing the comparative advantage of developing countries.

Generally speaking, these debates come together with two developments. Firstly, there is the proliferation of national biofuel regions, starting with Brazil but spreading to a still growing number of developed and developing countries. These national biofuel regions result in large-scale monocropping biofuel production and the increasingly centralised, homogenised production and refining of these crops, while local biofuel regions are losing their relevance.

Secondly, there is a clear tendency towards the development of a GIBN in which production, trade investment, consumption, control and governance lies beyond the control of nation–states (Worldwatch Institute 2006b). These developments result in major changes in the making in the networks and scapes that structure the biofuel flows. While initially farmers, co-operatives and individual processors were the main players in the local biofuel regions, increasingly nowadays large companies and conglomerates (of major agribusiness such as Cargill and Archer Daniels for the global grain trade[12], conventional oil companies such as Total and Shell[13] and car companies such as Toyota and Daimler–Chrysler) are moving to the fore as powerful players that are both part of and the architects of biofuel scapes.

Sometimes these conglomerates are actively constructed by state agencies through round tables. In France major oil companies, car industries and agro-industry and farmers associations met to discuss progress in biofuels. In the UK the Low Carbon Vehicle Partnership is a similar conglomerate of some 250 organisations, including the automotive and fuel industries, the environmental sector and government. In the USA the National Ethanol Vehicle Coalition brings similar interest groups together. Whether these round tables are actively constructed by state agencies or not, large-scale farms, agribusiness and other major companies in the biofuels networks increasingly manage to capture government subsidy programmes in both developed and in many developing countries (Kojima and Johnson 2005). And they are also moving into developing countries. For instance, in 2007 Swedish Scanoil was procuring land in Indonesia to grow jatropha as a feedstock for biofuel.

All the same the ownership of and access to the sources for biofuels, and even production facilities for them, are much more diversified and small scale, compared to conventional fossil fuel scapes. For instance, in Minnesota (USA) and São Paulo (Brazil) (Worldwatch Institute 2006b, p. 15) farmer co-operatives are still dominant in bio-ethanol production facilities. Furthermore, oil extraction facilities are more dispersed compared to highly concentrated petroleum refining facilities. This is partly related to the nature of feedstocks that disadvantages long-distance transport and thus large-scale production facilities and requires less capital compared to conventional oil.[14] But the trend is definitely towards concentration and capturing farmers in fixed contracts (Table 1; Worldwatch Institute 2006a). In 2005 Archer Daniels Midland produced about 25 per cent of ethanol in the USA and was the second largest biodiesel producer in Europe (Worldwatch Institute 2006a, p. 72).

It is not just that an emerging GIBN intrudes on the specific local space of place, where local biofuel production systems (in both developed and developing countries) are undermined and local environmental conditions are endangered (especially with

Table 1: *Farmer positions in US ethanol production (million litres) at the beginning of each year*

	2001	2002	2003	2004	2005	2006	2007
Ethanol production capacity	7,275	8,883	10,246	11,737	13,793	16,412	20,791
Production capacity by farmers (%)	25	28	29	34	38	39	39
Ethanol production capacity in construction	246	1,480	1,828	2,263	2,854	6,729	21,332
Production capacity in construction by farmers (%)	71	86	66	75	60	11	11

Source: Renewable Fuels Association statistics, various Available online at http://www.ethanolrfa.org/

respect to soil and water degradation through large-scale, high-input, monocropping farming), food availability and affordability for place-based locals (rather than the mobile cosmopolitans) are jeopardised and local marginal farmers become increasingly dependent on powerful global players in the GIBN. The emerging and increasingly dominant GIBN also supports and takes on board the increasing global mobility of biofuels, technologies, standards and so on, and prefers to tackle the environmental worries and problem definitions of the cosmopolitans (such as climate change) rather than those of the locals (who are concerned with water and soil degradation). The Worldwatch Institute (2006a p. 68), for instance, points to the fact that in Brazil biofuels do improve the quality of life of the urban cosmopolitans (through lower air emissions from traffic), at the costs of those in the rural areas. The Global Integrated Biofuels Network also enhances the global sourcing for scarce (non-fossil fuel) energy resources. But all this is no evolutionary, deterministic development. Then, how can the biofuel governance structure develop in a GIBN to modify these tendencies?

