

Chapter 5

Getting into the Right Lane for Low-Carbon Transport in the EU

Karst Geurs, Hans Nijland, and Bas van Ruijven

5.1 Introduction

Stabilising greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, achieving an affordable and secure energy supply, and feeding the world population are among the greatest challenges of our time. The Netherlands Environmental Assessment Agency and Stockholm Resilience Centre conducted a study titled *Getting into the Right Lane for 2050* to examine the European Union of today, from a global perspective, to look at long-term visions on the world of 2050, and to identify key decisions on the near term on global land resources and low-carbon energy systems, including transport.

To limit the increase in mean global temperature to 2°C, greenhouse gas emissions in high-income countries need to be 80–95% less in 2050 than in 1990. This study uses a vision for 2050 to achieve at least 80% CO₂ emission reduction within the EU. The distribution of emission reductions over sectors is an inherent part of this vision and not necessarily the most cost-effective. Emission reductions in transport amount to an ambitious 80%.

From this starting point, backcasts have been made of the pathways to the 2050 vision and the opportunities and challenges on the way. This approach of working back from vision to strategy is ambitious and differs from more conventional forecasting. It is typically applied to complex, long-term issues. The focus is on policy actions needed today and the implications for mid- and long-term policies of the EU.

The approach taken in this study is to view the EU from a global perspective, as one of the several economic blocks in 2050. By 2050, the EU will be equalled economically by new players and outgrown in terms of population. But as a major importer of goods and services from economic blocks such as India and China, the

K. Geurs (✉)

Department of Civil Engineering, Centre for Transport Studies,
University of Twente, Enschede, The Netherlands
e-mail: k.t.geurs@utwente.nl

EU is likely to exert considerable influence on production standards worldwide. While alternative expectations and views are possible, implicit in this study is that the future EU is a pro-active and consistent player on the world stage. The EU acts on the basis of values that go 'beyond GDP' and with a reputation for regional integration and global interest.

In *Getting into the Right Lane* three interrelated themes are examined. The first theme is *land resources*, including water, and the EU's role in a world providing food for all without further loss of biodiversity. This implies improving agricultural productivity in order to close 'yield gaps' in all regions, containing biodiversity loss worldwide on the way to 2050. It also implies a strategy of diversity in EU land and agriculture policies. The second theme is *energy* and envisages a low-carbon energy system in the EU in 2050. This amounts to 80% decrease in domestic emissions of greenhouse gases by 2050 and connects with the EU's need to improve energy security. The third theme is *transport*, with a vision for 2050 of low-carbon transport in Europe.

This paper focuses on the vision of and the pathways towards low-carbon transport systems in the EU. As well as being a major contributor to carbon dioxide emissions in the EU, transport also has significant societal costs including congestion, air pollution, and accidents. There are synergies between achieving low-carbon transport and reducing other societal impacts, but these are not discussed here.

The analysis in the study is mainly based on the existing scenario studies and secondary material, e.g. existing transport projections for the EU transport sector and technological developments. There has been no original modelling work, and indeed forecasting over a period up to 2050 with so many uncertainties is unlikely to be a precise science. Two studies have been commissioned for *Getting into the Right Lane*, and served as important inputs for the analysis. The first study was a review of sustainable transport futures for transport and options available, and a discussion of the role that the EU should play in leading the debate and in taking effective action (Banister 2009). The second study examined the role of the European transport sector within a competitive EU economy (Rothengatter 2009). The analysis on climate change, energy, and land resources was largely based on modelling and other tools used by the Netherlands Environmental Assessment Agency in recent global outlooks (see PBL 2008; OECD 2008).

The rest of this paper is structured as follows: in Sect. 5.2 we depict the future of European transport according to some accepted scenarios. CO₂ emissions from the EU-transport sector rise in all the scenarios. Sect. 5.3 describe a contrasting low-carbon vision for transport in Europe in 2050, and Sect. 5.4 describes the pathways to reach such a low-carbon transport, where big emission reductions are required. Those pathways are not always straightforward and certain. Uncertainties are described in Sect. 5.5. A low-carbon transport sector is closely interlinked with a low-carbon energy sector. These interlinkages are described in Sects. 5.6 and 5.7. The latter one focuses on the issue of biofuels, with links to land use and biodiversity as well. Section 5.8 shows the critical path towards low-carbon transport: what needs to be done now and what does the EU need to do? Finally, the chapter ends with overall conclusions.

5.2 Transport Projections Under Business as Usual

5.2.1 Transport Scenarios for 2050

Passenger and freight transport have, before the economic crisis, increased year on year, as shown in Fig. 5.1. Up until 2000, growth in freight transport kept pace with growth in GDP, but between 2000 and 2005 demand for transport led to substantial growth, exceeding growth in GDP. This growth reflects the substantial increase in commodity trading and especially container freight, following EU enlargement and market integration.

Transport projections up to 2050 are inherently uncertain, but some scenario studies conducted for the EU transport sector up to the year 2050 (Petersen et al. 2009; Banister 2009) have common results. Firstly, international aviation and maritime transport is projected to be the fastest growing transport modes. Air passenger kilometres are forecast to double Petersen et al. (2009) or triple between 2005 and 2050 (Banister 2009). Maritime transport is expected to grow substantially, with tonne kilometres increasing within and between the Member States by about 90% between 2005 and 2050. Maritime transport between Member States and the rest of the world is projected to increase by 150% between 2005 and 2050 (Petersen et al. 2009). Worldwide, maritime transport is projected to grow by 150–300% by 2050, particularly due to container shipping, which is projected to grow by 425–800% by 2050 (Buhaug et al. 2008).

