3

Renewable Energy for Transport

Dirk Aßmann, Niklas Sieber and Ricardo Külheim

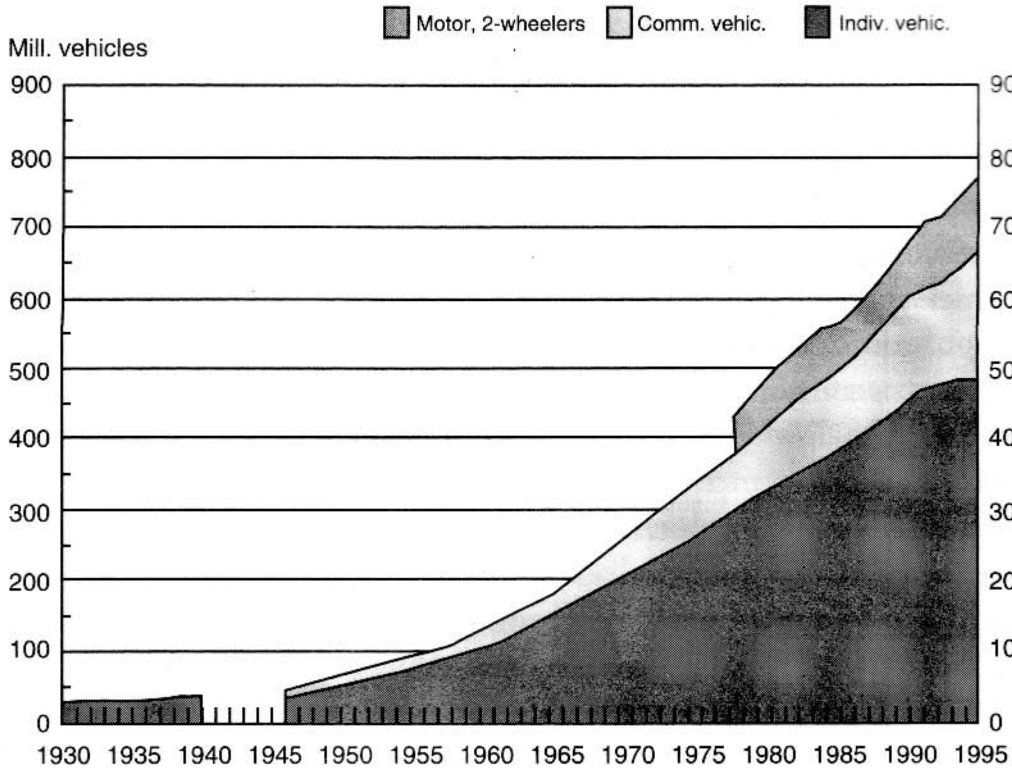
Introduction

Worldwide, the transport sector consumes about one-fifth of primary energy (IEA, 1997) and is responsible for almost 60 per cent of oil consumption in Organisation for Economic Co-operation and Development (OECD) countries, and consumption in the developing world is increasing. After the energy sector, transport is the largest emitter of carbon dioxide. Unlike the energy sector, energy consumption and greenhouse gas emissions of the transport sector are still increasing in many industrialized countries. The problem is even more severe in developing countries, where enormous growth is required to catch up with the industrialized world.

Figure 3.1 demonstrates the rapid increase of the worldwide motorization since 1930. Between 1980 and 1995 the global fleet of cars, trucks and buses increased by 60 per cent, with a third of the increase taking place in developing countries. World Bank research (Ingram and Liu, 1999) has revealed that vehicle fleets grow at the same pace as economic growth. These authors estimate that the vehicle fleet will increase sevenfold by 2050.

Transport has positive development effects linked to the economic growth process, but its negative impacts, such as the emissions of greenhouse gases and pollutants, are well known. Development strategists face a dilemma, since economic growth is highly desired, but not its negative side effects. Thus, a sustainable transport strategy has to take into account the growing transport demands in developing countries and reduce the emissions at the same time. The key question is: what are the main pillars for a sustainable transport system?

Transport emissions are dependent on transport volumes, specific fuel consumption and emissions per unit of fuel. Transport planners have various



Source: BMZ (2003)

Figure 3.1 *Motorization trend worldwide, 1930–1995*

leverage points in order to change emission volumes and energy consumption. This chapter will give an overview on the most relevant measures for developing countries:

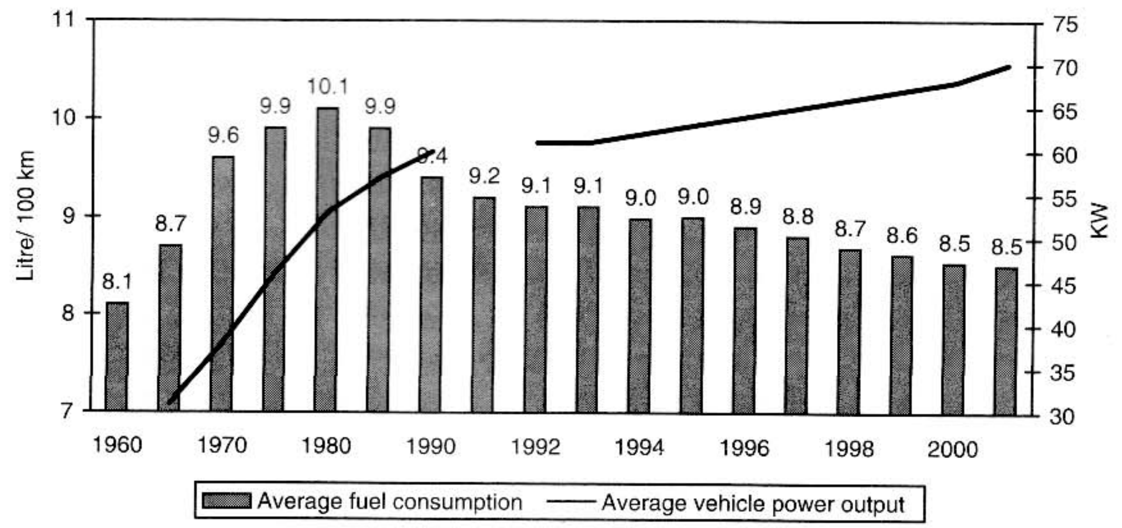
- technical options for conventional engines, such as engine technologies, vehicle characteristics, inspection and maintenance and fuel quality;
- options for renewable energies in transport, such as ethanol and biogas;
- planning approaches for efficient transport systems, such as transport demand management, land use planning and fuel pricing.

