# 6 Transportation

## What is covered in this chapter?

*Managing $CO_2$ emissions from transportation cannot be separated from managing congestion, air pollution, and oil imports. All of these problems emerge from the ever increasing transportation needs. The solutions overlap to a great extent. Understanding the drivers and the trends is a must. In terms of strategies to address the issues there is a hierarchy: reduce demand, shift transport modes, improve efficiency, and change the fuel. Policy intervention is needed to realize the many good options to drastically reduce congestion, air pollution, oil consumption, and $CO_2$ emissions.*

## Need for transportation

Mobility is an essential human need. Social relations and earning an income require transportation. Industrialization and specialization have created the need for shipments of large amounts of goods over short and long distances. Globalization of the economy has strongly accelerated this. Transportation of people and goods therefore is crucial for economic and social development.

In the year 2000 average transport per person ranged from 1700 km in Africa to 21 500 km in North America, reflecting the strong influence of income. About half the total passenger-kilometres was covered by cars[1], of course with huge differences between countries. The share of the different transport modes (so-called modal split) in cities varies a lot. Figure 6.1 shows the large share of public transport and walking/cycling in cities in areas other than North America and Oceania.

Historically there has been a strong correlation between income and car ownership (see Figure 6.2). At the same time there are marked differences. For similar income levels vehicle ownership in the USA is almost twice that in Denmark and 50% higher than in Switzerland, and in New Zealand it was more than twice that in South Korea despite having the same income. The most important consideration is of course how countries like China and India, still at the bottom of the curve, are going to develop. Will they go the American way or the Japanese/European way, or can they manage to keep car ownership at a lower level?

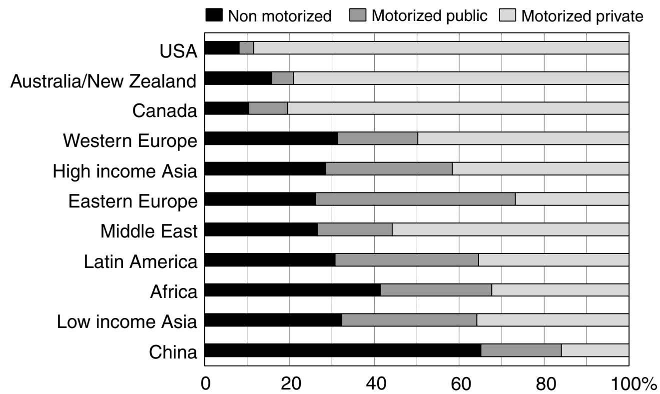



**Figure 6.1** **Share of different transport modes in selected cities in 1995. Indicated is the percentage of trips taken with the respective transport mode.**

*Source*: IPCC Fourth Assessment Report, Working Group III, figure 5.17; original data from Millennium Cities Database for Sustainable Transport.

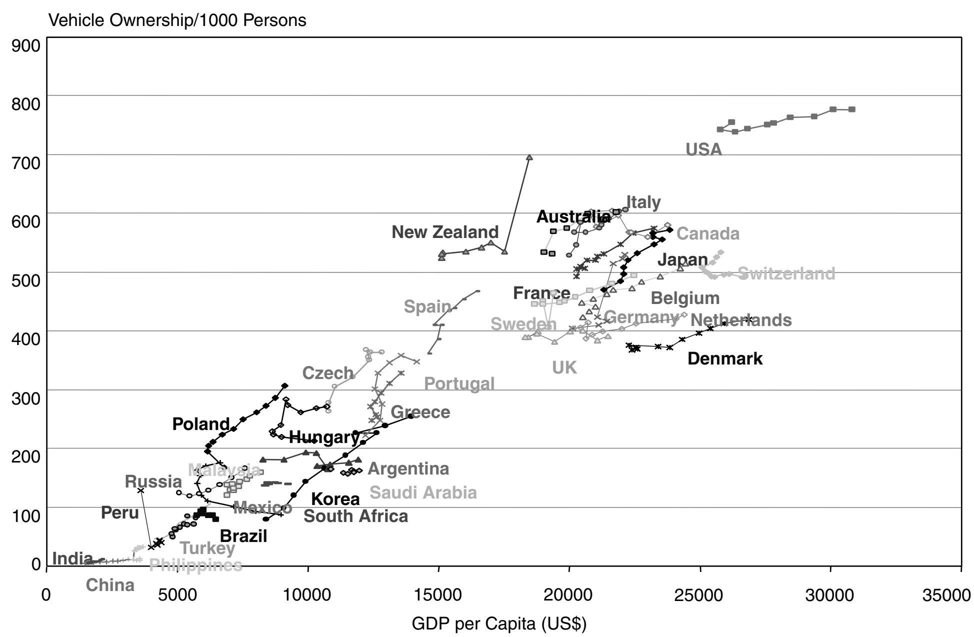



**Figure 6.2** **Comparison of vehicle ownership between countries as a function of per capita income. Data for the period 1990–2000 (with some differences for specific countries).**

*Source*: IPCC Fourth Assessment Report, Working Group III, figure 5.2. See Plate 12 for colour version.

Freight transport has roughly doubled over the past 30 years. Globally, in the year 2000, 70% of freight (measured as tonnes x kilometers) was transported by sea going ships[2], 15% by rail, and 15% by road. The rail/road ratio varies strongly between countries. In Western Europe it is now 16/84, in Eastern Europe 35/65 (in 1990 it was still 65/35!)[3], and in the USA it is 42/58[4]. The trend towards more road transport and away from rail has been stimulated by specialization in industry: production of parts and half-products, assembly, and processing are happening in different places; large retail firms have centralized their distribution centres; and companies have downsized their warehouses, resulting in 'just-in-time delivery', which means their supplies are on the road in a truck rather than in their warehouses.

## Development and climate implications

### Energy security implications

The transport sector used about 20% of total primary energy in 2006[5], almost all of it in the form of oil products. It consumes about half of all oil. Road vehicles represent more than three quarters of this, with passenger vehicles alone accounting for 45% of the total energy, trucks 25%, and buses 8%. Aviation, shipping, and rail transport together cover 20% of energy use[6]. Energy use in the transport sector has almost doubled between 1970 and 2000 and is still growing strongly at a little less than 2% per year. Oil imports in many countries are high (see Table 6.1), causing energy security concerns and putting pressure on foreign currency reserves.

### Traffic congestion and health impacts

Traffic congestion has become an almost universal problem in urbanized areas of the world. On weekdays downtown traffic speeds in Bangkok, Manilla, and Mexico City are 10 km/hour or less and in Sao Paolo and Kuala Lumpur 15 km/hour or less. Bicycles are faster. Public transport costs in Rio de Janeiro and Sao Paolo have increased by 10% and 16% respectively due to congestion. In Jakarta, Lagos, Manilla, and Kinshasa city trips on average last more than 1 hour. Economic losses due to congestion in many developing country cities are between 2% and 6% of local GDP, even though vehicle ownership in many of these cities is still relatively low[7].

In Chapter 4 the growing problem of air pollution in cities is discussed. More than 700 000 people die prematurely every year due to exposure to small particles in air. Traffic is a main source of that air pollution.

### Greenhouse gas emissions

Greenhouse gas emissions from the transport sector were about 13% of the global total in 2004 (see Figure 6.3). In most countries more than 95% of all emissions is in the form of $CO_2$, with small contributions from $N_2O$ (from vehicles with catalytic converters) and fluorinated gases (from air conditioners)[8].

**Table 6.1. Oil import dependency of selected countries**

| Country | Oil import as % of consumption 2007 | Expected oil import as % of consumption 2030 |
|---|---|---|
| USA | 65 | 62 |
| EU-27 | 82 | 92 |
| Australia/New Zealand | 92 | 89 |
| China | 51 | 74 |
| India | 72 | 92 |

*Source*: IEA, WEO 2008 reference scenario.

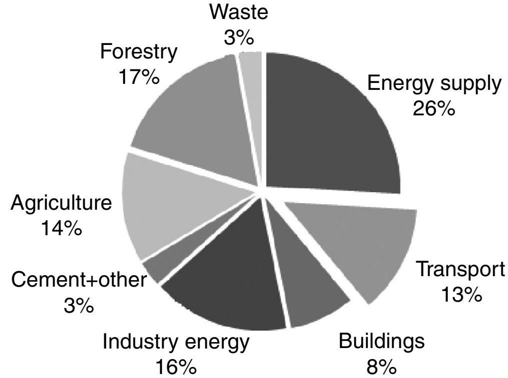



**Figure 6.3** **Transport sector contribution to global greenhouse gas emissions in 2004.**
*Source*: IPCC Fourth Assessment Report, Working Group III, ch 1.

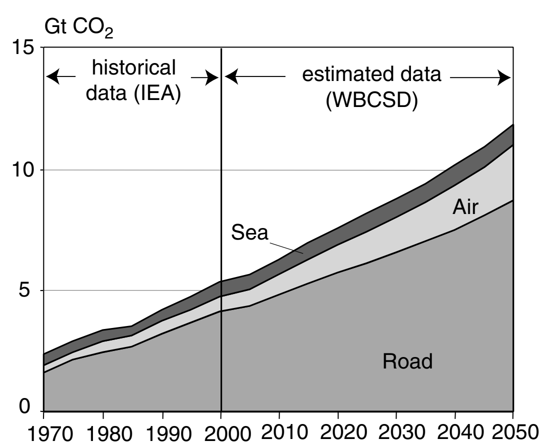



**Figure 6.4** **Historic and projected $CO_2$ emissions from transport.**
*Source*: IPCC Fourth Assessment Report, Working Group III, figure 5.4.