Secondly, of surface transport modes, *road freight* in the EU is a forecast to the strongest increase by about 60% between 2005 and 2050, and long-distance road freight (trips longer than 150 km) to more than double (Banister 2009). Passenger

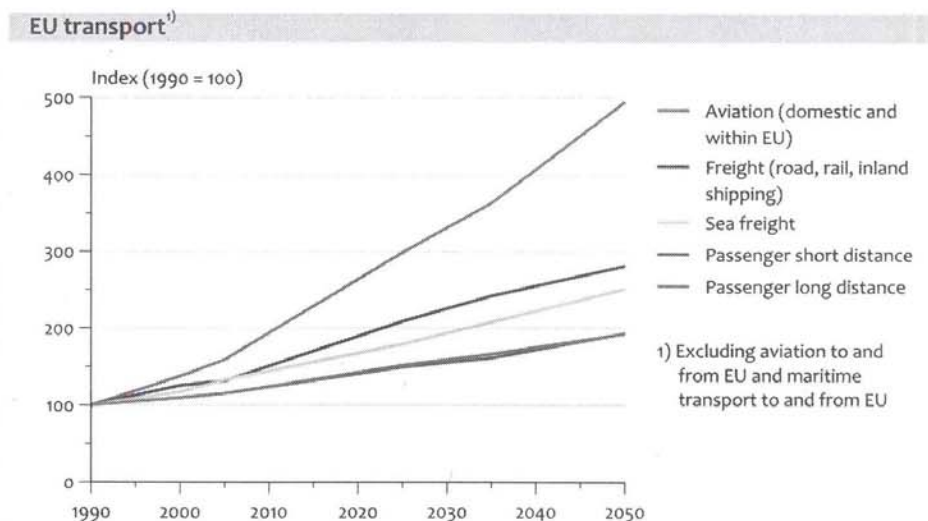


Fig. 5.1 EU transport, excluding international aviation and maritime transport to and from the EU (Source: Banister 2009)

car travel is projected to increase less strongly up to 2050, by about 40% (Petersen et al. 2009) to 70% (Banister 2009). Projections for rail transport differ significantly. Projections for rail passenger transport range from 30% (Banister 2009) to double (Petersen et al. 2009), between 2005 and 2050. Growth in rail freight ranges from 25% (Banister 2009) to treble current levels (Petersen et al. 2009).

Note that these projections do not incorporate the impact of the current financial and economic crisis. Growth in transport, particularly in freight transport, is likely to be delayed by about 5 years. The projections presented here, thus, are on the long run, slightly biased upwards. Figure 5.1 presents the EU transport projection as developed by Banister (2009). This scenario was developed based on the outputs from earlier EU transport scenario projects ETAG (Schippl et al. 2008) and Tremove (to 2030). This scenario is used in *Getting into the Right Lane* as base scenario, and used as input for a CO₂ emission projection for the EU transport sector (see next Section).

5.2.2 Baseline CO₂ Emission Projection for the EU Transport Sector

Greenhouse gas emissions from transport, excluding international aviation and maritime transport, increased by 27% over the period from 1990 to 2006, compared to a reduction of 3% in emissions across all sectors (EEA 2009). A projection of CO₂ emissions from transport, excluding international aviation and maritime transport to and from the EU, is presented in Fig. 5.2. Carbon dioxide emissions from the EU transport

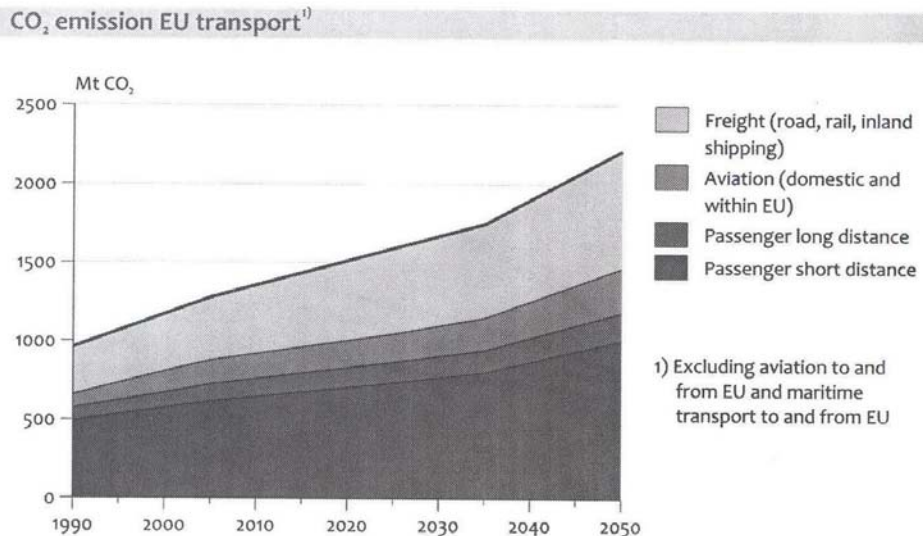


Fig. 5.2 Projected carbon dioxide emissions from EU transport, excluding international aviation and maritime transport to and from the EU (Source: Banister 2009)

sector, excluding international aviation and shipping, are projected to more than double (Banister 2009; Fig. 5.2). The largest growth in carbon dioxide emissions, over the last decade, has been from the international aviation and maritime shipping, which are not regulated by the Kyoto Protocol. Despite significant improvements in energy efficiency (albeit slowly diffused through the fleet), carbon dioxide emissions from international shipping are projected by IMO to increase by 10–25% in 2020 and by 125–220% in 2050, under baseline assumptions (Buhaug et al. 2008).