These options do not represent a comprehensive set, but represent the most prominent measures for improving transport systems in the developing world. They will be discussed with regard to their relevance for developing countries, their technical feasibility and competitiveness compared to existing solutions.

CONVENTIONAL ENGINES

In industrialized countries, public pressure has resulted in an increase of the energy efficiency of engines in transport, accompanied by improved emission regulations entailing air pollution reduction technologies, such as three-way catalytic converters and filters. While during the past four decades emissions of pollutants have generally decreased, fuel consumption and thus greenhouse gas (GHG) emissions resulting from transport have increased, owing to growing transport volumes and more powerful engines. The example of Germany (Figure 3.2) shows that during the past 40 years average engine power has more than doubled. Since the 1960s this process has been accompanied by an increase in specific fuel consumption. From the 1980s onwards a slight decline (16 per cent) can be observed, which is due to improvements in technical efficiency and a larger proportion of diesel-engined vehicles in the fleet. However, the efficiency improvements were not able to compensate entirely for the increasing engine power. Thus, the low consumption values from the 1960s have not been maintained. In North America a similar trend can be observed.

However, a significant potential for a further decrease of average fuel consumption exists in the industrialized countries. Volkswagen has demonstrated that a car driven by a one-piston diesel engine can reduce energy consumption to less than 1 litre per 100 km. However, this vehicle, a slow two-seater with very little space for baggage, is not available for everyday use. Commercially, low-consumption cars that consume 3 litres of diesel per 100 km are available; an example is the VW Lupo 3L TDI. The disadvantages of diesel engines are the higher CO_2 emissions per litre of fuel and the particulates when not using a filter. The best commercial petrol cars, such as the Daihatsu Cuore or the Opel Corsa Eco, consume slightly less than 5 litres per 100 km and are competitively priced. Hybrid engines combining petrol and electric engines have even higher energy efficiency, but are presently much more costly.[1] However, in the past the market for low-consumption cars was very small. In Germany, sales of the Lupo, which consumed only 3 litres per 100 km, were only 15,000 and thus Volkswagen decided to cease production. By contrast, 4.3 million high-powered vehicles with a maximum speed of more than 210 km/h are registered and the use of SUVs is



Source: Verkehr in Zahlen 2002/2003, own graph

Figure 3.2 *Fuel consumption and vehicle power of private cars in Germany* increasing rapidly. The question is, how much the fuel price has to rise until this attitude changes.

In most developing countries a large share of the vehicle fleet consists of second-hand vehicles purchased from industrialized countries. The general rule is, the richer the country, the smaller the share of second-hand vehicles. In low-income countries, especially in Africa, used cars are very common, while in emerging economies the share of new cars is considerably higher. Therefore, in poor countries the emission levels can be compared to those of used cars in the developed world, and any efficiency improvements implemented in the North will also have long-run effects in the South. Thus, without additional measures the energy efficiency of vehicles in developing countries will be no better than it used to be five to ten years ago in the developed world. In developing countries, fuel prices are often fairly low (see later in the chapter), and low-consumption vehicles make up only a small market share, which is balanced by the large number of off-road vehicles, which are badly needed on the poor roads.

The rapid motorization in the successful Asian economies entails growing environmental and congestion problems. China may serve as an example, since it has the world's fastest-growing automobile market. The country's vehicle population increased from 6.6 million in 1990 to 45.3 million in 2003, which implies an average annual increase of 21 per cent.[2] During the first half of 2005, 2.8 million vehicles were produced in the country.[3] China's increasing energy demand for transport not only had an impact on the international oil market, but led to national shortages. In order to save the country's scarce energy resources, the National Standardization Administration has set up a fuel consumption cap for new passenger cars. For example, a light-duty vehicle (between 1.2 and 1.3 tonnes) should be designed to consume no more than 9.5 litres per 100 km until 2008. From 2008 on, the limit will be lowered to 8.6 litres.[4] At present it is inconceivable that Western countries would enact similar measures in order to reduce GHG emissions.

A significant decrease in pollutant emissions could be achieved in developing countries if European emission standards such as Euro II to IV were implemented. Many countries have already introduced the Euro I standard, some Euro II, and a few even Euro III.[5] Preconditions are the introduction of legal binding requirements for mandatory roadworthiness tests, combined with a set of regulations dealing with fines and other sanctions. However, this requires a dedicated government willing to undertake a considerable effort in order to implement this comprehensive set of measures. A first step towards the necessary higher environmental standards is an improvement in the fuel quality, for example by reducing the sulphur content of petrol and diesel.

Anybody travelling in developing countries can easily observe that many vehicles produce black smoke. Emission standards are simply not met, because engines are badly adjusted and vehicles poorly maintained. The reason is the lack of a system of inspection and maintenance, or the inadequacy of the system. A good inspection and maintenance system can reduce fuel consumption by 3–7 per cent and hence leads to a similar decrease in CO_2 emissions.[6] This holds especially true for two- and three-wheelers, which emerge as a major problem in many Asian towns. In Delhi, two- and three-wheelers produce three-quarters of the particulates and roughly one-third of the hydrocarbon emissions.[7] Especially for two-stroke engines, the pollution problem is often visible. Since the vehicles are relatively cheap, reliable and easy to repair, they are a very popular mode for the poor. Because a replacement by cleaner technologies is not feasible in the short run, inspection and maintenance and tighter emission standards are the only measures available to limit the negative effects.

RENEWABLE ENERGIES IN TRANSPORT

Alternatives to fossil-based fuels

Renewable energies can be used in various forms and in different sectors for different purposes. For transport purposes there are in general three options: the transfer of solar radiation (or other RE) through, for example, solar thermal power plants into hydrogen, the transfer of RE into electricity which is directly used as 'fuel', or the conversion of biomass into liquid or gaseous fluids. As the hydrogen path is still too expensive and various technical problems still need to be solved, and the electricity path does not fulfil transport requirements, biofuels are highlighted in all discussion on alternative fuels.

If biomass is produced sustainably (for example, within organic land use systems, or the use of industrial waste as biomass), it is classified as a renewable energy. However, pure biomass production in the absence of an awareness of other environmental aspects may lead to deforestation or erosion.

Biomass can be used in two ways:

1 Traditional or non-commercial biomass, such as crop residues, fuel wood and animal dung, is frequently used with very low efficiencies for cooking and heating in many developing countries. This is a major cause of serious indoor pollution, particularly affecting women, small children and the elderly, and leads to diseases and overuse of natural resources. Therefore, programmes to develop and disseminate improved biomass stoves in many African and Latin American countries, China and India are of major importance.
2 Modern biomass is biomass produced in a sustainable manner and used for electricity generation, heat production and transportation (liquid fuels). It includes wood and forest residues from reforestation or sustainable forest management, energy crops from organic production, and rural and urban residues such as solid waste and liquid effluents.