The number of vehicles in the world today is about 900 million. By 2030 it is expected to be around 2.1 billion[9]. Freight transport (tonnes x kilometres), total energy use for transportation, and transport emissions in 2030 are projected to be roughly twice current levels. Developing countries' share of emissions, now about one-third, is expected to reach close to half of the total by 2030 (see also Box 6.1). Figure 6.4 shows the projected growth in $CO_2$ emissions from global transport.

**Box 6.1 Transport in India**

Transport in India is going through a rapid transition. Cars still provide less than 10% of all passenger kilometres, and public transport (rail and bus) about two-thirds. Car sales however are now growing by about 30% a year, showing that incomes in India are at the tipping point of car ownership. The introduction in 2007 of the TATA Nano, a UA$2500 car for the Indian market, and plans of other automakers to launch similar cheap models, reflects that as well. Car ownership is projected to grow from less than 10 million now to about 100 million in 2030. In addition there is a strong growth in motorbike ownership: 17% annual growth between 1990 and 2000 and an estimated increase to about 300 million motorbikes in 2030. Public transport is loosing ground because of lack of quality and traffic congestion (current average bus speed in cities is 6–10 km/hour). Serious air pollution from traffic, increasing oil imports, and one of the highest rates of road traffic accidents complete the picture.

Several policy initiatives have been developed to counter this trend: the National Urban Transport Policy, a combination of city planning, building metro and modern bus systems, providing dedicated space for public transport and introducing parking fees; the National Auto Fuel Policy, promoting cleaner fuels such as Compressed Natural Gas; and the Jawaharial Nehru Urban Renewal Mission, to provide cities with funding for structural changes in city planning. Analysis of what these policies can mean in moving towards a more sustainable transport system shows that transport energy use (and oil imports and $CO_2$ emissions) could be 30% lower than in a scenario without policy, a reduction equivalent to all of the transport energy used in India today. It also would lead to retaining a share of public transport of about 60% of all passenger travel (provided by modern and clean buses and trains), which would be an enormous contribution to creating liveable cities.

(Source: Schipper et al. $CO_2$ emissions from land transport in India, Transportation Research Record, 2009, in press)

Whether there is sufficient oil to fuel all this new transportation is addressed in Chapter 5. The conclusion drawn there is that conventional and unconventional oil resources, and liquid fuel production from coal and gas, can easily supply the required amounts, albeit with high $CO_2$ emissions.

## Aviation and shipping[10]

The contribution from aviation is growing rapidly. Expected annual growth rates of 4–5% for passenger traffic and around 6% for freight traffic in the period till 2030 will mean that aviation will have a share of about 15% of the transport emissions by the end of that period, despite better fuel efficiency of aircraft. And that is 15% of a total that is much bigger than today. In addition, emissions from aviation are more harmful than other transport emissions, because of the altitude where they take place. Water vapour and NOx emissions alter the concentrations of the greenhouse gases ozone and methane and form condensation trails. Together this leads to a warming effect that is 2–4 times as big as that from $CO_2$ alone[11].

World shipping (expressed as tonnes freight x distance) is growing by about 5% per year. $CO_2$ emissions are now 0.8 $GtCO_2$/year, double the amount that was mentioned in the IPCCs 4th Assessment[12]. For 2020 the increase is about 30%; for 2050 it could be 300%.

## How can transport emissions be reduced?

Asking about reduction of emissions is actually the wrong question to start with. The first question should be how transport itself can be controlled to get rid of congestion, air pollution, and rising oil imports, issues that are high on the political agenda in most countries. $CO_2$ emissions will follow. Except for building more roads to ease congestion, a strategy that has generally failed because it just attracts more traffic, solving congestion, air pollution, and growing oil imports goes hand-in-hand with reducing $CO_2$ emissions. An integrated transport policy would consist of the following elements:

- *reduce demand*: lower need for transport
- *shift means of transport*: shifting to other space saving and less polluting and $CO_2$ emitting transport modes
- *improve efficiency*: reduce the fuel consumption of vehicles, ships, and aircraft
- *change the fuel*: shift from oil products to less polluting and $CO_2$ emitting fuels

## Reducing demand

The place where people live, work, go to school, or take part in recreational activities drives transport. About half of all people in the world now live in cities and that percentage is expected to increase to 70% by 2050[13]. The way cities are designed therefore determines transport needs. But so does income. With more money to spend there is the option of moving to suburban areas with nicer homes, requiring a commute to work. People with a higher disposable income also want to travel more for leisure. In many cities people are forced to live further and further away from the city centre, because they cannot afford to live closer, and to commute to work in the city centre. That puts pressure on governments to keep travel cheap, although making it more expensive would provide an incentive to choose a place to live closer to work. Then there is the 'law of constant travel time'. With faster means of transport people are travelling (to work) longer distances, keeping the time spent on commuting constant. Finally there is the possibility of so-called telecommuting (working at home made possible by the internet). These are the factors that influence transport demand.

So let us look at how much reducing transport demand can deliver in terms of reduced congestion, air pollution, oil imports, and emissions. Building compact cities helps, with workplaces, shops, schools, recreational, and residential areas not too far apart. This would require conscious decisions to go against the trend, but it is possible. What also helps is to make it affordable and attractive to stay in city centres, or creating suburbs with a good mixture of work and living places. Experience makes it very clear: the higher the density of people and jobs, the lower the demand for transport. Cities like Vancouver, Melbourne, Vienna, Perth, and Toronto, the top 5 in the Economist's Most Liveable Cities list[14], have managed to achieve this, in addition to providing enough space and green areas (see also Box 6.2 on Copenhagen). The building of cities however is a slow process and changing their design even more so. Only in rapidly growing cities in developing countries can this make a difference for transport emissions in the near term.

Information on the effect of the price on transport demand usually covers both demand reduction (such as car-pooling) and shifting away from car travel to other transport modes. So it is very hard to give an accurate picture. Parking charges proved to be quite effective in promoting car-pooling[15]. For poor people the effect is the clearest: an increase in bus or bush-taxi fares can prevent them from travelling. But that is of course not what should be aimed for. Basic services should be preserved. For air travel over longer distances no real alternative exists. Price increases do have more of an effect here. The relative cost of different transport modes and the possibility of people choosing other means of transport will be discussed in the next section.

Experience with telecommuting (working from home via internet connections) shows rather modest results in terms of reducing travel. In the USA, the reduction in vehicle kilometres travelled is estimated to be not more than 2%[16]. Some of the gains by not commuting to work are lost via additional trips for other reasons during the day.

Freight transport demand reduction would have to come from a change in the current 'just-in-time' delivery structure and reduced national and international specialization. This would only happen in the longer term and needs a strong price signal. If it becomes cheaper to build warehouses and have deliveries done in big volumes than keeping stock on the road, then something may change; likewise if it becomes cheaper to carry out processing of materials in one place, rather than in multiple locations. Fuel price increases are probably not going to be sufficient. Road taxes or tolls would also have to increase substantially.

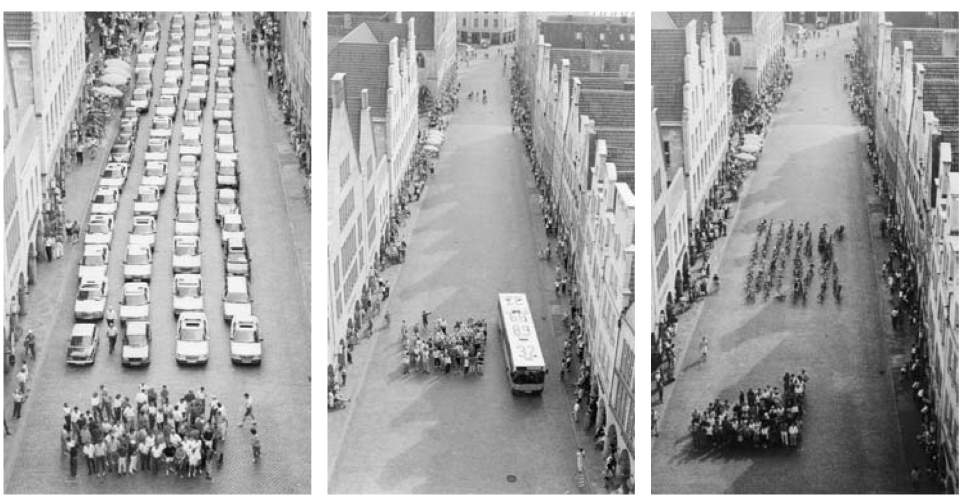
For the period till 2030, the prospects for significant changes in transport demand compared to the trend (not counting modal shift) is poor, except for rapidly developing cities in developing countries. Over longer periods of 50 years or more however the strategy of reducing demand through structural changes in urban planning and industrial manufacturing can have a much bigger impact.

## Shifting transport modes

Moving people from A to B in private cars is very inefficient. Average occupancy of cars in Melbourne, Australia is about 1.2 people per car. In the UK it is 1.6. In developing countries it is usually much higher. Figure 6.5 shows how much more space is required to move 100 people with cars, compared to that for bus or bike transport. Car travel produces more pollution, more $CO_2$, and requires more fuel.