Under the Kyoto protocol, passenger air travel outside the EU is not included in EU statistics on carbon dioxide emissions, but is five to six times higher than kilometres flown within the EU (Petersen et al. 2009). If these emissions are included, emissions from EU aviation by 2050 would be roughly equal to road freight transport in the EU.

5.3 A Vision for a Low-Carbon Transport Sector in the EU

Transport currently accounts for a third of all final energy consumptions in Member States and for more than a fifth of greenhouse gas emissions (EEA 2009). Although carbon dioxide emissions in the EU decreased slightly between 1990 and 2006, emissions related to transport have risen by about 30% (EEA 2009). As transport is one of the fastest growing sectors in the economy, energy consumption and greenhouse gas emissions are projected to increase significantly up to 2050. Action is needed to reduce emissions in line with the climate change goals.

The vision for 2050 used in *Getting into the Right Lane* is that of low-carbon transport in the EU by decreasing carbon dioxide emissions from all transport modes – road and rail passenger travel, aviation, road freight, and shipping. Low carbon in this vision means 80% less carbon dioxide emissions by 2050, compared to 1990 levels. This is neither a forecast nor a blueprint, but a vision of low-carbon transport in Europe in 2050. This target equals the EU average decrease in greenhouse gas emissions as envisaged in this study. But it is more difficult to achieve, in view of the steep growth as projected for EU transport, without new policies. In fact, to achieve the target of 80% emission reduction relative to 1990 levels amounts to reducing emissions by almost a factor of 12 below those in the baseline scenario, by 2050.

The potential emission reductions of technological measures are primarily taken from the IEA's BLUE Map scenario (IEA 2008), but with different penetration rates, particularly for biofuels. The BLUE Map scenario uses a 50% CO₂ reduction target for the transport sector worldwide.

There main instruments to achieve the envisioned large-scale CO₂ emission reduction for the transport are:

1. Large-scale introduction of low-carbon fuels, such as hydrogen, electric traction, and biofuels.
2. Improving vehicle energy and logistic efficiency.
3. Reducing traffic volumes and shifting to more energy-efficient modes, such as rail transport

Route towards a low-carbon transport system in the EU in 2050

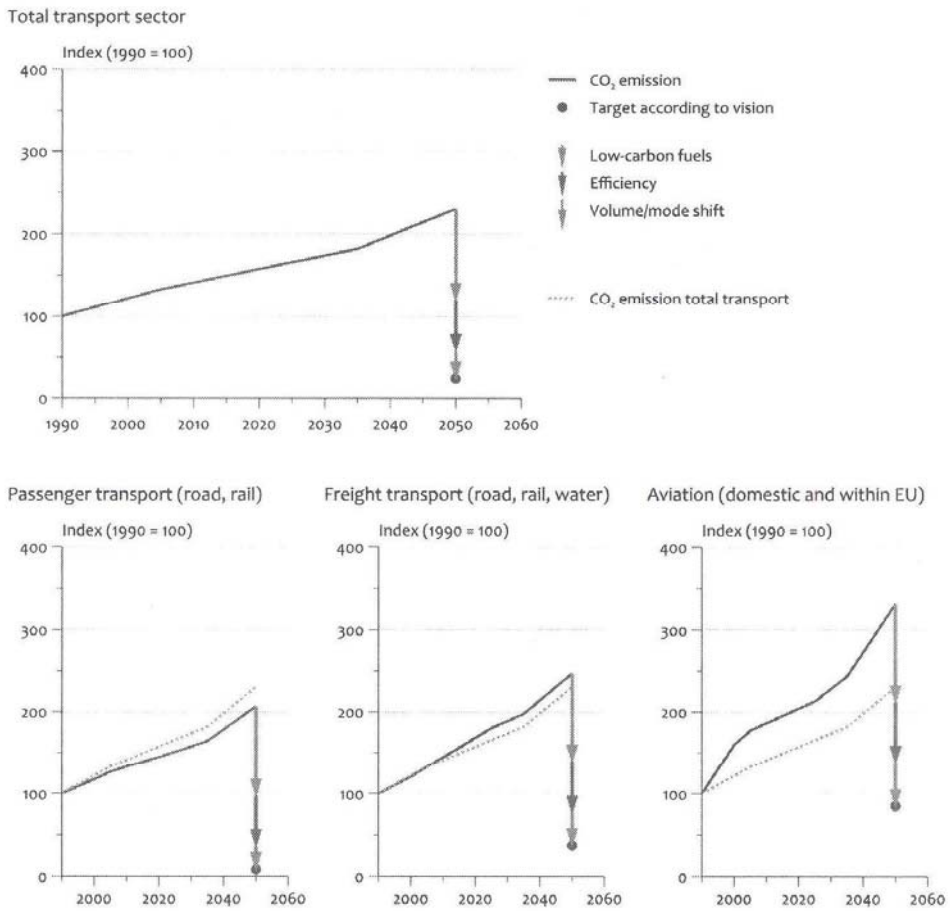


Fig. 5.3 A vision on low-carbon transport in the EU in 2050

The vision for low-carbon transport, based on 80% reduction in carbon dioxide emissions, is presented in Fig. 5.3. It includes emissions outside the EU territory from aircraft and ships fuelled in the EU. In achieving the 80% reduction target by 2050, reduction of carbon dioxide emissions is not the same in all transport modes. Passenger transport contributes most to the overall target. Road freight, aviation, inland shipping, and maritime transport contribute less to the overall reduction target because fewer cost-effective technologies are available. In short:

- *Road passenger transport* reduces carbon dioxide emissions by 95%, relative to the baseline scenario in 2050 (by a factor of 20–25). Current cars are replaced by electric vehicles and/or fuel-cell vehicles with hydrogen from low-carbon sources. Both technological routes require low-carbon or zero-carbon power generation technologies.

- *Road freight transport* reduces carbon dioxide emissions by about a factor of 6, relative to the baseline scenario, by 2050, resulting from a complete shift to advanced bio-diesels and maximum improvement in vehicle energy and logistic efficiency, and, to a small extent, from mode shifts to rail freight and shipping. Changes in logistic organisations result in higher truck utilisation and fewer kilometres.
- Emissions from *maritime transport and aviation* are reduced by a factor of 6 and 10, respectively, relative to the baseline scenario, by 2050. This is achieved through a 50–75% use of advanced biofuels and a combination of technological, logistic, and operational measures, including speed reductions (50–60% reduction in carbon dioxide emissions per vehicle km). Further emission reductions in aviation result from changes in travel behaviour.

5.4 Pathways to Low-Carbon Transport in 2050

There is a wide range of low-carbon technologies moving towards commercial production or in various stages of development that could be applied to different transport modes to reduce energy consumption and carbon dioxide emissions. Further reductions in emissions can be achieved by improving energy and logistic efficiency, and with modal shifts. As well as reducing emissions, low-carbon transport will make transport in the EU less vulnerable to volatility in oil supply and price.

5.4.1 *Electric Traction and Hydrogen for Urban Transport*

Almost complete decarbonisation of passenger road transport is technically feasible by 2050 (King 2008). Most promising technological options are full-electric vehicles and fuel-cell vehicles, with hydrogen produced from low-carbon sources (van Ruijven et al. 2008), for cars, buses, and urban freight transport, such as urban delivery trucks, at least in the near to medium term. However, to compete with fossil-fuel vehicles and fossil-fuel alternatives, several technological hurdles have to be overcome, and the cost brought down considerably for wide-scale application. While progress is being made, both electric and hydrogen passenger vehicles still have a long way to go in the development and commercialisation process. Commercialisation of the hydrogen cell is more problematic, largely because of the new infrastructure development required. The most likely route to making the transition from fossil fuels is gradual replacement of current fossil-fuel cars by hybrids, plug-in hybrids, and then by full-electric and/or fuel-cell vehicles. Electric and hydrogen road transport, whether full electric, (plug-in) hybrid, or hydrogen fuel cell, bring additional environmental benefits. These technologies produce less noise at low speeds, reducing noise nuisance and air pollution in urban areas.

On the critical path to achieving near-zero carbon transport in urban areas is a sufficient supply of clean power after 2030. Because of the slow pace of change

where major infrastructure investment is involved, decarbonising the energy sector needs to be even higher on the agenda than is the development of low-carbon vehicle technologies. See for a further discussion on transport and energy sector linkages Sect. 5.6.

5.4.2 Bio-Fuels for Road Haulage, Aviation, and Maritime Transport

The current state-of-the-art technology indicates few options for achieving substantial reduction in carbon dioxide emissions by 2050, for long distance road freight transport, shipping, and aviation. Neither electricity nor hydrogen is well suited for long-distance road freight transport because of storage capacity. Hydrogen as jet fuel will require total aircraft redesign and vast changes in infrastructure (IEA 2008). In addition, the global warming effect of increased water vapour at high altitude needs to be investigated. Fuel-cell utilisation in inland shipping is complicated because of the large quantities of hydrogen needed and the limited on-board storage space. Currently, some of the best options to reduce carbon dioxide emissions are advanced bio fuels manufactured from a wide range of biomass sources. There is, however, a high degree of uncertainty surrounding wide-scale use of biofuels, such as second-generation and third-generation biofuels, biomass-to-liquid jet fuels, and hydrogen and fuel cells (see Sect. 5.5).

Further policies are needed to ensure smart use of biofuels in reducing carbon dioxide emissions across the economy. For instance, in the current EU policy framework for road transport, fuel targets carry the risk that the car users may consume too much biomass in relation to other transport modes (trucks, aviation, and shipping), as well as other sectors, such as heat and power. Thus, direct links need to be made between the EU vehicle-efficiency targets and fuel targets.

There is an urgent need to prepare the way for low-carbon aviation and maritime transport by 2050. These slow-changing transport modes are growing rapidly in terms of volume and emissions. Thus, every effort is needed to promote the development and adoption of low-carbon fuels for aviation and maritime transport. However, total emission reduction awaits biofuels becoming commercially available, and sufficient land becoming available for biofuel production. See Sect. 7.7 for a further discussion of biofuels, land resources, and biodiversity.