Today an enormous variety of technologies are available to convert the energy provided by plants into fuel energy for transportation. The use of pure plant oil as a fuel for transportation has a long history, leading us back to Rudolf Diesel's earliest compression engines working on peanut and hemp oil. Pure plant oils (PPO) can be extracted from almost any oil seed crop such as rapeseed, sunflower or soybean. Because of their different combustion properties as compared with fossil diesel, PPO cannot be used in normal engines but requires special refitting, or dedicated engines such as the Elsbett technology. As yet, no car manufacturers have offered plant oil motors; there are just small companies offering engine conversions. Apart from some niche sectors (e.g. sensitive areas, fleet owners), the use of pure plant oil does not seem to be appropriate for broad markets.

The most widely used biofuel is *ethanol*, accounting for more than 90 per cent of total biofuel production. Ethanol is produced by fermenting sugar, such as from sugar cane or sugar beet, or by converting corn starches (and other starchy feedstocks) into sugar before fermentation. Ethanol can either be blended with gasoline in low concentrations without any engine modifications or, with modified engines, it can be burned in higher concentrations up to 100 per cent.

The special characteristics of ethanol lead to higher octane numbers and thus increase engine efficiency. New developments such as flex-fuels (flexible-fuel vehicles), which are able to switch between various mixtures of ethanol and gasoline, are gaining market relevance since the automobile industry successfully introduced them on a large scale in Brazil. It was expected that 60 per cent of the new cars sold in Brazil in 2005 would be flex-fuels. Furthermore, ethanol can also be used as an additive. Ethyl tertiary-butyl ether (ETBE) can replace the fossil-based methyl tertiary-butyl ether (MTBE). Recent data on the energy balances of ethanol show that the ethanol production chain is highly efficient. Brazil, with its production based on sugar cane, has by far the highest energy output/input relationship of all biofuels, varying from a factor of 8.3 to 10.2.

Biodiesel is the second important biofuel. It is also known as fatty acid methyl ester (FAME), because of the transesterification process of plant oils. Biodiesel has similar characteristics to those of conventional diesel and can thus be used in conventional vehicles without major changes. Minor refitting, mostly concerning seals, is required when biodiesel is used in high proportions. Blending biodiesel to conventional diesel in a proportion of 5 per cent is technically no problem. Research on the biodiesel life cycle concluded that owing to its closed carbon cycle it has a strong impact on greenhouse gas mitigation, reducing carbon dioxide emission by more than 75 per cent compared to fossil-based diesel. Most other emissions will also be reduced. However, like diesel engines, biodiesel causes particulate emissions that need to be reduced by particulate traps. As NO_x emissions also rise by 10 per cent, using biodiesel does not mean that catalytic converters can be dispensed with.

In parallel to the biofuels options already mentioned, there are other alternatives, such as gaseous or liquid biofuels. Some of them are not yet marketable; others are at a preliminary development stage and still need further research before becoming a technically and economically interesting option.

Biogas is produced by means of a process known as anaerobic digestion. It is a process whereby organic matter is broken down by microbiological activity in the absence of air. It occurs naturally at the bottom of ponds and marshes, and gives rise to marsh gas or methane, which is similar to natural gas. There are two common technologies for obtaining biogas. The first, more widespread, is the fermentation of human and/or animal waste in specially designed digesters. The second is a more recently developed technology for capturing methane from municipal waste landfill sites.[8]

At the moment, the biogas sold is usually collected from municipal waste landfills. Also, cattle farmers produce it in small fermenters, and China and India have had much success with family-sized biodigesters. The gas is compressed and used in co-generation plants, in vehicles equipped for natural gas or for cooking. However, compared to other forms of energy, biogas has a very small market share, but there is still a huge potential for both stationary and mobile use.

Although *hydrogen* is often highlighted as 'the fuel of the future', it is not expected to be available before 2020. Since there is still no mature technology for hydrogen production based on renewables, a large-scale launch does not seem realistic within the next 10 or 15 years.

Along with hydrogen, fuel cells are the technology that is most often mentioned. However, modified engines would also be able to utilize hydrogen; it has not yet been decided which technology will be at the forefront. The use of hydrogen could lead to a big reduction in GHG emissions if renewable energies were used to produce the fuel, and if the efficiency of the entire production and consumption chain were high. At present, most fuel cells run on natural gas. This may lead to better efficiencies but the improvements are fairly small. On the other hand, technologies based on biomass are not sufficiently developed to be used on a large scale.

Research into so-called designer fuels, such as 'Synfuel', developed by Choren Industries, is under way. The *biomass-to-liquids* (BtL) process is mostly based on the Fischer–Tropsch reaction, but other research is being done as well. In general, solid biomass will be gasified and afterwards liquefied. It is still in the development phase but the first demonstration plant will probably begin to produce in 2006. Therefore, BtL is rather more developed than hydrogen technology, and most scientists expect it to be on the market within the next five to ten years. However, many technical problems still need to be solved. As the characteristics of 'designer fuels' will be similar to those of fossil-based fuels, there will be little need to modify conventional engines – an important aspect for their marketing and for their acceptance by car manufacturers.

Natural gas vehicles (using compressed natural gas, *CNG*) do not use a renewable energy form, but emit 15–20 per cent less GHG than do petrol vehicles. As regards its environmental impacts, liquefied petroleum gas (*LPG*) has similar features to those of natural gas, but GHG emissions are slightly higher. Since LPG is collected from oil wells, where it is usually burned, its supply is limited.

Biofuels – today's market

Until industrialization in the 18th and 19th centuries, energy supply was mainly based on renewable energies, especially biomass and hydro. Rising demand and new technologies led to better living and working conditions, but also to an ecologically harmful change in the energy supply. Today there are important differences in the energy systems of OECD countries and developing countries respectively, as indicated in Table 3.1.

Table 3.1 *Characteristics of global primary energy demand, 2000*

	Fossil fuels (%)	*Renewable energy (%)*	*Nuclear (%)*	*Growth rate, all sources (%/yr, 1971–2000)*
OECD	82.7	6.2	11.0	1.6
Developing countries	71.7	27.6	0.7	3.9

Source: IEA (2004)

In OECD countries, which have reached a very high level of development, gains in energy efficiency have been the main strategy used to decrease energy consumption. In developing countries, where renewables (mainly biomass) are already very important (see Table 3.1), albeit used in inefficient ways, modernization of their usage seems the better strategy to follow.