The carbon intensity of passenger transport modes varies greatly. Walking and cycling produce zero $CO_2$ emissions. Emissions from buses, trams, metro, and trains vary with the fuel or electricity used and the occupancy, but are generally lower than for private vehicles or motorbikes. Occupancy has a large influence. For developing country circumstances (with relatively high occupancy per vehicle) Table 6.2 gives a comparison of emissions per passenger kilometre. Note that even when bus occupancy is down to 10 people, it is still lower in $CO_2$ emissions than a car with 2.5 people. Single occupancy cars (heavily used for commuting to work everywhere) cannot compete with anything.

What drives the choice of transport mode? Income and costs are very important. Currently, more than 3 billion people in the world cannot afford a car. They rely on walking, bicycles, motorbikes, and buses. With rising incomes, more people will one day realize their dream of buying a car (see Figure 6.2). This tells us three things: (1) the majority of people are better served by good public transport and safe cycling and walking spaces than by building roads (note: the car industry is politically very influential); (2) if public transport is good, people may postpone or refrain from buying a car; and (3) even if people have a car, it is still possible to encourage them to use public transport. Increasing the cost of parking, congestion charges as applied in London,



(a) (b) (c)

**Figure 6.5 Space required for transporting the same number of people by (a) car, (b) bus, or (c) bicycle.**
*Source*: UNEP GEO4; original picture from the city of Muenster in Germany.

**Table 6.2. Greenhouse gas emissions from different transport modes in developing countries**

| | Load factor (average occupancy) | $CO_2$-eq emissions per passenger-km (full energy cycle) |
|---|---|---|
| Car (gasoline) | 2.5 | 130–170 |
| Car (diesel) | 2.5 | 85–120 |
| Car (natural gas) | 2.5 | 100–135 |
| Car (electric)[a] | 2.0 | 30–100 |
| Scooter (two-stroke) | 1.5 | 60–90 |
| Scooter (four-stroke) | 1.5 | 40–60 |
| Minibus (gasoline) | 12.0 | 50–70 |
| Minibus (diesel) | 12.0 | 40–60 |
| Bus (diesel) | 40.0 | 20–30 |
| Bus (natural gas) | 40.0 | 25–35 |
| Bus (hydrogen fuel cell)[b] | 40.0 | 15–25 |
| Rail Transit[c] | 75% full | 20–50 |

*Note*: All numbers in this table are estimates and approximations and are best treated as illustrative.
[a] Ranges are due largely to varying mixes of carbon and non-carbon energy sources (ranging from about 20–80% coal), and also the assumption that the battery electric vehicle will tend to be somewhat smaller than conventional cars.
[b] Hydrogen is assumed to be made from natural gas.
[c] Assumes heavy urban rail technology ('Metro') powered by electricity generated from a mix of coal, natural gas, and hydropower, with high passenger use (75% of seats filled on average).
*Source*: IPCC Fourth Assessment Report, Working Group III, table 5.4.

Singapore and a few other cities[17], and lowering the cost of public transport are important measures.

Time spent on commuting is another important driver for deciding on the means of transport. If the car can get you to work quicker (and more comfortably), then taking public transport does not look very attractive, even if it is cheaper. Of course this only applies if income is not a constraint. So developing an efficient and streamlined public transport system on the one hand, and making car travel slower through speed limits and reducing capacity on the other, should go hand-in-hand. Many cities have understood this and are now reserving specific lanes for buses, taking the capacity away from private vehicles and increasing the speed of public transport.

Figure 6.1 shows the large differences in the contribution of private cars to transport in cities around the world. Developing countries can go in two possible directions: the North American/Australian way with a dominance of private cars or the high income Asia/Western European way with a much larger share of non-motorized and public transport.

City planning is key to shifting transport modes. Ensuring new housing developments have excellent access to public transport, reducing parking space, limiting access and speed of vehicles, pedestrian streets, good walking and cylcing facilities, and clean and reliable public transportation can make a big difference. Asian cities like Singapore, Hong Kong, and Shanghai are applying these principles. Maintaining urban density is a key condition for making such an approach cost effective (see Figure 6.6 and Box 6.2 on Copenhagen).

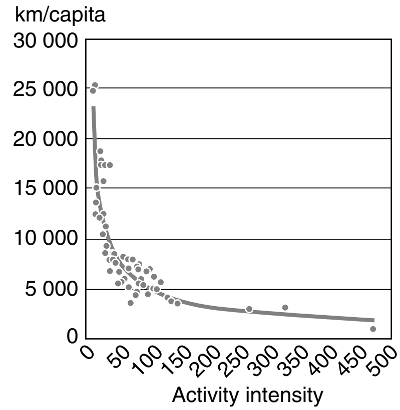



**Figure 6.6** **Personal car use as a function of the density of people and jobs in 58 higher income cities.** *Source*: UNEP GEO4.

**Box 6.2** **Copenhagen's 10-step programme towards a low-car/high-bike liveable city**

**1. Convert streets into pedestrian thoroughfares**
The city turned its traditional main street, Strøget, into a pedestrian thoroughfare in 1962. In succeeding decades they gradually added more pedestrian-only streets, linking them to pedestrian-priority streets, where walkers and cyclists have right of way but cars are allowed at low speeds.

**2. Reduce traffic and parking gradually**
To keep traffic volume stable, the city reduced the number of cars in the city centre by eliminating parking spaces at a rate of 2–3% per year. Between 1986 and 1996 the city eliminated about 600 spaces.

**3. Turn parking lots into public squares**
The act of creating pedestrian streets freed up parking lots, enabling the city to transform them into public squares.

**4. Keep scale dense and low**
Low-slung, densely spaced buildings allow breezes to pass over them, making the city centre milder and less windy than the rest of Copenhagen.

**5. Honour the human scale**
The city's modest scale and street grid make walking a pleasant experience; its historic buildings, with their stoops, awnings, and doorways, provide people with impromptu places to stand and sit.

**6. Populate the core**
More than 6800 residents now live in the city centre. They've eliminated their dependence on cars, and at night their lighted windows give visiting pedestrians a feeling of safety.

**7. Encourage student living**
Students who commute to school on bicycles don't add to traffic congestion; on the contrary, their active presence, day and night, animates the city.

**8. Adapt the cityscape to changing seasons**

Outdoor cafés, public squares, and street performers attract thousands in the summer; skating rinks, heated benches, and gaslit heaters on street corners make winters in the city centre enjoyable.

**9. Promote cycling as a major mode of transportation**

The city established new bike lanes and extended existing ones. They placed bike crossings – using space freed up by the elimination of parking – near intersections. Currently 34% of Copenhageners who work in the city cycle to their jobs.

**10. Make bicycles available**

People can borrow city bikes for about US$2.50; when finished, they simply leave them at any one of the 110 bike stands located around the city centre and their money is refunded.

(Source: http://www.metropolismag.com/html/content_0802/ped/)

Latin America led the way with development of modern, clean, and fast bus systems (Bus Rapid Transit systems; BRT). Curitiba in Brazil was for a long time an isolated example, but now BRT systems are found in more than 40 cities around the world and many more big cities are planning BRT systems (see Box 6.3).

**Box 6.3** **Bus Rapid Transit Systems in Latin American cities**

Bus Rapid Transit is a bus-based public transport system for big cities, characterized by: safe, clean, comfortable, and modern buses; high speed by using dedicated bus lanes, preferences at traffic lights and intersections, and high frequencies; and integration with follow-up transport to residential areas. They started in Latin America and now altogether more than 40 cities on six continents have a BRT system, including in developed countries (see table below). BRT systems have proven to be relatively low cost (US$1–8 million per kilometre, compared to light rail US$10–30 million and metro US$50–300 million), allowing systems to operate without subsidies. They can be installed relatively quickly (1–3 years from inception). They can have capacities of 13 000 to 45 000 passengers per hour in each direction of a BRT line. They reach speeds of 23–30 km/hour on average. Key success factors for BRT systems are:

- Careful analysis of transport demand and selection of bus corridors
- Including provision of good ‘follow-up’ transport in the form of safe ways to walk, cycle, or use smaller buses
- Easy and tamper free fare collection systems (coin machines, magnetic cards, smart cards)
- Friendly staff and security personnel
- City planning to concentrate residential and commercial buildings around the bus corridors
- Public participation in the design stage and an active marketing strategy during operation

BRT systems are revolutionizing public transport – see table below (from Bus Rapid Transit Planning Guide).