4. Biofuels governance: from regions to global integrated networks

To a significant extent scapes for biofuels are currently still nationally oriented and diverse, as they have been constructed by non-state and state actors through their national systems in the transition from local to national biofuel regions. But increasingly, the process of constructing one uniform global scape is on its way, through the harmonisation of national scapes in reference to the scape of conventional fossil fuel, and this change is driven by globalising trade, investment and production in the biofuel sector.

Up until 2007 biofuels have been largely governed through national governments promoting the growth of biofuel crops and the processing of these crops into bioethanol, biodiesel and, to a much lesser extent, other products. Governments in most countries (such as Brazil with respect to sugarcane for ethanol, the USA regarding maize for ethanol, Germany with rapeseed for biodiesel and Malaysia with respect to oil palm for biodiesel) have been stimulating this market through various protective measures against foreign competition. These include subsidising farmers, ethanol and biodiesel processing companies, as well as biofuel end users such as car

manufacturers, taxi drivers, car hire companies, public transport and so on (via tax reductions, soft loans and credit facilities); mounting large R&D programmes; experimenting with various transport technologies and programmes; creating markets by setting mandatory targets for biofuel use in petrol and diesel and through a number of other policies and measures. As long as the main share of biofuels is consumed domestically and imports are limited, governments might be able to remain in some control.

But with increasing international trade, world market development and global – rather than national – players, this form of state control will continue to decrease. The direct import and exports of biofuels or biomass is growing, but so is foreign direct investment (FDI). USA and Brazilian businesses see major commercial opportunities in supplying advanced equipment to countries in, for instance, the Caribbean and Central America and oil companies are starting to invest in production facilities in biomass-rich regions. This globalisation questions the relevance of national biofuel scapes, calling for a global harmonised regime. Hence we see increasing discussion and debate, proposals and criticism during the last two years on what kind of development should be put in place of a global scape for biofuels, to arrange and control a global market and playing field.[15] Several issues stand out in this move towards a global scape: free trade, certification and standardisation and new power relations.

Free trade and protectionism is high on the biofuels agenda. In order to protect their own farmers, the US has followed a protective policy towards biofuel imports, especially from Brazil (but not from many Caribbean countries). But with demand for feedstock from the growing number and capacity of US based ethanol plants, major demands on US farmers for higher production levels of corn, and increasing prices of corn, this protectionism is coming under pressure. In 2007 a switch could be noticed in the US standpoint towards trade restriction. By linking up with Brazil, the EU, China, India and South Africa in launching the UN International Biofuels Forum, it became party to developing international standards and open markets, encouraging investments in industry and marketing biofuels globally.

The accepted view is that such trade liberalisation will decrease the price of biofuels and thus encourage the substitution of biofuels for fossil fuels (Steenblik 2006). But to achieve this harmonisation and standardisation is also required. Fuel specifications for biodiesel (that are strongly dependent on the source material) have developed differently in the USA and the EU, for instance, thus endangering global trade. With emerging global markets there is a need for global collaboration on standards and specifications of biofuel quality. But there is still considerable lack of clarity as to how biofuels fit into the existing trade regime. Should they be seen as agricultural, industrial or environmental goods? The reply has consequences for the subsidies allowed (Howse *et al.* 2006; Dufey 2006). How should they be classified and what kind of import tariffs will fall on them (Loppacher and Kerr 2005)? The variations in import duties for ethanol in 2004 ranged from 0.19 Euro in Australia to none in Japan and New Zealand (Dufey 2006). While protective measures in terms of tariff barriers would need to be broken down (and there seems increasing consensus on this issue), is the reduction of protectionism also the case for subsidies to domestic primary producers, processors, car manufacturers and

other categories of user? And what would be the consequences of a trade regime that followed the World Trade Organisation for domestic regulations and standards (such as mandatory use of biofuels, fuel content requirements)? Perhaps most importantly, how would a trade regime in biofuels develop criteria with respect to sustainable production methods,[16] such as is increasingly being proposed by several governments and NGOs? While this is not the place to enter into the specifics of a biofuels trade regime,[17] the direction of discussions and developments among the main state and economic actors that make up the current global biofuels network in the making is clear: it is towards further harmonisation and uniform standardisation of biofuel products, markets and regulatory regimes. Overall, there is a tendency towards standardised products that can be detached from the local space of place and be transferred in a globally integrated network with a uniform scape.