As Figure 3.3 shows, around 14 per cent of total world energy (around 425 EJ in 2002) is provided by renewable energies. Apart from biomass (meaning here combustible renewables and waste), hydro has the highest share. The 'new' renewables such as solar, wind and geothermal energy contribute less than 1 per cent of global production.

In developing countries the non-commercial use of solid biomass ranks bio-energy before hydropower and other renewable sources of energy. According to the IEA Renewable Information, 48.4 per cent of global biomass consumption takes place in Africa. This is mainly accounted for by domestic cooking and household heating in stoves, fireplaces and domestic and district heating boilers.

Today, about 33 billion litres per year of biofuels is used commercially in North and South America, Europe and South Africa. As a whole, Europe has the largest biodiesel production capacity, estimated at 2.3 million litres per year in

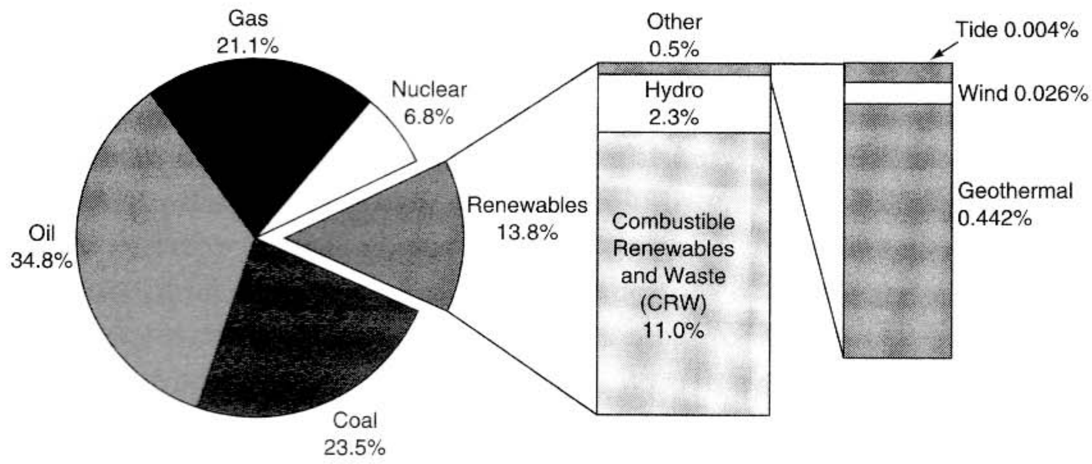


Figure 3.3 *Global primary energy demand, 2000*

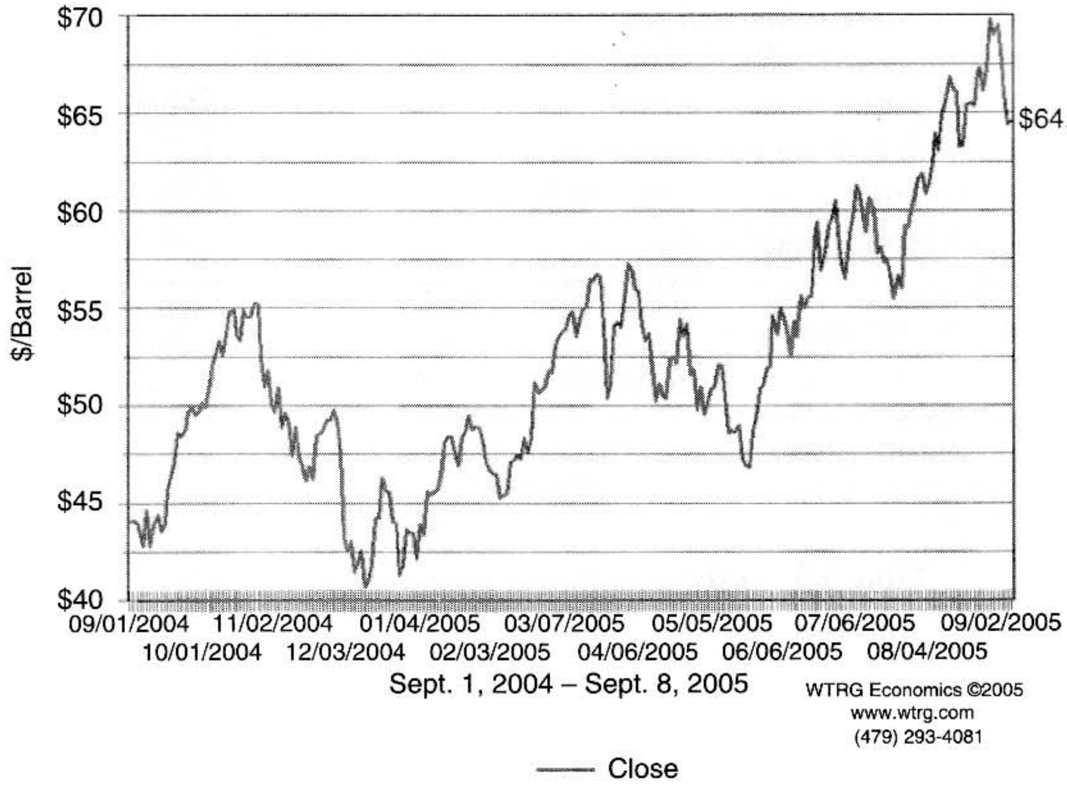
more than 40 dedicated installations, mostly in Germany, France, Italy and Austria. Germany is currently the largest producer, accounting for almost half of the global biodiesel production.