Cities with BRT systems, as of March 2007

| Continent | Country | Cities with BRT systems |
|---|---|---|
| Asia | China | Beijing Hangzhou, Kunming |
| | India | Pune |
| | Indonesia | Jakarta (TransJakarta) |
| | Japan | Nagoya (Yutorito Line) |
| | South Korea | Seoul |
| | Taiwan | Taipei |
| Europe | France | Caen (Twisto), Clermont Ferrand (Léo 2000), Lyon, Nancy (TVR line 1), Nantes (Line 4), Nice (Busway), Paris (RN305 busway, Mobilien, and Val de Marne busway), Rouen (TEOR), Toulouse (RN88) |
| | Netherlands | Amsterdarn (Zuidtangent), Eindhoven, Utrecht |
| | UK | Bradford (Quality Bus), Crawley (Fastway), Edinburgh (Fazdink), Leeds (Superbus and Elite) |
| | Germany | Essen (O-Bahn) |
| Latin America and Caribbean | Brazil | Curitiba (Rede Integrada), Goiania (METROBUS), Porto Alegre (EPTC), Sâo Paulo (Interligado) |
| | Chile | Santiago (Transantiago) |
| | Colombia | Bogotá (TransMilenio), Pereira (Megabus) |
| | Ecuador | Quito (Trolé, Ecovía, Central Norte), Guayaquil (Metrovía) |
| | Guatemala | Guatemala City (Transmetro) |
| | Mexico | León (Optibus SIT), Mexico City (Metrobus) |
| North America | Canada | Ottawa (Transitway) |
| | United States | Boston (Silver Line Waterfront), Eugene (EmX), Los Angeles (Orange Line), Miami (South Miami-Dade Busway), Orlando (Lynx Lymmo), Pittsburgh (Busway) |
| Oceania | Australia | Adelaide (O-Bahn), Brisbane (Busway), Sydney (T-Ways) |

Cities with BRT systems under construction as of March 2007

| Continent | Country | Cities with systems under construction |
|---|---|---|
| Africa | Tanzania | Dar es Salaam |
| Asia | China | Jinan, Xi'an |
| Europe | France | Evry-Sénart, Douai, Clermont-Ferrand |
| | Italy | Bologna |
| Latin America and Caribbean | Colombia | Bucaramanga, Cali, Cartagena, Medellin |
| | Venezuela | Barquisimento, Mérida (Trolmérida) |
| North America | United States | Cleveland |
| Oceania | Australia | Canberra |
| | New Zealand | Auckland (Northern Busway) |

(Source: Bus Rapid Transit Planning Guide, http://www.itdp.org/documents/BRTPG2007%202007%2009.pdf and Fulton L. Emissions and Transport: a global perspective, ADB Conference on Climate Change Mitigation in the Transport Sector, Manilla, 2006)

Information is very scarce on how much emissions of $CO_2$ can be reduced through land use planning and policies on modal shift. Studies for Delhi (India), Shanghai (China), and Santiago (Chile) suggest that a strong policy package can halve emissions in cities compared to business as usual by 2020[18]. However, caution is needed, because in many instances new and cheap public transport facilities have drawn their users from other forms of public transport or from those who walked or cycled[19].

Reliable cost estimates are even scarcer and, if available, usually allocate all costs of the package to $CO_2$ reduction. That is of course very unfair, because the benefits of reduced congestion, reduced air pollution, reduced oil imports, and, maybe even more importantly, a more liveable city also need to be taken into account. Some calculations for Bus Rapid Transit Systems in some Latin American cities cite a cost of about US$30 per tonne of avoided $CO_2$ for a package of measures that would reduce emissions by 25% compared to business as usual[20]. Bringing in the other benefits would drastically reduce the costs, which makes these policies very cost effective.

## Freight transport and modal shift

For freight transport, rail and shipping have about 5 times lower $CO_2$ emissions per tonne kilometre than road transport (see Table 6.3). Nevertheless the trend has been away from rail and towards road trucks as indicated above. Changing freight transport from road to rail or water is however difficult and costly in most places, due to absence of rail connections or waterways, crowded railway systems, and need for additional transport from port or railway station. In terms of getting trucks off the road and improving congestion and air pollution it is fairly attractive, since small reductions in traffic volume

Table 6.3. $CO_2$ emissions per tonne kilometre for different freight transport modes

| Freight transport mode | Average $CO_2$ emissions (grams per tonne kilometre) | Remarks |
|---|---|---|
| Inland shipping | 31 | |
| Ocean shipping | 14 | Varies from 8 for bulk tankers to 25 for container ships and 124 for refrigerated cargo ships |
| Rail | 23 | Mix of electric and diesel trains |
| Road | 123 | Varies from 92 for heavy trucks to 400 for light trucks |

*Source*: EEA, TERM 2007 and 2003: indicators tracking transport and environment in the European Union.

can have a relatively large effect. Switzerland is currently undertaking a large programme of expansion in its rail infrastructure to shift environmentally damaging transalpine road freight transport towards rail[21].

## More efficient fuel use

### Passenger vehicles

New cars in Europe have become 30% heavier during the last 30 years[22], while fuel consumption has improved by 25% or so. So much of the progress in producing more efficient engines and transmissions has been cancelled out by heavier cars and more horsepower. In the USA fuel consumption of new cars has not improved for the last 25 years[23] and the share of SUVs (Sports Utility Vehicles like four wheel drives) with much higher fuel use has increased enormously. How can this trend be reversed?

Technically, drastic reductions in fuel use are possible. Just look at the cars on the market today. Fuel consumption of one of the best new passenger vehicle for sale (Toyota Prius hybrid) is about 1 litre for 20 km[24,25], while the average fuel consumption of all cars in the USA in 2005 was about 1 litre for 7 km[26]. In terms of $CO_2$ emissions per kilometre, a Toyota Prius emits about 105 g/km, compared with the average new car sold in Europe in 2005 emitting 161 g/km[27] (a Lamborghini Diablo about 520 g/km).

By improving aerodynamics, reducing size, reducing weight (with lighter materials such as aluminium and plastic), reducing power (smaller engines), further improvements in engines and overall design, and choosing (clean) diesel and hybrid systems (gasoline and electric combined; see Box 6.4), new cars by 2030 could be about 50% more fuel efficient than the best car for sale today[28]. Hybrid cars have a big role to play. For a significant reduction in transport $CO_2$ emissions their market share of newly sold cars would have to grow to something like 75% in 2030. Additional costs of hybrid and diesel hybrid vehicles by 2030 are estimated at US$3500–4500 per vehicle, but they are earned back within the lifetime of the vehicle (see also Table 6.5 below).

If fuel efficiency of new vehicles is halved by 2030, total transport energy use and emissions as a result of efficiency improvement only could then be reduced by 5–10% compared to business as usual[29]. Not a big contribution to the necessary reduction of emissions, but that is because cars on average last 10–20 years and changes in the fuel efficiency of the whole car fleet are slow. A 5–10% reduction in oil imports could be a useful contribution to improving energy security. The good news is that at oil prices above US$60 per barrel these measures together earn themselves back well within the lifetime of the vehicle.

Are more aggressive fuel efficiency improvements for the car fleet as a whole possible? A realistic way to speed up penetration of fuel efficient vehicles would be to take older, inefficient cars out of circulation. Such 'buy back' programmes have been applied at limited scale and have low cost per tonne of $CO_2$ avoided.

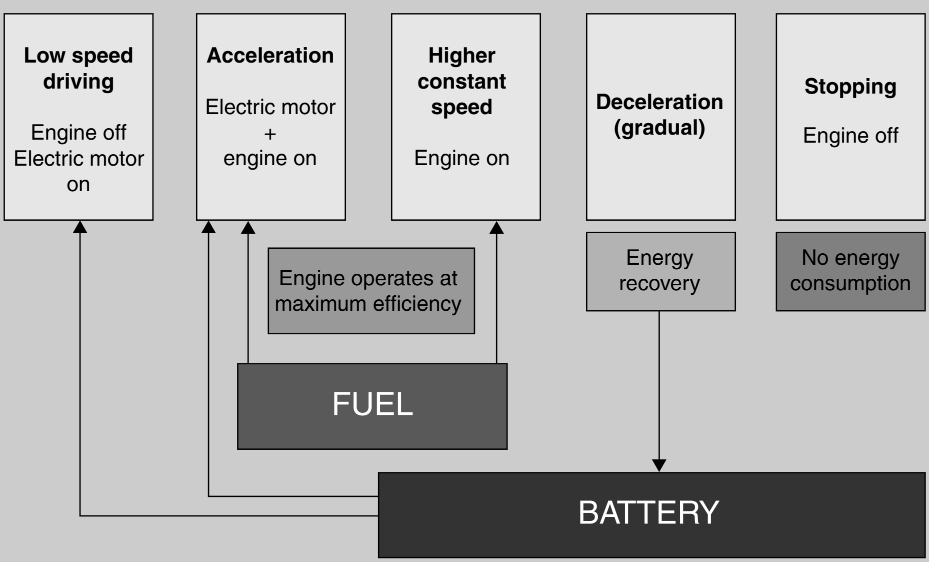
**Box 6.4** **Hybrid cars**

Hybrid vehicles get their higher fuel efficiency from the following features (see diagram below):

- Using an electric motor to drive the vehicle at low and constant speed
- Using the gasoline or diesel engine only to recharge the battery and provide additional electric power when accelerating
- Capturing energy when braking and storing that in the batteries

The gasoline/diesel engine only runs to produce electric power, which makes it much more efficient. Particularly in city traffic with frequent stops and idling, the brake energy recovery and engine switch off make hybrids so efficient.

Hybrid electric engines are also applied in rail locomotives, buses, trucks, and submarines.




**How hybrid vehicles save fuel.**
*Source*: King Review of low-carbon cars, part I, UK Treasury, 2007.

## Policy matters

The problem is this scenario of strong efficiency improvement cannot happen without fuel efficiency standards legislation. Experience in North America (frozen fuel efficiency standards between 1980 and 2006 and increased purchases of gas-guzzling SUVs), Japan (an increase in fuel use between 1985 and 2000), and Europe (a slowly declining fuel use and a failing voluntary agreement with automakers to reduce $CO_2$ emissions) shows that stronger policies are required. Fuel prices alone are also insufficient. Average European fuel consumption of newly sold cars is about 20% lower than in North America[30], as a result of taxes leading to three times higher fuel prices. With such differences in fuel prices one would have expected much better fuel efficiencies of European cars. However, when people decide on the purchase of a car, fuel efficiency is simply not an important factor, although differentiating (high European) car purchase taxes according to fuel efficiency can make some difference[31].