Achieving emission reduction in aviation requires a shift to bio-kerosene. At present, there is no 'bio' equivalent for kerosene. An aviation biofuel has been developed, and several test flights have been carried out, but without conclusive results. The European Commission has called for tenders on more research to evaluate the feasibility of these biofuels. Nevertheless, a substantial shift to bio-kerosene would achieve emission reductions in aviation (see 2). In IEA's BLUE Map scenario, biomass-to-liquid fuels are assumed to account for 30% of aviation fuel by 2050, provided carbon prices are high enough. To achieve a reduction in carbon dioxide emissions in aviation, relative to the 1990 levels, however, much higher levels of advanced biofuels will be needed, at least 50–75%.

The cost-effectiveness of EU policies on biofuels can be improved by closely linking current biofuel targets with EU vehicle-efficiency targets. This could be achieved by establishing a carbon-intensity obligation for all fuels, such as in the California's Low-Carbon Fuel Standard where carbon-intensity of fuels is reduced through a system of tradable credits, also applicable to biofuels. The EU could also set up a wider road transport obligation which links carbon intensity of fuels to vehicle efficiency, possibly through tradable credits. Ultimately, road transport could be covered by a 'cap and trade' scheme such as the current ETS.

5.4.3 Improving Vehicle Energy and Logistic Efficiency

Next to a substantial shift to biofuels, a significant contribution can be made to the near zero-carbon target by improving the technical and logistic efficiency of heavy-duty road freight vehicles. Efficiency improvements of 15–30% have been estimated using vehicle hybrid technologies (De Lange et al. 2008; Lensink and De Wilde 2007; Hanschke et al. 2009). This potential is difficult to achieve for long-haul freight vehicles, because hybrid technologies are not very effective for vehicles operated at constant speed and power.

However, carbon savings can be achieved by improving logistic efficiency in road freight transport and modal shift to rail. Different logistic organisations, such as green, reverse, and cooperative logistics, have great potential to increase truck utilisation and reduce truck kilometres (Rothengatter 2009). Here, smart logistics are assumed to reduce intensity (transport input per unit of GDP) of road freight transport induced by higher fuel costs.

Logistic efficiencies to achieve maximum potential of technological and operational measures in international shipping, including speed reduction, may reduce emissions by up to 60% per tonne kilometre by 2050 (Christ 2009; IEA 2008).

The BLUE Map scenario, assuming a 'maximum technology' case, includes 10% improvement in technical efficiency, beyond the baseline scenario, by 2050. This represents a total improvement of 35% in fleet fuel efficiency on the current average and an additional 10% reduction in global aircraft energy use through the optimisation of operational systems. According to CCC (2008), a production aircraft in 2025 flying in an improved operational environment can be 40–50% more fuel efficient than a new production aircraft flying in a 2006 operational environment. However, because of the long lifetime of aircraft, the potential reduction in carbon dioxide emissions in 2050 is modest.

5.4.4 Cutting Traffic Volumes and Shifting Transport Modes

Technology alone will not be sufficient to achieve an 80% reduction in carbon dioxide emissions from transport by 2050. Low-carbon transport requires full engagement and participation of all stakeholders to bring about changes in behaviour. It will also

be necessary to reduce demand for transport and to stimulate a modal shift in both passenger and freight transport. This is particularly the case if European emissions include transport emissions caused by EU residents outside EU territory.

Thus, changing consumer preferences is an essential element in achieving a low-carbon transport. Changes in transport volume and mode shifts are assumed to contribute about 15% to the emission reduction target. This involves reducing short-distance passenger travel and long-distance passenger and freight transport, particularly air travel. For instance, reducing car use in urban areas for short distances requires a shift to non-motorised and public transport, and would need to achieve as much as a 20% reduction in car use in urban area and carbon dioxide emissions.

Even with optimistic assumptions on energy-efficiency improvements and use of advanced biofuels, significant reductions in air travel growth are needed in order to reduce carbon dioxide emissions from aviation to below 1990 levels. Here, growth is assumed to decrease from a forecasted tripling of air passenger kilometres between 2005 and 2050, to a doubling or less.

Pricing is a key factor in bringing about change. Demand for air travel can be reduced by eliminating all subsidies and introducing taxes and charges and/or including aviation in a global carbon trading system which results in sufficiently high carbon prices (e.g. all permits are auctioned, and the cap is progressively lowered by reducing the amount of permits auctioned each period). Also, growth in air travel will partly be curtailed by higher fuel prices based on a higher share of bio-kerosene which is likely to remain more expensive than jet fuel. In addition, incentives are needed to partly shift passenger air travel to high-speed rail between European cities.

5.4.5 Re-aligning Infrastructure Development

Currently, a significant proportion of the EU budget goes to co-financing investment in Trans-European networks (TEN-T). The overall cost of 28 priority projects is about 400 billion euros, of which 270 billion euros has yet to be invested. TEN-T investments have, however, not been fully successful in achieving EU policy goals. Firstly, according to the TEN-T policy review (European Commission 2009), planning of the Trans European Network has not been driven by genuine European objectives, resulting from a lack of funding and sovereign responsibility by the Member States in infrastructure planning (subsidiarity). Secondly, the economic efficiency of TEN-T investment is subject to debate. The EU project TIPMAC has, for example, shown that the net economic impact of the TEN-T programme is very small in the period up to 2020. This is largely because a number of transport projects on the corridor list will have difficulties generating enough transport benefits in the next two decades (Rothengatter 2009). Furthermore, TEN-T policy has not provided a sound basis for an effective contribution to climate change objectives. Within a low-carbon transport system, TEN-T policy should contribute more to reducing carbon dioxide emissions, and thus to EU climate change objectives, financing projects only with a proven economic rationale and with environmental benefits.