World ethanol production rose to nearly 41 billion litres in 2004, of which 73 per cent was for fuel. The countries with the highest current use of fuel ethanol are Brazil (14.6 billion litres, corresponding to roughly 30 per cent of the country's non-diesel motor fuel use in 2004) and the US (14.3 billion litres). The two countries together are responsible for almost 70 per cent of total production, followed by China (9 per cent), India (4 per cent) and France.[9]

Production and costs of renewables

For the assessment of the future competitiveness of renewable energies, the price of crude oil is a crucial topic. The rapidly increasing energy demand from the growing economies in Asia has resulted in a tremendous increase in crude oil prices in recent years. First peaks were reached in November 2004, when a barrel of oil reached US$55, which expressed in real terms compares to the second oil price shock at the beginning of the 1980s. However, in September 2005, after Hurricane Katrina, the price temporarily passed the US$70 threshold. On 12 September the price per barrel was down to US$64, and petrol cost around US$0.52 per litre.[10] Long-term forecasts to the end of the decade range between US$42 (Merryl Lynch) and US$60 (Goldman Sachs).[11]

Given these price levels, renewable energies are becoming increasingly competitive. The most successful example is ethanol production in Brazil. The Proálcool Programme is, worldwide, the largest application, and initially was promoted by massive government support. Recent experience shows that even though government subsidies have been cut, ethanol prices are close to being competitive with petrol. The break-even was reached at the beginning of the decade, when oil prices began to rise while ethanol continually became cheaper



Source: WTRG Economics

Figure 3.4 *Crude oil prices, 2004–2005*

(see Figure 1.2 in Chapter 1) due to economies of scale entailed by increased production. Table 3.2 shows that in 2003 the cost of biofuel production based on sugar cane in Brazil was competitive with that of petrol. Given the expected oil price level of at least US$42/bbl, ethanol will be economical in the long run.

In the future, further cost reduction can be expected, since the new conversion technologies described above, that make use of ligno-cellulosic feedstock, either from waste materials or grown as dedicated energy crops, will reduce costs further. The International Energy Agency (IEA) estimates that production cost will initially be $0.53/petrol equivalent and decrease to $0.43 in the near term and to $0.27 after 2010 (IEA, 2004, p78). This has to be compared to the petrol price of around US$0.5 in September 2005.

The biodiesel case is different, as Table 3.3 shows. With oil price levels at their 2004 levels, biodiesel has not yet achieved competitiveness. In Germany it is used only because of tax exemptions. Increased oil prices, new technologies and reduced production costs in developing countries might increase its competitiveness in the future.

According to Berndes et al (2005), advanced biofuels such as bio-dimethyl ether (bio-DME), biomethanol and compressed substitute natural gas (SNG) might be competitive with an oil price of US$60–100/bbl, and further cost reduction might decrease the threshold to $40. However, the availability of the new production technologies is a determining factor. Furthermore, other

Table 3.2 *Ethanol and petrol production costs before taxes, 2003*

Fuel type	*Source*	*Country*	*Production costs (US$/litre petrol equivalent)*
Ethanol	Corn	US	0.43
	Sugar beet	Europe	0.63–0.90
	Wheat	Europe	0.53–0.93
	Sugar cane	Brazil	0.20–0.30
Petrol	Crude oil		0.26–0.28

Note: The volumetric energy content of ethanol is one-third less than in the case of petrol. To compare, the costs per litre are therefore transferred into petrol equivalents.

Table 3.3 *Biodiesel and diesel production costs, 2003*

Fuel type	*Source*	*Country*	*Production costs (US$/ litre diesel equivalent)*
Biodiesel	Rape seed	Europe	0.35–0.80
	Soy beans	US	0.48–0.73
Diesel	Crude oil		0.20–0.24

Note: The volumetric energy content of biodiesel is a few per cent less than in the case of diesel. To compare, the costs per litre are therefore converted to diesel equivalents.

processes, such as the use of hydrogen or the liquefaction of coal, might also become economic.

In Europe a replacement of 5 per cent of the fuel demand (petrol and diesel) would require about 20 per cent of available cropland for production (IEA, 2004, pp17–18). The reduced food crop production would increase food prices and thus would reduce the need for agricultural subsidies in industrialized countries. Thus, in industrialized countries, without major importation only a small proportion of the transport energy demand can be satisfied. This gives developing countries the opportunity to improve their trade balance and generate additional income for their rural populations, where poverty is prevalent. Assuming adequate productivity, the low labour costs of developing countries might reduce production cost and make biofuels even more competitive. The IEA estimates that in the near term (2020) biofuels can replace 20 per cent of world gasoline consumption and in the long run (2050–2100) a third or more of road transportation fuels.

Social and ecological aspects

The Brazilian Proálcool Programme was started in the 1970s with research and development activities in the field of ethanol for reasons of energy security and self-sufficiency. The programme is known to have created major social and environmental problems on the agricultural side (Weber, 2004, pp69–70). Proálcool has been criticized for its negative environmental impacts, the result of large-scale monoculture. All ecological investigations show that the evaluation of biofuels greatly depends on the type of agriculture used to produce the plants. The results are quite simple: the lower the use of mineral fertilizers and chemical pesticides, the more appropriate the crop rotation; and the more efficient the use of by-products (such as bagasse or straw in co-generation), the better the ecological evaluation. Therefore, in order to achieve environmentally sound production, environmental standards and criteria through the whole production and consumption chain need to be developed and implemented.

Another important aspect of the production of biofuels is the future land use. If a significant share of worldwide road fuels is to be replaced, large-scale agricultural production will be necessary. The IEA assumes that low-value grazing lands will be put under cultivation. Proálcool had the advantage of using old farmland formerly cultivated for sugar production, but past experience shows that agricultural expansion has often entailed a reduction or degradation of tropical forests. Furthermore, the production of biofuels should never affect food production.

In the past five to seven years a social component has been added to the discussion. The discussion focused on the question of whether farmers could be the 'oil sheikhs of tomorrow'. As with ecological evaluation, social impact assessment did not lead to a clear and distinct result in Brazil. The argument about farmers becoming oil sheikhs is, in general, a myth. The overwhelming majority of ethanol producers are not small-scale farmers but agro-industrials whose farm workers are paid extremely low wages, whereas producers of bio-diesel in Europe are 'normal' farmers. However, here the market is not yet developed enough to undertake a social impact assessment. Some experience in the field of solid biomass, for example in power plants, shows that big players such as energy utilities try to use their power to make extra profit by paying the farmers extremely low prices.

In this regard the Malaysian case is quite interesting, as the production of plant oil does not automatically lead to poverty reduction. Malaysia is the world's biggest producer of palm oil, with agriculture having a share of 11 per cent in the economy, and palm oil contributes 70 per cent to it. However, in order to become such a big player, Malaysia destroyed large parts of its primary rainforest and thus minimized the habitat for certain species, especially tigers and orang-utans. At the same time, the average salary (2003: US$92) of the farm workers is 80 per cent below the poverty level, and has increased by only $1 within the past 45 years.

The question of whether production of biofuels will be of general benefit in developing countries remains open. A number of factors influence the sustainability, such as existing land tenure systems, land use conflicts, trade protectionism from industrialized countries, technology transfers, wage levels in agriculture and industries, availability of adequate finances for small-scale farmers, and access to transport infrastructures. A good example of a sustainable approach is that of German Technical Cooperation (GTZ), which has started a public–private partnership project on biofuels in India that might lead to a three- to fourfold increase in farmers' incomes within a few years – while protecting the environment and generating new business opportunities.