The European Union has introduced a legal $CO_2$ emissions standard of 130 g $CO_2$ per kilometre to be achieved by 2012–2015 and is discussing lowering these standards for 2020. Figure 6.7 compares standards in various countries and states.

## Freight transport

Freight transport fuel efficiency should not be measured in kilometres per litre as for passenger vehicles, because it is the tonnage that matters. The correct unit is tonne

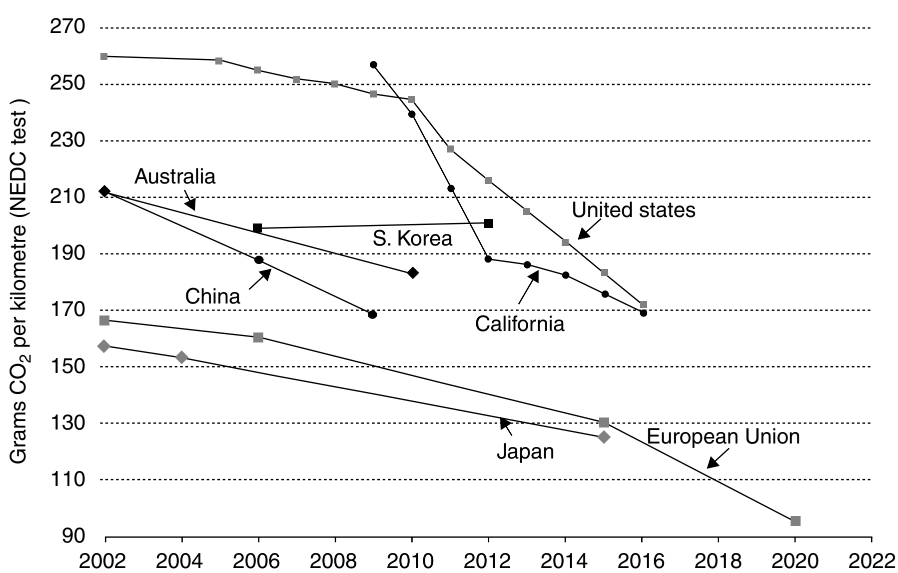



**Figure 6.7 Actual and projected greenhouse gas emission standards for new passenger vehicles by country.**
*Source*: ICCT, Passenger vehicle greenhouse gas and fuel economy standards: a global update, August 2008.

kilometres per litre or for emissions grams $CO_2$ per tonne kilometre. Table 6.3 shows the emissions of various freight transport modes. What efficiency gains can be made?

Technically a lot can be done to make trucks more fuel efficient by improving aerodynamics, tyres, engines and transmission, electrifying heating and lighting in stand-still mode, and introduction of hybrid electric systems. Hybrid electric trucks are particularly interesting for delivery vehicles, buses, etc. that make frequent stops where recovery of breaking energy makes sense. For long-haul trucks the advantages are small. In addition, limiting maximum speed through built-in speed controllers also can contribute significantly. There is an interesting behavioural factor here. In many countries drivers are paid by the distance they cover, so they have incentives to move as fast as possible. This is bad for fuel efficiency and road safety. Changing the payment system would make roads safer and reduce fuel use.

Altogether by 2030 freight truck fuel consumption and $CO_2$ emissions per tonne km could be reduced by 20–30%[32] compared to today. This does not include the gains that could be made by increasing the weight allowed (to be accompanied by lowering speed for safety reasons). Emissions per tonne kilometre in Australia where larger trucks are allowed are 20–50% lower than in Europe or North America[33]. Improved logistics (minimizing empty trucks) through ICT systems can also make a contribution, although only substantially higher transportation costs are likely to create meaningful incentives. Congestion is increasing fuel consumption, so there is a strong correlation between managing congestion and reducing $CO_2$ emissions.

In terms of policy for improving truck fuel efficiency governments have mostly relied on financial incentives, such as fuel taxes and toll charges. The reasoning is that freight companies are very motivated to reduce costs in light of the competition. So far only Japan has introduced fuel efficiency standards for new trucks, and those may be needed to speed up the penetration of advanced technical options.

The potential for improvements in fuel efficiency of freight transport by ships, rail, and aircraft is mixed. For shipping a combination of technical and operational measures could deliver $CO_2$ emission reductions of more than 30% compared to business as usual, which would still lead to an increase of total $CO_2$ emissions of shipping. The use of alternative fuels that could realize further reductions is discussed below. Opportunities for freight rail efficiency improvement are poorly studied and contributions to $CO_2$ reduction would probably be marginal. Air freight is growing strongly. Opportunities for fuel efficiency improvements are limited because of the slow turnover of airplanes. Fuel use and $CO_2$ reductions of 10–20% compared with business as usual are possible when $CO_2$ prices go up to 50–100 US$/tonne $CO_2$ avoided.

## Change the fuel

Fuel efficiency improvements only have limited influence in the short term. Other measures are needed to significantly reduce oil consumption, air pollution, and $CO_2$ emissions. Changing the fuel is the only big option left. What are the alternatives?

**Table 6.4. Main producers of biofuels in 2005**

| Country | Ethanol (Mtoe) | Biodiesel (Mtoe) | Total (Mtoe) |
|---|---|---|---|
| USA | 7.5 | 0.22 | 7.72 |
| Canada | 0.12 | 0.00 | 0.12 |
| EU | 0.48 | 2.53 | 3.01 |
| Brazil | 8.17 | 0.05 | 8.22 |
| China | 0.51 | 0.00 | 0.51 |
| India | 0.15 | 0.00 | 0.15 |
| WORLD | 17.07 | 2.91 | 19.98 |

*Source*: IEA WEO 2006.

## Biofuel

The most discussed alternative is biofuel, i.e. alcohol or diesel fuel produced from plants. There are a number of processes for producing biofuels (see Figure 6.8). Fuel alcohol is produced commercially today from sugar cane, maize, wheat, and sugar beet. The sugar is biologically converted to alcohol, which then has to be separated into concentrated form. Alcohol can be used in blends with gasoline (up to 25% alcohol without the need for engine adjustment) or in pure form (which requires engine adjustment). The fuel alcohol policy in Brazil triggered automakers to develop so-called flex-fuel vehicles (FFVs[34]) that automatically adjust engine settings, according to the composition of the fuel. This has given an enormous boost to fuel alcohol production, since cars no longer depend on specific fuelling stations (see also Chapter 4). FFVs are not yet available in all countries however.

Diesel is produced from animal fat, waste vegetable oils, and oilseeds, such as soybean, oil palm fruits, rapeseed, and cottonseed. In 2005 the global production of biofuels was about 20Mtoe, or less than 0.1% of all transport energy (but about 2% of fuel use in the EU, see Table 6.4). Brazil (mainly sugar cane alcohol), the USA (mainly maize based alcohol), and the EU (mainly biodiesel) were the biggest producers[35]. Biodiesel is normally blended with regular diesel – up to 20% – so that no engine adjustment is required. It can also be used in pure form, if engines are adapted.

There are several other biofuel processes under development, producing so-called 'second generation biofuels'[36]. These are derived from cellulosic materials such as straw, other crop residues, grasses, or wood chips. Alcohol is produced through a biological process using specific bacteria that can break down cellulose into sugar. Alternatively chemical processes can be used to break down cellulose, leading to biodiesel. A third process gasifies the biomass and makes a synthetic diesel or other hydrocarbon fuel via a chemical process, the so-called Fisher Tropsch synthesis. None of these processes has so far reached the stage of commercial production, but prospects for large scale commercial deployment before 2020 are good.

Yet another process under development uses oil producing algae that are grown with sunlight and nutrients, after which oil is separated from the algae and processed as diesel. At small scale these algae systems have shown a high productivity. There are still

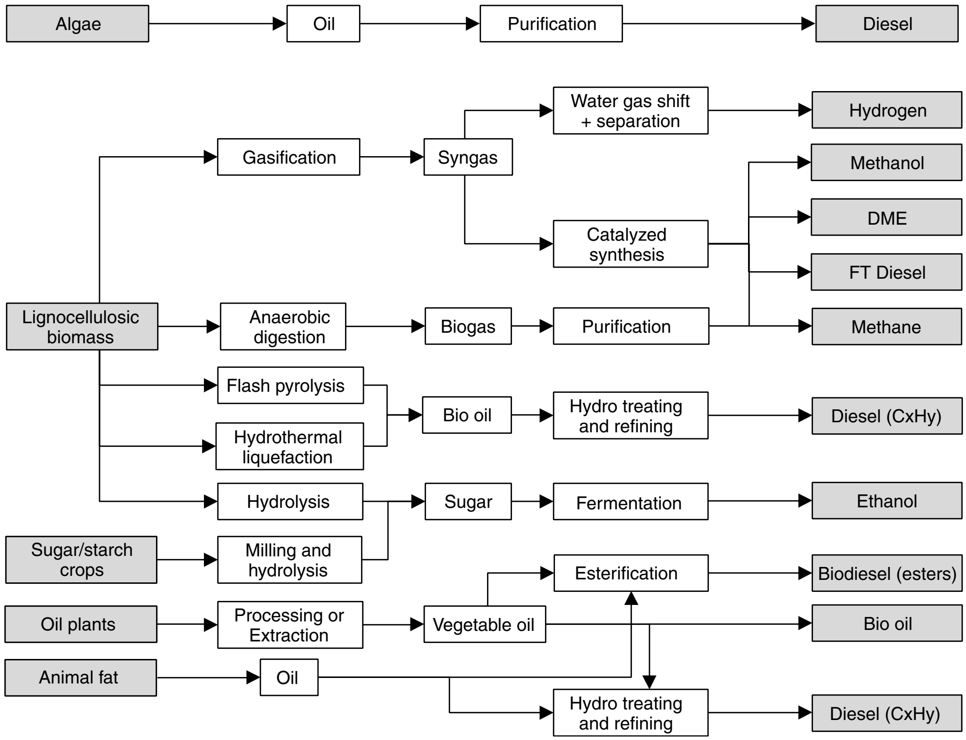



**Figure 6.8** **Overview of conversion routes from biomass raw materials to biofuels.**
*Source*: adapted from IPCC Fourth Assessment Report, Working Group III, fig 5.8.