Certification and labelling is often seen as an institutional arrangement that could bring the specific place-based environmental and social interest into the space of flows (Oosterveer 2007). And indeed, with respect to the emerging GIBN a similar call for certification and labelling systems can be heard, or is already beginning to be established. Brazil has a Social Fuel Seal for sugarcane-based biofuels, guaranteeing that the biofuels produced benefit poor farmers. Several environmental NGOs,[18] local farmer organisations, scientists (Verdonk *et al*. 2007), national state authorities and governance arrangements (such as in The Netherlands, as articulated by Cramer Commission 2006; in the UK through the Low Carbon Vehicle Partnership and in the USA through the National Ethanol Vehicle Coalition) and international organisations have called for and proposed voluntary or mandatory certification schemes. These represent a variety of interests such as protection of the local environment, food sovereignty, adequate conditions for labour and biodiversity. Agribusiness and oil industry tend to be rather critical towards such sustainability labelling. Several developing countries have labelled such conditionalities 'green imperialism', restricting them from profiting from their comparative advantage in natural resources. Other developing countries collaborate strategically in developing such schemes (as in the Round Table for Sustainable Palm Oil Production).

With the emergence of such a global scape, and the interdependency and the increased merging of the biofuel scape with the fossil fuel scape, power relations will change dramatically. Harmonisation, standardisation, certification and globalisation of biofuel flows will include and empower the (large) organised actors who operate beyond region networks, as they are better able to co-construct and work within global socio-material infrastructures. States, and especially developing states, farmer co-operatives and localised NGOs are not empowered through an increasingly globalising scape, as their access to and power in these networks are limited. Large-scale farming and plantation are the preferred mode that fits in this evolving scape. Hence, we witness various initiatives to try to protect small-scale farming and local small biofuel business, such as the Cramer Commission (2006), the UN (2007), the Low Carbon Vehicle Partnership in the UK and the National Ethanol Vehicle Coalition in the USA, but these initiatives are rowing in the face of the major biofuel flows.

Conclusion

Biofuels represent the first serious challenge to petroleum-based fuel for a century, but it will take at least two more decades before biofuels will seriously challenge the oil economy. However, the architecture of a global biofuel scape is already emerging. While the US Renewable Fuels Association (2006) only recently captured the development of biofuels in the title of their annual report: 'From niche to nation', it will not be long before a revision will follow: 'From nation to global'. With the proliferation and globalisation of biofuels comes a proliferation and intensification of the debate on its merits. Environmental sustainability and vulnerabilities stand out as two of the most critical issues in the development of a GIBN. Such a network highlights both the inclusion of places of biofuel production and consumption into global structures and the increased mobility of biofuel flows and systems.

It is not too difficult to imagine that environmental sustainability will be integrated in designing the socio-material infrastructure that will structure global biofuel flows or how this may happen. Indeed, if we use the language of mobile sociology, environmental sustainability can be seen as an attractor that will trigger and structure the biofuel scape, increasingly merging with – and transforming – the conventional fossil fuel scape. This is certainly true in that climate change is one of the main drivers behind biofuels, but it is also likely that some of the other environmental aspects will do so in the future. But it is much more difficult to see the inclusion and mitigation of new social vulnerabilities in future GIBNs, especially those related to smaller farmers and the poorer developing countries. The highly technological, capital intensive nature of the global socio-material infrastructure in the making (with standardised products, advanced logistics and management and global actors) does not easily provide these vulnerable actors access, power and representation in such a GIBN.