PLANNING APPROACHES FOR EFFICIENT TRANSPORT SYSTEMS

Since at present technical improvements and the use of renewable energies in transport are limited in developing countries, planning approaches are needed to reduce energy in order to meet both the increasing transport demand and greenhouse gas reduction targets. Like planners in industrialized countries, transport planners in developing countries have a large variety of options to manage transportation demand. Since transportation demand management has already been discussed in depth in the transport literature (McClintock, 2001; Newman and Kenworthy, 1999), this section will highlight how transport planning has to be adapted to the needs of developing countries. But what makes the difference between planning in the North and planning in the South? The following factors are involved:

- a high demand for low-cost means of public transport;
- the abundance of non-motorized transport;
- high-density urban settlements with expected future urban sprawl;
- severe financial constraints on public budgets.

Planning low-cost public transport systems

Individual means of transport have a higher energy consumption per person transported compared to public and non-motorized modes of transport. In general, passengers driving in cars in industrialized countries consume roughly three to five times more energy than passengers transported by public modes of transport.[12] Thus, energy efficiency in transport can be increased tremendously by shifting passengers from individual to public and non-motorized means of transport. Transport demand management encompasses many measures, ranging from traffic calming, alternative work schedules, encouragement of walking and cycling, road pricing to the improvement of mass transport systems, to mention just a few.

Most important for transportation demand management is the choice of the system for mass transportation, since large-scale investments are related to its implementation. Experience in industrialized countries shows that mass rapid transit systems, such as metros, commuter rails or light rail transit, are often not economically viable. Practically no European mass transit system operates without large-scale subsidies. Investment costs are extremely high if subterranean metro lines are to be constructed.

In developing countries the problems are more acute, since public funds are even scarcer than in industrialized economies. Appropriately, low-cost solutions have been developed in Latin America, using high-quality buses for public urban transport. A very efficient bus rapid transit system has been developed with the following features (Wright, 2004, p31):

- segregated busways with transit prioritization at intersections;
- rapid boarding and alighting using pre-paid tickets;
- clean, secure and comfortable stations with real-time information displays;
- modal integration of railways and non-motorized means of transport at bus stations and terminals;
- 'soft' characteristics, such as marketing identity (brand) or advanced customer service.

A comparison with conventional mass rapid transit systems shows that bus rapid transit can achieve results comparable to those given by rail systems as regards carrying capacity and service, but average speed is slower, mainly because of the lack of grade separation and the lower maximum speed achieved on the busways. The main advantage is a significantly lower capital cost, especially when compared to subterranean metro systems. The main disadvantage is the large surface areas required by the buses, especially in the case of four-lane operations.[13]

Planning for non-motorized transport

Walking is the dominant mode of transport for the poor. The poorer the country, the remoter the region, the smaller the integration into markets, then the more non-motorized means of transport dominate the picture. Even though walking consumes less energy, it is not the most efficient means of transport, as Figure 3.5 demonstrates. The graph lists typical costs in Africa for goods transported a medium distance (50 kilometres) on a good road and a short distance (5 kilometres) on a poor road. The most expensive mode of transport is walking.[14] But the good news is that tremendous efficiency improvements can be made by using other low-cost means of transport, such as bicycles and animal carts.

The efficiency improvement in transport which non-motorized means can generate is a lesson to be learned by transport planners, especially in rural areas, where export of agricultural goods is essential in the struggle against poverty. The solution is intermodal logistic transport systems, with the low-cost means taking care of the 'first mile's' journey from the field to the collection point, where the trucks pick up their loads.

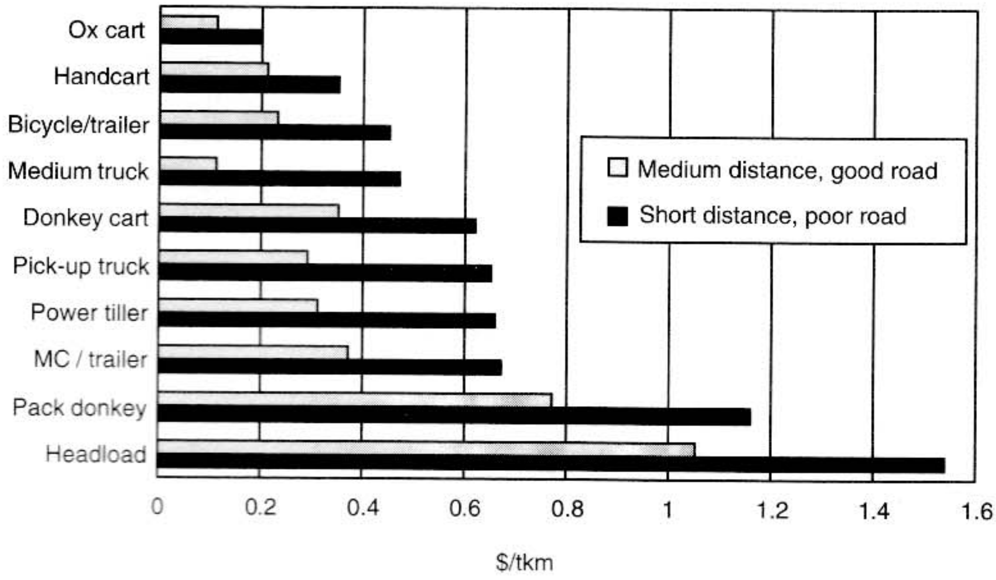


Figure 3.5 *Typical transport costs in Africa*

In urban areas, especially in Asian cities, non-motorized means of transport have an important role in transporting goods and passengers. More often than not, transport planners educated in the North ignore these modes and simply forget to implement adequate facilities, such as walkways, footbridges, bicycle lanes or loading facilities at markets. The lack of these facilities makes walking and cycling even more dangerous, cumbersome, time-consuming and costly. As a matter of course, this lack will have negative impacts on the use of public transport systems.

Improved land use planning

The spatial development in industrialized countries may be characterized as showing a concentration in the cities, which took place during the industrialization phase, followed by a process of massive suburbanization after the establishment of the automobile as the main mode of transport. During this period, urban sprawl took place not only along the railway lines, but in the entire suburban area around conurbations. Cars allowed for a decentralization of urban functions, making it possible to live in the countryside in a detached house and commute to the urban centre for work. Urban sprawl produced spatial structures that result in long commuting distances and developments that are less easy to accommodate to public transport systems. Given the lower energy requirements of public transport, suburbia is a settlement structure that entails large-scale energy inefficiencies in transport. An international comparison of cities (Kenworthy and Laube, 1999) shows that a strong relationship exists between urban density and car use (mileage). Higher-density locations result in lower specific energy consumption in transport.