problems to be solved, particularly to get the sunlight to the algae when equipment is being scaled up. The algae form a thick 'green soup', where light is not penetrating easily. This is the same phenomenon that makes 'algal bloom' in polluted lakes lead to oxygen depletion and dying off of fish. The amount of energy algae systems can produce per hectare could be 10 to 30 times that of bioenergy crops. This would be a great advantage. Several big oil companies, such as Shell and BP, are investing in further development of this technology[37].

In Chapter 5 bioenergy was discussed in general. Questions were raised about the net carbon reductions and sustainability of bioenergy. For biofuels it is worse. The additional processing needed for biofuel requires additional energy compared to burning biomass. And the price paid for transport fuels is relatively high so that competition with food production becomes more of a problem.

Let us first look at the net carbon reduction as a result of using biofuel, compared to gasoline and diesel. Figure 6.9 shows results from two different studies. No land use change emissions due to conversion of forests, natural vegetation, or grassland were taken into account. Only energy use and emissions from producing and processing the crops were considered. Calculations like this are complex and large uncertainties still exist. As far as the results are concerned, sugar cane alcohol from Brazil is performing best with a net $CO_2$ emission reduction of about 80%. Alcohol from maize and wheat only achieves a

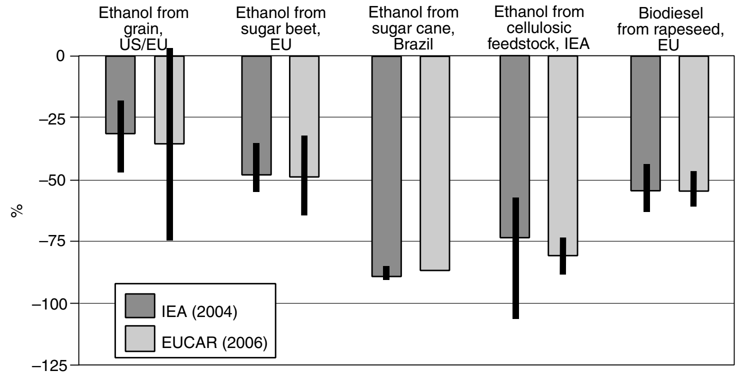



**Figure 6.9** **Reduction of overall life cycle greenhouse gas emission reductions from biofuels compared to vehicles running on conventional fuels.**
*Source*: IPCC Fourth Assessment Report, Working Group III, fig 5.10.

30% reduction, but poor systems are getting close to zero. Biodiesel lies somewhere in between with about a 50% reduction. The prospects for cellulosic alcohol are good: around 75% $CO_2$ emission reduction can be expected.

However when land use change is assumed to take place, things can change dramatically. Whether or not land use change happens is a complex question. The plot where bioenergy crops are grown could have been used for other crops, in which case there is no displacement. In another location however new cropland might have been created from natural vegetation or forest to produce food that was displaced by bioenergy crops. In case of degraded land, where regular agriculture is not possible, crops do not displace food production. But refraining from bioenergy cropping could have meant recovery of the degraded land through natural vegetation with a fair amount of carbon stored in trees, shrubs, and soil. From currently available studies no reliable picture on the carbon emissions from land use change can be obtained.

The conclusion from this is that the first generation biofuels are contributing to reducing oil imports, but probably not much to $CO_2$ reduction. There is even a risk that some of them, particularly alcohol from grains and biodiesel from palm oil, produce more $CO_2$ than gasoline or diesel. A lot will depend on how fast the second generation biofuels that have a better performance become commercially available. The question now is whether this second generation biofuel can become available soon enough for the EU to maintain its 10% biofuel requirement for 2020.

To safeguard food production and biodiversity protection, a lot of effort is being put into the development of sustainability criteria and certification systems. The EU has adopted a target for biofuels of 5.75% by 2010 and 10% by 2020 and has made it clear that qualifying biofuels have to meet sustainability standards. Standards are under development within the EU and elsewhere[38]. Important criteria are the net carbon reduction, the risk of displacing food production, and the risk of destroying biodiversity. There are however other, more positive factors that should not be forgotten: creation of income for small farmers, opportunity to provide rural areas with modern energy services, and energy security.

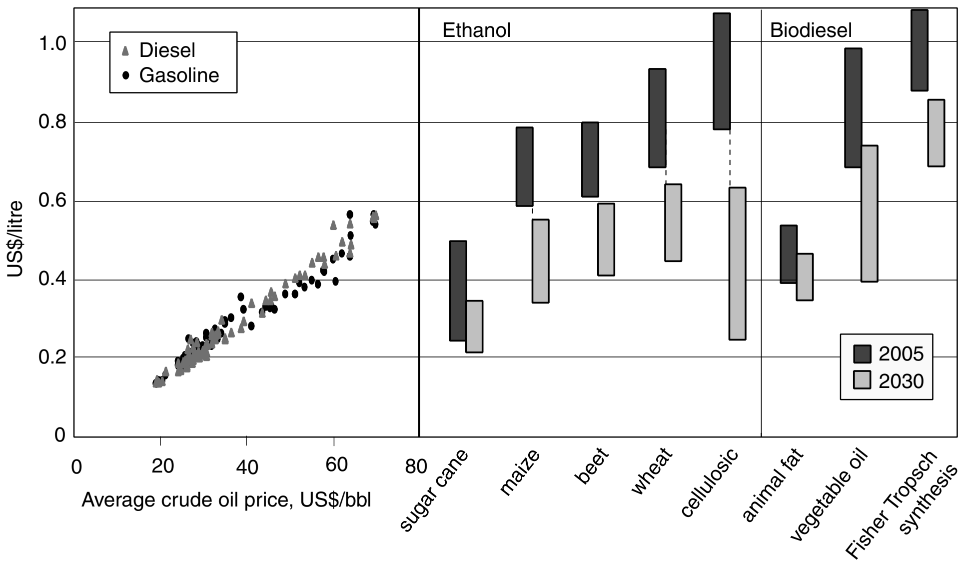



**Figure 6.10** **Comparison between current and future biofuel production costs (in US$/litre) versus gasoline and diesel prices (at refinery gate, so excluding fuel taxes).**
*Source*: IPCC Fourth Assessment Report, Working Group III, fig 5.9.

For a long time biofuels have been more costly to produce than gasoline and diesel. This depends on the oil price of course. For oil prices above US$50 per barrel, alcohol from sugarcane is competitive with gasoline and biodiesel from animal fat with regular diesel. For oil prices of US$100 per barrel, alcohol from grains and vegetable biodiesel also are competitive. Expected cost reductions by 2030 would make most biofuels, including the second generation ones, competitive with gasoline and diesel for oil prices of more than US$80 per barrel[39] (see Figure 6.10).

To realize these expected cost reductions, investments in production need to be made to realize economies of scale. So over the next 20 years or so additional costs have to be borne to get there. What are these costs and who is paying them? What you currently see in terms of policy instruments being used is a combination of quota (like the EU targets), subsidies (mainly to farmers to produce bioenergy crops cheaper), and excise tax exemptions on biofuels sold.

Calculations of costs per tonne of $CO_2$ avoided are highly dependent on the oil price assumed and on the amount of $CO_2$ avoided by using biofuels to replace gasoline or diesel. One way to estimate these costs is to look at subsidies provided and $CO_2$ avoided. This results in costs per tonne of $CO_2$ avoided of 160 to more than 4000US$/tonne for a range of countries in 2006[40]. This definitely is not cost-effective. Interestingly, per barrel of oil avoided these costs are in the same range as oil prices of 60–100US$/barrel[41]. So current subsidy schemes may be beneficial from an energy security or agricultural point of view, but they are far from cost-effective for $CO_2$ reduction.

Another way to calculate cost per tonne of $CO_2$ avoided is to calculate the additional costs of biofuel production compared to gasoline and diesel, without considering subsidies. That leads to very different outcomes. For US$25/tonne $CO_2$ avoided (and assuming an oil price of US$60/barrel) biofuel could cost-effectively replace 5–10% of transport fuels[42]. For higher oil prices this would increase. The conclusion can only be that current subsidy systems pump way too much money into this sector.

How much can biofuels contribute to reduction of oil imports and $CO_2$ emissions? It will be clear from the discussion above that uncertainties are high. The most realistic scenarios available show a biofuel share of 3% of the total transport fuel by 2030 in the business as usual case. With ambitious policy this could grow to 5–10%[43]. This would translate into a global $CO_2$ reduction of 0.6–1.5 Gt$CO_2$/year in 2030 at costs below US $25/tonne $CO_2$ avoided, although these costs will be higher if carbon loss from land use change (as discussed above) is factored in.