As long as the emerging GIBN takes on too many of the characteristics of the current fossil fuel GIN, we cannot expect a fuel switch to result in better positions for such vulnerable actors. But at the same time, other vulnerabilities are being mitigated, such as the dependence of fuel-consuming nations on the OPEC countries and the vulnerable justifications of major oil companies and car producers in the increasingly dominant debates on climate change. Thus, it is not that the scapes and networks must remain equal to current structures when moving to a more biofuel-based global integrated fuel network, but that the position, power and security of some of the most vulnerable actors is not likely to change for the better.

In coining the biofuel developments in GIN spatialities I deliberately avoided discussion on a liquid post-national, completely deterritorialised and footloose framing of biofuels as global fluids. Hence, I do not foresee that biofuels will easily become truly boundless. Interpreting biofuels in terms of global fluids (as disorganised, boundless, non-directional and non-governable time–space constellations) requires a refocusing on carbon flows rather than biofuels. Then, indeed, the boundaries of nations and walled routes, and those between fuels, feed, food and gasses like methane and carbon dioxide will melt into thin air, the directionality of (carbon) flows will become meaningless and there will no longer be an obligatory 'point of passage'. Flows will then become mobilities that mutate and vary in their configuration (Law

and Mol 2003). Carbon configurations switch between food, feed, fuel and air. While this is also true with respect to fossil fuels in a glacial time frame, the time horizons are notably shorter when biofuels become common. But it can be questioned what such a global fluids analysis could contribute to understanding current vulnerabilities and sustainabilities.

Notes

[1] However, in 2007 China announced plans to set aside 13.3 million ha of land, mainly in Yunnan and Sichuan provinces, to grow oilseeds and to increase biodiesel production to 10 million tonnes by 2020.

[2] Canada, Columbia, India, and Thailand have recently set targets for increasing the biofuel contribution to transport fuels. In the Energy Policy Act of 2005 the USA states that in 2010 25.8 billion l have to be used as fuel (individual states, especially the corn-belt states, have their own policies). The EU Directive 2003 /30/EC (EU, 2003), requires biodiesel to account for 5.75 per cent of the overall amount of petrol and fossil fuel diesel in 2010.

[3] Russia significantly reduced oil exports to the EU a few times due to disagreements with the Ukraine on prices. In the same period Venezuela's President Chavez offered a major challenge to the Bush administration, using its oil exports as a strategic resource. Increasing conflicts around Iraq (and, to a lesser extent, Afghanistan) increased tensions between a number of OECD countries and some of the OPEC countries, while the production levels of Iraq continued to be low.

[4] Initially the oil crises in the 1970s were the main driver for Brazil to develop its sugarcane–ethanol programme. But low oil prices in the 1980s and 1990s seriously endangered this Brazilian programme, to gain support and momentum again in the twenty-first century.

[5] Historically, there have been earlier periods of major attention to biofuel production and use. When Diesel first demonstrated his compression engine in 1898 he used peanut oil. Henry Ford was one of the main promoters of biofuel in the USA in the 1920s (Eikeland 2006), and in the early part of the twentieth century biofuels approached a 5 per cent share of total fuel consumption in Europe and Brazil (Worldwatch Institute 2006a, pp. 61–77). The mutual strengthening of the four factors mentioned in this article is likely to sustain the more enduring growth of biofuel production globally today.

[6] Many authors, such as Worldwatch (2006b, p. 6) point to the large potential for biofuel production in tropical countries, where high crop yields and lower land and labour costs provide them with an economic advantage over developed and densely populated countries in temperate regions.

[7] When the percentage of bio-ethanol used in petrol goes above 10 per cent, cars need to be slightly adapted. Flex-fuel cars have been developed to be able to run on all kind of ethanol/petrol mixes in Brazil (and up to 85 per cent ethanol to 15 per cent petrol mixes in the USA). These have been widely introduced in Brazil from early 2003 onwards.

[8] These oil seeds are mainly grown for edible oil production and consumption, and only incidentally used for biofuel production, with the non-edible jatropha as the most important exception. Other biomass sources are used for biofuels, although they are used in solid, not liquid form (wood, dung) or gas (biogas from digesters).