Figure 3.6 *Similar population but different size*

In many developing countries the process of suburbanization is still in its early stages. Even so-called megacities, such as Cairo, cover a surface area that is only a small fraction of that occupied by cities in industrialized countries, such as Los Angeles, even though the two conurbations have about the same number of inhabitants. However, the tremendous urban growth, reaching levels up to 10 per cent annually, will lead to a rapid expansion of urban areas in most developing countries. Additionally, it can be expected that in the future, income in developing cities will increase and similar processes of suburbanization can be expected in the South.

Since spatial developments are very difficult to reverse, it is advisable to influence urban sprawl before car-dependent settlement structures have developed. The target is to create urban regions amenable to public transport, including a city of short travel distances. A number of urban and transport planning measures can be taken in order to achieve this goal. The city of short distances is liveable, needs less transport infrastructure, produces fewer external effects and consumes less energy in transport. If early measures are taken, the mistakes made in industrialized countries during past decades can be avoided in developing cities.

Financial planning under severe budget constraints

Tight budget constraints and constant lack of financial resources are salient features of developing countries. The fuel sector plays an important role in the economy of these countries. In the transport sector more than 90 per cent of transport modes use conventional fuel, much of which has to be imported. In low-income countries, fuel imports often represent up to one-third of all foreign imports, causing large imbalances of trade. Thus, measures to increase energy efficiency in transport have strong impacts on the whole economy of developing countries.

In addition, the fuel sector can be an important source of revenue for the state. Taxes on fuel and energy may comprise up to 36 per cent of all state taxes – or in the reverse case fuel subsidies may form a burden of up to 8 per cent of the state budget. Worldwide, revenues from fuel taxation finance roads. In Africa a fuel tax amounting to only US$0.10 is sufficient to finance the adequate maintenance of the whole road network. However, an overview of fuel taxation worldwide (GTZ, 2003a) shows that many developing countries do not even generate this minimum amount and thus the road networks continue to deteriorate. This not only implies a depreciation of the state's largest assets, but also forces the individual user to pay for higher transport costs. Every euro saved on maintenance costs the user three additional euros, mainly through increased vehicle operating costs. Therefore, pricing and taxation issues for conventional fuels are of prime importance in developing countries.

Next to the issue of revenue collection, fuel taxes may serve as a means of environmental taxation. Economic instruments are most important to achieve improvements of energy efficiency in transport. The instruments may serve to reinforce or support the above-mentioned measures regarding the introduction of renewable energy sources, transportation demand management and transport-avoiding land use planning. Conventional taxes such as fuel levies and vehicle licence fees may focus on the reduction of environmental effects of transport, such as by favouring more energy-efficient engines. Transport-specific instruments, environmentally oriented vehicle taxation, road tolls and spatially or temporally differentiated road pricing systems may serve as efficient tools with which to move regional transport patterns towards higher energy efficiency.

The potential for changing behaviour should not be underestimated. Training drivers to achieve an economically and ecologically sound driving style is a cheap method to save fuel and money, as well as contributing to road safety and the reduction of greenhouse gas emissions. The average reduction of fuel consumption amounts to 10 per cent. Payback periods of the training lessons are reasonably short. Nevertheless, development of the market for eco-driving is slow, at least in Europe.

CONCLUSIONS FOR INTERNATIONAL DEVELOPMENT COOPERATION

The cheapest and most promising means to reduce energy use in transport is through the improvement of energy efficiency, either by technical improvements or by modern urban planning approaches. This fact should be in the mind of each decision-maker who is interested in reducing environmental damage, human disease and the societal costs caused by the transport sector. But if serious predictions come true (for example, the price of oil remains at high levels of between US$40 and US$60/bbl) or further political targets are implemented (such as the European Directive on biofuels), renewable energies such as ethanol and biodiesel will come to play a more important role in transport. However, in each case energy efficiency should be paid special attention.

Currently, many developing countries are fascinated by biofuels, as they might have positive impacts on their economy and social situation. In industrialized countries the production capacities of fossil fuels as well as the potential of renewables can only satisfy a small share of the energy demand in transport. Therefore, developing countries expect to have the option of producing biofuels for export. As, ultimately, farmers have to produce and sell plants, this might have positive effects on rural development, where poverty prevails. However, social and economic conditions are so complex that no general predictions on sustainability can be made. Here, the key question is: what are the market conditions for the farmers? Can they take part in the creation of value or do they only produce for a very small income?

Furthermore, the ecological question is also not easy to answer. Environmental advantages are related to reduced GHG emissions; this is clear so far. But negative effects may occur through eutrophication, acidification and ozone depletion caused by excessive use of nitrogen fertilizers. Additionally, a serious risk is related to the further reduction and degradation of tropical forests. Appropriate farming methods, such as organic farming, are absolutely necessary to avoid substituting one problem by another.

The above deliberations show that the use of renewables in transport is related to a number of uncertainties regarding their sustainability, and the usage will be limited in the next decade. Therefore, a number of strategies to reduce energy consumption and thus improve energy efficiency in transport are recommended. Improved and more frequent technical inspection and maintenance of vehicles can improve energy efficiency significantly. Other strategies comprise measures from the 'traditional' repertoire of transport planners. Especially in the rapidly growing cities in developing countries, large-scale impacts can be expected. A modal shift towards more energy-efficient means of transport – or the retention of the existing high proportion of people walking, cycling or using transit systems – and the planning of cities with short distances are two issues that will be of crucial importance in order to secure liveable cities and reduce GHG emissions.

An important aspect is the expected urban sprawl of developing cities. If planning mistakes from the North, such as the establishment of car-dependent settlement structures, are to be avoided in the South, a planning approach that integrates transport and regional planning has to be taken. So far, neither donors nor decision-makers in developing cities seem to be aware of the future problems and they have yet to take appropriate measures.

To date, emission reductions from the transport sector have not played a significant role in the Kyoto mechanisms, such as the Clean Development Mechanism or Joint Implementation. Only a very few transport-related projects have been registered under these mechanisms. Action is urgently needed.