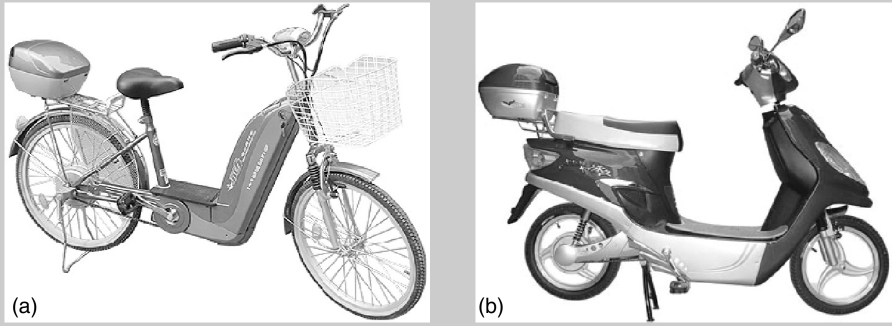
## Electricity

The prospects for all-electric vehicles (driven by an electric motor that runs on a large battery that needs to be recharged) are a bit unclear[44]. There is a niche market for small electric vehicles like golf carts, distribution vehicles, warehouse trolleys, limited edition passenger vehicles, and electric sports cars and an emerging market for electric two-wheelers (30 million now operating in China alone, see Box 6.5).

The electric two-wheeler market has a lot of growth potential in developing countries, because it is one of the first things households purchase when they can afford it. In China, India, Africa, and many other developing countries the number of two-wheelers is expected to at least double between now and 2030[45]. Where electricity is available (which is not the case for many rural areas in India and Africa), this can then be an important option. In terms of oil consumption or $CO_2$ emissions two-wheelers contribute only a small percentage however. From an air pollution point of view electric vehicles could make a bigger contribution: two-wheelers are relatively big polluters.

**Box 6.5** **E-bikes in China**

Electric motorbikes have become very popular in China. In 2005, 10 million e-bikes were sold in hundreds of different models, either bicycle or scooter style (see picture). They typically have a range of 40–50 km on a single charge and can be charged at standard electrical outlets. In most cities they may be used in bicycle lanes, without a driver's license. With city planning in many Chinese cities leading to the move of residential areas to the outer parts of the city, bicycle use has been declining strongly and motorbikes and e-bikes have replaced them.




**Bicycle style and scooter style electric bikes.**
*Source*: http://www.forever-bicycle.com.

Success factors for the e-bikes have been:

- Low costs (about a third of a motorbike per kilometre due to lower fuel costs)
- Setting of national standards for e-bikes, ensuring good quality
- Promotion of e-bikes by city governments (not all cities have been in favour though) to help improve air quality

(Source: Weinert JX, Ma C, Cherry C (2006) The Transition To Electric Bikes In China: History And Key Reasons For Rapid Growth. Springer Transportation 34 (3), 301 – 318)

Currently there is a small number of serious electric passenger vehicles types for sale[46] in very limited numbers and with a limited range (the best up to about 350 km, because of battery limits[47]). Although most people do not drive their car further than that each day, not being able to drive further is a strong barrier. Progress on the front of better batteries with higher loads and low weight is slow. Much is expected of lithium ion batteries, now used extensively in laptop computers and applied in the TESLA Roadster electric vehicle, but their costs are still high.

How much could electric vehicles reduce $CO_2$ emissions? The origin of the electricity is obviously very important. For the average US electricity fuel mix, all-electric cars emit typically in the range of 60–130 g$CO_2$/km, compared to the US fleet average of 230 tsg$CO_2$/km and hybrid cars around 100 g$CO_2$/km. The climate change advantages of all-electric vehicles in high carbon electricity areas are therefore limited. In countries with low carbon electricity they perform much better of course. Costs are still high. There are no reliable estimates of the global contribution that all-electric vehicles could make to the reduction of $CO_2$ emissions. From an air pollution point of view they have strong advantages of course.

## Plug-in hybrids

The road to all-electric vehicles (if reached at all) more likely goes via hybrid electric vehicles. A mixture between a classic hybrid and an electric car is the so-called ‘plug-in

Table 6.5. **Cost comparison of hybrid and plug-in hybrid cars**

| Near-term incremental costs | Conventional hybrid | Plug-in hybrid (with a 40-mile all-electricity range) |
|---|---|---|
| Battery | US$2000 | US$17500 |
| Other | US$1500 | US$1500 |
| Annual fuel savings | US$480 | US$705 |
| Payback (years) | 7.3 | 27.0 |
| Long term incremental costs | | |
| Battery | US$600 | US$3500 |
| Other | US$1000 | US$1000 |
| Annual fuel savings | US$480 | US$705 |
| Payback (years) | 2.9 | 6.4 |

*Source*: Plug-In Hybrids: an Environmental and Economic Performance Outlook, ACEEE, 2006.

hybrid' vehicle. They operate as hybrid vehicles, but the batteries can be charged from the grid. In this way the vehicle can operate on battery power for a larger fraction of the time (initially probably 50–100km). In the US this would mean $CO_2$ emissions could be 15% lower than for conventional hybrid vehicles, while in California it could be 30% lower[48]. In countries with a low carbon electricity supply the advantages would of course be greater. However, battery costs are currently very high, making these vehicles too costly (see Table 6.5). Many automakers have announced their introduction, but so far they are not available commercially. Before 2030 costs are expected to come down sufficiently for plug-in hybrids to penetrate the market. Their contribution to emission reduction in the 2030 timeframe will be very limited.

## Hydrogen

Hydrogen can be used to operate fuel cells, a type of battery that generates electricity through the reaction of hydrogen with oxygen from air. The process is extremely clean: only water comes out of the tailpipe. Electric motors drive the car. The $CO_2$ reduction that can be achieved completely depends on the source of hydrogen. As explained in Chapter 5, hydrogen is used extensively in the oil and chemical industry. It is produced from coal or gas. By using $CO_2$ capture and storage (CCS, see Chapter 5) near zero carbon hydrogen can be obtained. In principle biomass can be used as a source, leading also to near zero hydrogen, albeit at much higher costs. Hydrogen from electric decomposition (electrolysis) of water with renewable energy would also be near zero carbon, but costs are currently even higher. This could only change if hydrogen were produced with excess renewable power at off-peak times.

With low carbon hydrogen from gas or coal with CCS, the $CO_2$ emission is about 10–20% of that of regular gasoline cars[49], i.e. 30–50 $gCO_2$/km. Other air pollutants are not emitted.

All major automakers have prototypes of hydrogen fuel cell vehicles (HFCVs). There are three major problems still to be resolved before commercial production could be considered: the supply of hydrogen to fuel stations, the hydrogen storage in the vehicle, and the fuel cell reliability and cost. Hydrogen pipelines exist in areas with oil and petrochemical complexes. Extending that to whole countries would be costly, but feasible. The biggest problem is the fact that there are no hydrogen cars, and there will be no HFCVs unless there is a hydrogen infrastructure, which is down to the government. Hydrogen is clean, but is has a low energy density. This requires compressing hydrogen to very high pressures to keep the volume of the fuel tank to a reasonable size for a good driving range. Pressurized hydrogen tanks are now available that use three times the pressure of a compressed natural gas tank in cars, allowing a driving range of up to 450 km. Another approach being developed is to absorb hydrogen in a special metal hydride powder, allowing larger amounts to be stored at lower pressures. Fuel cell development still has some way to go to get to cheaper and more reliable fuel cells.

Significant penetration of HFCVs in the vehicle fleet is not expected before 2030. In the period thereafter however contributions could be significant.

## So what can be achieved in terms of reduction of energy use and $CO_2$ emissions?

In Table 6.6 the potential contributions by 2030 are shown from the various measures to reduce energy use and $CO_2$ emissions with costs up to US$100/tonne $CO_2$ avoided[50]. The potential is expressed as the so-called 'economic potential' (see Box 6.6).

**Box 6.6 Economic versus market potential**

Economic potential is the mitigation potential, calculated with payback times for investments as used in public sector projects (low discount rates) and assuming that market barriers are removed through policy intervention.

Market potential is the mitigation potential based on private payback times for investments used in business and household decisions (big discount rates) and occurring under real market conditions, including policies and measures currently in place, noting that barriers limit actual uptake.

The difference between the two is that market potential assumes all sorts of barriers, limiting the uptake of measures, i.e. not everything that is economically sensible is being done. Economic potential only looks at the question that makes economic sense at a certain carbon price, if barriers are removed by policy actions. Normally there is a pretty large difference between those potentials: economic potential is higher than market potential.