In this respect, more attention needs to be given to stimulating electric public transport. Investments in electrified high-speed rail, serving as a substitute for air travel, will help achieving low-carbon transport, provided the power is produced from low-carbon fuel sources and seat occupancy levels are high enough. To achieve significant shifts from road to rail transport, at least 10% of projected investment in road infrastructure should go to rail infrastructure (Rothengatter 2009).

5.5 Balancing Potential and Uncertainty of Measures

To achieve an 80% reduction in carbon dioxide emissions in transport by 2050, relative to 1990 levels, new solutions are needed. Continuous incremental technological improvements can provide substantial emission reductions but are not sufficient. However, the potential emission decrease from new policies and technological options is more uncertain than from the existing policies and from the incremental technological changes. From a strategic point of view to reach the vision of 2050, options can be clustered according to their potential emission reduction and the degree of uncertainty in emission reduction potential, the costs, or the side-effects. As illustrated with some examples in Table 5.1, there are:

Table 5.1 Examples of carbon dioxide mitigation options clustered by emission reduction potential and uncertainty in potential, costs, and/or side effects

CO ₂ emission reduction potential	Uncertainty in potential, costs, or side-effects	
	Small to moderate	Moderate to large
Small to moderate	<ul style="list-style-type: none"> • Current carbon dioxide-efficiency standards • Pricing measures, e.g. ETS for aviation and shipping, EU-wide road pricing for trucks • Energy-efficiency measures for road freight, shipping, aviation • Logistical-efficiency measures, e.g. green logistics • Land-use planning 	<ul style="list-style-type: none"> • First-generation biofuels (ethanol, bio-diesel) • Current commercial jet biofuels
Moderate to large	<ul style="list-style-type: none"> • Plug-in hybrid cars • Heavy oil biofuel substitutes for inland shipping and maritime transport 	<ul style="list-style-type: none"> • Full electric cars • Fuel-cell hydrogen road vehicles • Second-generation biofuels for road vehicles (ethanol, bio-diesel) • Second-generation and third-generation jet biofuels • Biomass-to-liquid biofuels with carbon capture and storage

- A range of technology options that may deliver large-scale emission reductions over time, but are associated with a high degree of uncertainty, such as second-generation and third-generation biofuels, biomass-to-liquid jet fuels, and hydrogen and fuel cells. These technologies require further technical progress leading to performance improvement and cost reduction, and also require radical changes in areas such as vehicle production, fuel supply, and agricultural systems. Supporting innovation for these technologies, support from EU and Member States for relevant R&D projects, and effective carbon pricing policies will be crucial.
- Options that have a low emission reduction potential and a low degree of uncertainty in technology or cost. Uptake of these technologies may lead to a small increase in vehicle or transport prices which may be offset by fuel savings. These technologies and measures are considered ‘no-regret’ measures for the EU on the way to low-carbon transport. They include carbon dioxide standards for new vehicles, energy-efficiency measures, ETS for international aviation and shipping, EU-wide road pricing schemes, and land-use planning.
- Technologies and policy measures that have a high emission reduction potential and a low degree of uncertainty in technology or costs. In these cases, industry and consumers will have to accept the cost in order to benefit from reduction in carbon dioxide emissions. This is the case for biofuels substitutes in heavy-duty vehicles and shipping. Use of biofuels (essentially FAME or bio-crude) in the maritime transport and heavy-duty road vehicles does not pose any fundamental or insurmountable technology challenges. The key barriers to biofuels are economic rather than technical, particularly for biofuels replacing marine diesel fuel (AEA 2007; Christ 2009).
- Some technologies have low potential for emission reduction and major side-effects. This is the case for the first-generation of biofuels and current commercial jet biofuels. These technologies have low and uncertain reduction potential and thus should not be further pursued by the EU.

5.6 The Transport Sector in a Low-Carbon EU Energy System

5.6.1 A Low-Carbon Energy Sector

In the study *Getting into the Right Lane*, a low-carbon energy system is envisioned for the EU energy system in 2050. An 80% reduction on 1990 levels in energy-related carbon dioxide emissions is assumed within the EU. In this envisioned low-carbon energy system, the end-use of energy is based predominantly on non-carbon energy carriers such as electricity or hydrogen from low-carbon sources or biofuels. The use of fossil energy is centralised to enable application of carbon capture and storage technology. Large renewable energy farms are interlinked in a European high-voltage electricity grid connecting Member States to distant energy sources, to reduce the

impacts of intermittency and enable the use of the cheapest renewable resources. In this low-carbon energy system, diversification of energy sources leads to increased security of supply through reduced dependency on imported fossil energy.

The global energy model TIMER (de Vries et al. 2001; van Vuuren et al. 2006) was used to consistently link energy demand, supply, and trade. These calculations are based on the scenario of the OECD Environmental Outlook (OECD 2008), with specific adjustments to simulate the envisioned energy system. The main assumptions for the energy sector are a rapid increase in the share of electricity particularly in passenger transport and buildings and carbon taxes leading to aim specifically to 80% reduction in carbon dioxide emissions in the EU. The transport sector is assumed to reduce emissions by 80%, shifting towards carbon neutral road passenger transport and biofuels for heavy transport modes, as described in Sect. 5.4.