[9] In 2006 17 per cent of US corn was converted to ethanol, supplying 2 per cent of that nation's motor car fuel. In 2007 this will increase to 27 per cent of the corn. The Earth Policy Institute estimates that in 2008 50 per cent (140 million metric tons) of US corn will be used in close to 200 ethanol processing plants and that this will have a major impact on world grain prices and availability. A study by Tokgoz *et al.* (2007) shows that the USA will reach a tipping point when over-reliance on corn-based ethanol to meet stringent government

regulations further drives up retail food prices, reducing domestic meat and poultry production and eroding meat and grain export markets. Other authors question these estimates of price increases, celebrate high prices for farmers, and/or trust the market mechanism to regulate supply and demand.

[10] Global beer brewer Heineken warned in February 2007 that the expansion of the biofuel sector was beginning to show a structural shift in European and US agricultural markets, causing the price of beer to rise, as less barley and hops were grown and thus become more expensive.

[11] The Brazilian bio-ethanol programme involved a million workers in 2005, mostly lower skilled workers in rural areas. This increase in employment will be much lower for the mechanised production methods of soy and corn. Tariff barriers for exports to EU and the USA are generally zero for most developing countries (and recently also for Brazil, following the summit between Presidents Lula (Brazil) and Bush (USA) in the spring of 2007, but there are non-tariff barriers for palm and soy oil exports to the EU. Countries like Thailand and South Africa still face tariff barriers (Jank *et al.* 2007). There are also major distortions of free trade through subsidies of different kind for the agricultural sector in many developed countries (Dufey 2006).

[12] There is fierce lobbying by agribusiness on ethanol in the USA. The Center for Responsive Politics (n.d.) reveals that agribusiness like Archer Daniels Midland donated US $365 million to politicians between 1990 and 2005, compared with only US$ 182 million donated by oil and gas companies.

[13] Eikeland (2006) shows how in 2005 major oil companies were hardly active on the biofuel market in Europe, although there were variations among them. Total Elf was quite active and companies as Shell and BP were starting to show an interest, while Exxon, Statoil and Hydro remained rather passive. But most oil companies have now moved into biofuels. Shell is now active in joint ventures for cellulosic ethanol and gasification. In Brazil oil companies were initially resistant towards biofuels, but they have fully incorporated that market into their business.

[14] This also differs between sources for biofuels. In the USA corn-based ethanol plants have a capacity three times higher than the sugarcane-based ethanol plants in Brazil. One reasons for this is that harvested corn can be stored for long periods, while sugarcane should be processed within one or two days after harvesting to avoid the deterioration of the sugar (Worldwatch 2006b, p. 5). But in a US Congressional hearing in May 2007 energy experts asserted that around 70 per cent of the biofuel production facilities in the USA are small business, without further specifying the definition of a small business (Renewable Energy Magazine 2007).

[15] The latest indicator is the UN (2007) report on biofuels with warnings about the environmental and food security dangers of the current massive biofuel developments. The existence of the report in itself is remarkable, as the UN does not often succeed in moving forward on energy, given the multitude of opposing vested interests (OPEC, nuclear lobby).

[16] As the growth of biofuels will most likely go together with the advancement of genetically modified (GM) crops, especially in maize, soy and sugarcane GM technologies are widely used), this may further spread the GM controversy and the controversy regarding the legal base on which GM crops may be regulated (Loppacher 2005).

[17] Others have called for a specific international biofuels agreement (Matthews 2007) or a UN agreement on bio-energy (Verdonk *et al.* 2007), which could specify several of these points, in addition to further commitments of OCED countries towards developing countries.

[18] Such as the European Environmental Bureau that sees a system of certificates relating to the production methods of biofuels as the *sine qua non* condition for any further increase of biofuel production and use. The Institute of Science in Society (2006) has produced a similar proposal.

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Arthur P. J. Mol
Dept of Environmental Policy
Wageningen University
Hollandseweg 1
6706 KN Wageningen
The Netherlands
e-mail: Arthur.mol@wur.nl