NOTES

1 The Toyota Prius, which can be used as a family vehicle, consumes 4.3 litres and, especially in urban areas, is without competitors with respect to noise and emissions (owing to the high efficiency of electric engines in urban transport).
2 *China Statistical Yearbook 2004*.
3 *Stuttgarter Zeitung*, 10 September 2005, p11.
4 *China Daily*, 31 October 2004.
5 GTZ (2003b, Module 5a: 'Air Quality Management', p28).
6 GTZ (2003b, Module 4b: 'Inspection & Maintenance and Roadworthiness').
7 GTZ (2003b, Module 4c: 'Two- and Three-Wheelers').
8 ITDG Practical Action Technical Brief on biogas and liquid fuels, www.itdg.org/docs/technical_information_service/biogas_liquid_fuels.pdf (accessed 1 November 2005).
9 Brazilian ethanol production from BEN 2005; US ethanol production from Renewable Fuels Association, 'Industry Statistics', at www.ethanolrfa.org (viewed 1 November 2005); world ethanol production from F.O. Licht World Ethanol and Biofuels Report, cited in Renewable Fuels Association, ibid; European production from Observ'ER, Biofuels Barometer', *Systèmes Solaire* (European Commission Directorate General for Energy and Transport), 13 June 2005.
10 On 9 October 2005 the price per gallon was $1.9597 (New York Harbor).
11 CNN, 19 August 2005.
12 Data used are from *Umweltbundesamt und Verkehr in Zahlen*, 2002/2003.
13 More information on bus rapid transit can be retrieved from GTZ (2003b, Module 3b).
14 For walking, travel time valuations are essential in order to estimate transport costs. Assuming an average load of 25 kg/person and a speed of 3 km/h, the transport of 1 tonne-kilometre requires 27 hours of travel time. Forty return trips covering a distance of 80 kilometres have to be walked.

REFERENCES AND FURTHER READING

Aßmann, Dirk (2003) *Akteure, Strukturen und Technologien für ein zukunftsfähiges Energiesystem*, Frankfurt am Main, Peter Lang Verlag

Berndes, Göran, Wakker, A., Egging, R., van Thujil, E., et al (2005) *Biofuel and Bio-energy Implementation Scenarios*, final report of VIEWLS WP5 modelling studies, Energy Research Centre of the Netherlands, Unit Policy Studies, Petten, the Netherlands, and Chalmers University of Technology, Energy and Environment, Department of Physical Resource Theory, Göteborg, Sweden

Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung (BMZ) (2003) *Transport und Verkehr – Zukunftsfähige Mobilität für eine gerechte und nachhaltige Entwicklung*, Bonn

Crossley, P. and Ellis, S. (1997) *A Handbook of Rural Transport Vehicles in Developing Countries*, Bedford, Silsoe College, TRL

EIA (1999) *Annual Energy Outlook 2000 – with Projections to 2020*, US Department of Energy

EIA (2004) *Annual Energy Outlook 2005 – with Projections to 2025*, US Department of Energy

Gesellschaft für Technische Zusammenarbeit (GTZ) (2003a) *International Fuel Prices*, 3rd edn, May, Eschborn. Download at worldbank.org/transport or http://zietlow.com/docs/engdocs.htm

GTZ (2003b) *Sustainable Transport: A Sourcebook for Policy Makers in Developing Cities*, Eschborn. See www.sutp.org/docs/sourcebook/sourcebook.aspx

GTZ (2004) *Transport in Developing Countries: Renewable Energy or Energy Reduction?*, a reader prepared for the Side Event at the Renewables 2004 Conference, edited by Niklas Sieber, Eschborn

Goldemberg, J., Coelho, S. T., Nastari, P. M. and Lucon, O. (2003) 'Ethanol Learning Curve – the Brazilian Experience', *Biomass and Bioenergy*, vol 26, no 3, pp301–304

Ingram, G. K. and Liu, Z. (1999) *Determinants of Motorization and Road Provision*, World Bank, Washington, DC

International Energy Agency (IEA) (2004) *Biofuels for Transport – An International Perspective*, Paris, IEA

Johansson, T., McCormic, K., Neij, L. and Turkenburg, W. (2004) *The Potentials of Renewable Energy*, Thematic Background Paper, International Conference for Renewable Energies, Bonn

Kartha, S., Leach, G. and Sudhir Chella Rajan (2005) *Advancing Bioenergy for Sustainable Development*, Guideline for Policymakers and Investors, three vols, Stockholm, Stockholm Environment Institute, Energy Sector Management Assistance Program (ESMAP)

Kenworthy, J. and Laube, F. (1999) *An International Sourcebook of Automobile Dependence in Cities 1960–1990*, Updated Edition, Boulder.

McClintock, H. (2001) *Comprehensive Transportation Planning Bibliography*, Institute of Urban Planning, University of Nottingham, www.nottingham.ac.uk/sbe/planbiblios/bibs

Newman, P. and Kenworthy, J. (1999) *Sustainability and Cities: Overcoming Automobile Dependency*, Island Press, Boulder

Quirin, M. et al (2004) *CO_2 Mitigation through Biofuels in the Transport Sector*, Heidelberg, IFEU Institut für Energie und Umweltforschung (IFEU)

Schmitz, N. (ed) (2005) *Innovationen bei der Bioethanolerzeugung und ihre Auswirkungen auf Energie und Treibausbilanzen*, Schriftenreihe 'Nachwachsende Rohstoffe', Band 26, Fachagentur Nachwachsende Rohstoffe, Gülzow

Sieverts, T. et al (1998) *Zwischenstadt zwischen Ort und Welt, Raum und Zeit, Stadt und Land*, Braunschweig and Wiesbaden, Bauwelt-Fundamente, Verlag Vieweg

Weber, M. (2004) *Bioethanol – Herstellung in Deutschland und Brasilien. Ein technischer, ökonomischer und ökologischer Vergleich*, Offenburg, University of Applied Sciences

World Bank (1994) *World Development Report 1994 – Infrastructure for Development*, Oxford University Press, New York

World Business Council for Sustainable Development (WBCSD) (2001) *Mobility 2001 – World Mobility at the End of the Twentieth Century and Its Sustainability*, WBCSD, Geneva

Wright, L. (2004) 'The Limits of Technology: Achieving Transport Efficiency in Developing Nations', GTZ, *Transport in Developing Countries: Renewable Energy or Energy Reduction?*, a reader prepared for the Side Event at the Renewables 2004 Conference, edited by Niklas Sieber, Eschborn

WTRG (2005) *Brent Spot Prices*, 25 January 2005, www.wtrg.com, London, WTRG Economics