5.6.2 Transport and Energy System Linkages

Achieving low-carbon transport in the EU in the coming decades is closely linked to measures in the energy sector in three ways. First, regardless of which non-carbon energy carrier is used for rail, urban transport, and medium-distance transport (electricity or hydrogen), it has to be produced with low-carbon emissions. Yet, roughly the same amount of energy would be required to produce low-carbon electricity or hydrogen. Secondly, failure to decrease carbon dioxide emissions from transport will most likely need to be compensated in the energy sector. Thirdly, retaining options for hydrogen as an energy carrier in transport will affect design features of the future power grid.

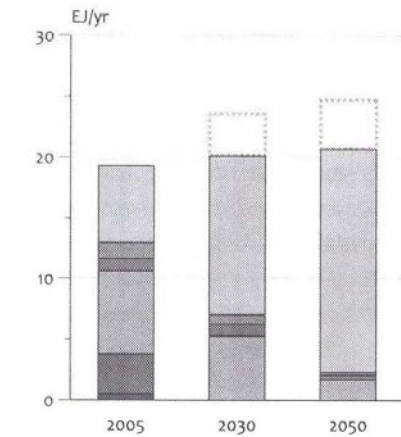
5.6.3 What If EU Transport Sector Is Less Successful in Reducing CO₂ Emissions?

Emission reductions in transport amount to an ambitious 80%. Such reductions are possible, but what are the consequences when the transport sector does not deliver this target? Considerable doubts remain whether a sufficient decrease in carbon dioxide emissions from transport is feasible without a broad, frontal approach to achieve policy coherence, EU-wide, and for aviation and maritime transport, globally. Many scenario studies assume less-ambitious reduction targets, particularly for international transport. For example, IEA's BLUE Map scenario projects worldwide CO₂ emissions from maritime transport to remain fairly constant at the 2005 level, and a doubling of CO₂ emissions from aviation by 2050, relative to 2005 levels, assuming major efficiency improvements and a substantial share (30%) of advanced biofuels in overall fuel use (Fig. 5.4).

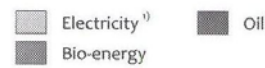
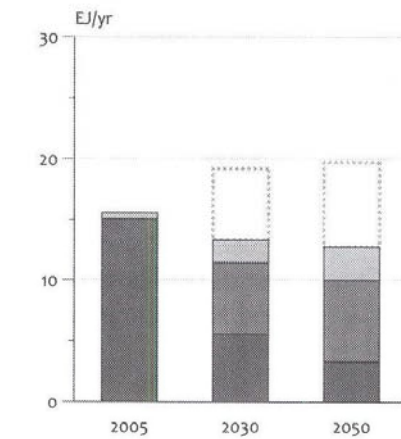
With regard to reductions in greenhouse gas emissions, economic sectors can be seen as “communicating vessels”: if emission reductions are smaller in transport,

Towards a low-carbon EU energy system, vision

Final energy consumption buildings



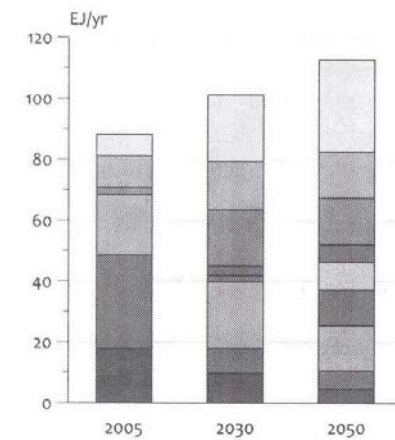
Final energy consumption transport



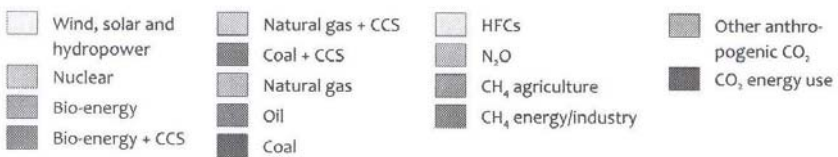
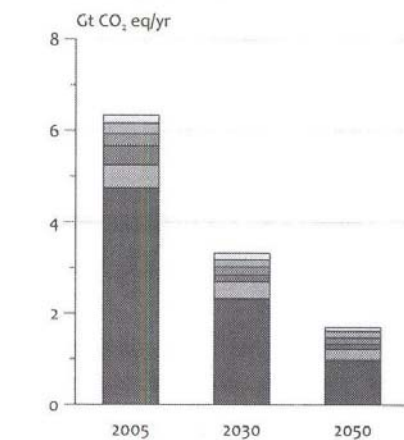
Efficiency improvement compared to baseline

Efficiency improvement compared to baseline

Primary energy use



Greenhouse gas emission



1) Alternatively, the carbon-free carrier could be hydrogen

Fig. 5.4 A vision of a low-carbon energy system in the EU in 2050

then the power sector needs to achieve greater emission reductions (up to 100–120%). Negative emissions can be achieved in the power sector by using bio-energy in combination with carbon capture and storage. The use of wood-based bio-energy in power plants with carbon capture and storage generates is attractive as it creates a double benefit in decreasing carbon dioxide emissions: firstly taken up by crops, followed by subsequent storage. These net ‘negative emissions’ facilitate high emission reductions in the power sector.