The total emission reduction potential is at least about 1.6–2.3 $GtCO_2$, equivalent to a reduction of 15% of the expected emissions without policy. Public transport and biking facilities in cities will add to this, but no reliable estimates of the reductions are available

**Table 6.6. Global economic potential for reduction of $CO_2$ emissions from transport by 2030 with costs up to US$100/tonne $CO_2$ avoided**

| Measure | Total oil consumption reduction (% from BaU) | $CO_2$ emissions reduction compared to BaU ($GtCO_2$/year) | Other benefits |
|---|---|---|---|
| Reduce demand | Low | Low | Congestion can benefit more |
| Modal shift passenger transport | Moderate | Moderate | Congestion can benefit considerably |
| Modal shift freight transport | Negligible | Negligible | |
| Efficiency passenger road transport | 10 | 0.75 | |
| Efficiency freight road transport | 2–5 | 0.1–0.4 | |
| Biofuel | 5–10 | 0.1–0.4 | Sustainability constraints could reduce this amount |
| Electricity | Low | Negligible | |
| Hydrogen | Negligible | Negligible | |
| More efficient airline transport | n/a | 0.28 | |
| Freight shipping | n/a | 0.3–0.4 | |
| Rail | Negligible | Low | |
| TOTAL | | 1.6–2.3 | |

*Source*: based on IPCC Fourth Assessment Report, Working Group III, ch 5.

unfortunately. This also means oil consumption can be reduced by a significant amount. Congestion will be reduced and air pollution from transport as well.

The real big reduction in the transport sector can only come after 2030, with hydrogen fuel cell vehicles and possibly electric vehicles in combination with a largely decarbonized energy system, second generation biofuels from sustainable biomass, as well as structural changes in city planning and public transport systems.

## How do we get it done?

As indicated above, policy action is needed to make reduction potentials a reality. Table 6.7 summarizes the most effective policy approaches for the various segments of the transport sector. If you look at the mix of policies, there is a strong emphasis on regulation and infrastructure. It reflects the experience that with financial incentives alone transportation problems cannot be managed effectively.

**Table 6.7. Summary of policy approaches that have proven to be effective in managing transport problems**

| Segment | Effective policy approaches in industrialized countries | Effective policy approaches in developing countries |
|---|---|---|
| Reducing passenger transport demand | • Teleworking<br>• City gentrification<br>• Tax air travel | • City planning<br>• Tax air travel |
| Reducing freight transport demand | • Increase cost of freight transport (taxes, road fees)<br>• Truck road use restriction | • Industrial zoning<br>• Increase cost of freight transport (taxes, road fees)<br>• Truck road use restriction |
| Modal shift passenger transport | • Make driving and parking more expensive and time consuming (congestion charges, fuel tax, restricted areas, parking charges)<br>• Pay-as-you-drive for road taxes (shift costs from one-time to operational)<br>• Provide good public transport | • Maintain bicycle/walking provisions<br>• Provide efficient, clean, and affordable public transport (e.g. Bus Rapid Transit Systems; intercity bus systems) |
| Modal shift freight transport | • Develop rail/water infrastructure | • Maintain/develop rail/ water infrastructure |
| Fuel efficiency improvement | • Set fuel efficiency standards<br>• Make road/vehicle taxes dependent on $CO_2$ emissions<br>• Subsidize hybrid vehicles<br>• Scrap old vehicles | • Set fuel efficiency standards<br>• Make road/vehicle taxes dependent on $CO_2$ emissions<br>• Ban inefficient second hand car imports<br>• Subsidize hybrid vehicles<br>• Scrap old vehicles |
| Biofuel | • Set quota<br>• Mandate sustainability certification<br>• Support R&D second generation biofuels, incl for jet fuel | • Set quota<br>• Mandate sustainability certification<br>• Support R&D second generation biofuels |
| Electric/hydrogen fuel cell vehicles | • Provide hydrogen infrastructure<br>• Support R&D (fuel cell vehicles) | • Promote e-bikes (allowing the maintenance of bicycle facilities, subsidies)<br>• Support R&D (fuel cell bikes) |

*Source*: based on IPCC Fourth Assessment Report, Working Group III, ch 5.

In addition to these specific policies, general economy wide policies have an important role to play. This particularly applies to carbon taxes and so-called cap and trade systems. These general polices are discussed in Chapter 11, but remarks need to be made here regarding their application to the transport sector. Cap and trade systems basically limit the amount of GHG emissions from the sector (or subsector, such as aviation), thereby creating a price for $CO_2$. There is a lot of debate as to whether this can sufficiently control emissions from transport, since car users would probably only notice an increase in fuel price, which is not so effective in changing the vehicle fleet. Fuel efficiency standards and more structural changes in public transport systems are more effective. In aviation the situation is better, because the cap and trade system could work through the aviation companies, who could be held accountable for their respective emission quotas. They can then either reduce emissions by using more efficient airplanes, use biofuel (in the future), or purchase allowances on the emission trading market. The EU has decided to include the aviation sector in the EU Emission Trading System.

Policies can only have an impact when they are carefully integrated in a coherent package. Different parts of the transport system require different policy instruments. And keeping a focus on the combined effect of policies to deal with congestion, air pollution, reducing oil imports, and $CO_2$ emissions is crucial.

## Notes

1. World Business Council on Sustainable Development, Sustainable Mobility, 2004.
2. ICCT, Air pollution and greenhouse gas emissions from ocean-going ships, 2007.
3. Climate for transport: indicators tracking transport and environment in the European Union, EEA report 1/2008
4. http://www.fra.dot.gov/us/content/25.
5. IEA, WEO 2008.
6. IPCC Fourth Assessment Report, Working Group III, fig 5.1.
7. Worldbank, Cities on the move: a Worldbank Urban Transport Review, 2002.
8. IPCC Fourth Assessment Report, Working Group III, box 5.1.
9. IEA WEO 2007.
10. IPCC Fourth Assessment Report, Working Group III, ch 5.2.2.
11. IPCC Special Report on Aviation and the Global Atmosphere, 2000.
12. http://www.imo.org/Safety/mainframe.asp?topic_id=1709&doc_id=10268.
13. UN, World Urbanization Prospects: the 2007 Revision Population Database.
14. http://www.economist.com/markets/rankings/displaystory.cfm?story_id=8908454.
15. IPCC Fourth Assessment Report, Working Group III, ch 5.5.1.5.
16. See note 15.
17. IPCC Fourth Assessment Report, Working Group III, ch 5.5.1.2 and table 5.16; CEMT, Cutting Transport Emissions: what progress, OECD, 2007, ch 5.5.
18. IPCC Fourth Assessment Report, Working Group III, fig 5.13.
19. IPCC Fourth Assessment Report, Working Group III, ch 5.5.1.1.

20. IPCC Fourth Assessment Report, Working Group III, table 5.6.
21. IEA Energy Review Switzerland, 2007.
22. WBCSD, Sustainable mobility, p81.
23. http://pdf.wri.org/automobile-fuel-economy-co2-industrialized-countries.pdf.
24. http://www.eta.co.uk/car_buyers_guide gives 23 km per litre, based on test data; in real-use cars have about a 15% higher fuel consumption.
25. Converson factors: from km/l to miles per gallon (US): multiply by 2.35; from km/l to miles per gallon (UK) multiply by 2.82.
26. Davi, Diegel, Transport Energy Data Book, ONRL, 2007, table 4–2.
27. EEA, TERM, 2007, table 7.1.
28. IPCC Fourth Assessment Report, Working Group III, table 5.9a.
29. IPCC Fourth Assessment Report, Working Group III, ch 5.4.2.1.
30. See note 23.
31. ECMT, Cutting transport $CO_2$ emissions, OECD, 2007.
32. Grezler A. Heavy duty vehicle fleet technologies for reducing carbon dioxide: an industry perspective. In Sperling D, Cameron J (eds) Climate policy for transportation, Springer, Dordrecht, 2008.
33. Schipper L. http://pdf.wri.org/automobile-fuel-economy-co2-industrialized-countries.pdf.
34. IPCC Fourth Assessment Report, Working Group III, box 5.2.
35. IEA WEO 2006 (table is from there).
36. Childs B, Bradley R. Plants at the pump: biofuels, climate and sustainability, WRI.
37. http://www.shell.com/home/content/aboutshell/swol/jan_mar_2008/algae_13022008.html.
38. UN Energy, Sustainable bioenergy: framework for decision makers, 2007; Eickhout B et al. Local and global consequences of the EU renewable directive for biofuels, Netherlands Environmental Assessment Agency, 2008.
39. Biofuel production costs have gone up after the publication of this graph in the IEA World Energy Outlook 2006, while fossil fuel prices soared also. So for 2008 oil prices the biofuel cost bars are higher and the ‘break-even point’ as reflected in the text more or less stays the same.
40. OECD. Biofuels: is the cure worse than the disease? OECD Paris, SG/SD/RT (2007) 3.
41. Metcalff GE. Using tax expenditures to achieve energy policy goals, National Bureau of Economic Research, 2008; http://www.nber.org/papers/w13753.
42. IPCC Fourth Assessment Report, Working Group III, ch 5.4.2.3, based on IEA WEO, 2006 and IEA Energy Technology Perspectives 2006.
43. IPCC Fourth Assessment Report, Working Group III, ch 5, Exec summary.
44. See http://www.ieahev.org/.
45. WBCSD Sustainable Mobility, figure 2.9.
46. See http://www.autobloggreen.com/2007/02/07/the-top-ten-electric-vehicles-you-can-buy-today-for-the-most-pa/.
47. A range of 300 km would require batteries with a weight of more than 400 kg (IPCC, 2007, ch 5.3.1.3).

48. Kliesch J, Langer T. Plug-in hybrids: an environmental and economic performance outlook, ACEEE, Report T061, September 2006.
49. IPCC Fourth Assessment Report, Working Group III, fig 5.11
50. $50/t $CO_2$ avoided is equivalent to an increase in gasoline prices of about 13 $c/litre or 50$c per gallon.