5.7 Biofuels, Land Resources, Food, and Biodiversity

Many studies on climate mitigation have identified bio-energy as a key option to reduce greenhouse gas emissions and as an economic opportunity to reduce poverty in the developing countries. Based on the energy security considerations, policy makers have focused on stimulating the use of bio-fuels in road transport. This push for bio-fuels, mainly in 2008 with blending proposals in the USA and fixed renewable targets for transport in the EU, has led to scientific and societal debate on whether bio-fuels are a sustainable solution. The debate is dominated by issues such as risk of biodiversity loss, increase in food prices (Dornburg et al. 2008), the greenhouse gas balance of bio-fuels being negatively influenced by N₂O emissions (Smeets et al. 2009), and indirect changes in land use (Fargione et al. 2008; Searchinger et al. 2008).

Given the limitation in bio-energy potential and likely negative side-effects of energy-crop production, bio-energy needs to be directed strategically to applications that maximise its contribution to decreasing carbon dioxide emissions and minimise the required inputs. Currently, bio-fuel seems to be one of the few feasible low-carbon or zero-carbon options for aviation, shipping, and road freight before 2050. But is there sufficient global potential for bio-energy production, taking into account restrictions on for example land resources and nature protection?

Estimates vary widely on the global potential for bio-energy production. The long-term potential could be as low as 100–500 EJ/year, taking account of uncertainties in yield increase, sustainability criteria, water availability, fragile states (e.g. civil wars reducing investment opportunities), and other external factors (Dornburg et al. 2008; WBGU 2009). Based on the integrated modelling analysis of land-use and energy (van Vuuren et al. 2009, 2010) and because of uncertainties in production potential, this study limits the use of bio-energy to the lower end of the range. This is 100 EJ/year global bio-energy production, partly based on waste and residues, and partly on specific cultivation (Fig. 5.5). This could require about 3 million km² of land. For comparison, the current total EU agricultural area is approximately 2.2 million km².

A global bio-energy production of 100 EJ/year is sufficient to fuel long-distance road transport, aviation, and shipping, and to produce a sufficient amount of bio-energy to be used in power plants to achieve the vision of low-carbon energy and transport systems in the EU.

Estimates of global bio-energy potential, 2050

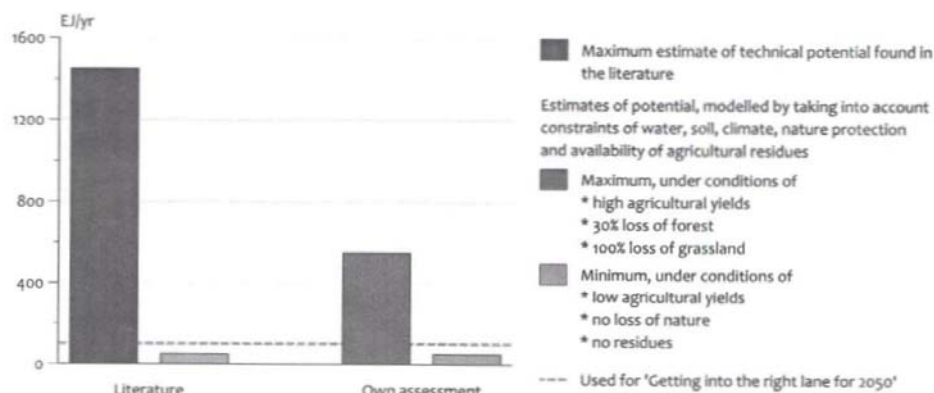


Fig. 5.5 Assessment of bio-energy potentials (Source: van Vuuren et al. 2009b)

Targeting bio-energy to long-distance road freight transport, aviation, maritime transport, and the power sector enables large carbon mitigation with a small volume of bio-energy inputs and minimal pressure on nature and food production. This requires the EU to extend bio-energy strategies with specific targeted applications. Thus, technology development of second-generation and third-generation bio-fuels could best be aimed at advanced bio-diesels for shipping and trucks and bio-kerosene for airplanes such as FT diesel or algae-based fuels. To achieve this, it requires a long-term EU vision on the application and production of bio-energy and a bio-energy directive that stimulates innovation in the direction needed for the long-term, and the current renewable energy directive to be aligned with a long-term vision on transport in the EU.

5.8 The Critical Path to Low-Carbon Transport in the EU

Achieving low-carbon transports in the EU in 2050 requires policy action in the coming decade, to set transport in the right lane to achieve this goal, because of the long lifespan of vessels and aircraft, many of which in operation today will still be operative in 2050. There is no single option to bring the emission reduction target within reach. The key elements to bring about the 80% decrease are technological options and a reduction of the increase in transport demand, for example, through pricing mechanisms. Thus, a package of policies is essential. The following steps are on the critical path – actions to be taken in the near-term future – to achieve this vision:

1. The EU needs to formulate a coherent policy on achieving low-carbon transport and energy systems, addressing the risks, vulnerability, security, and resilience associated with diversified energy carriers for transport in Europe. This policy

should become the basis for an integrated EU approach to both transport and energy aimed at facilitating transition to production of advanced vehicles and low-carbon energy carriers. On the critical path to low-carbon urban transport is a sufficient supply of clean power after 2030, as well as a host of standardisation issues. Because of the slow pace of change where major infrastructure investment is involved, decarbonising the energy sector needs to be even higher on the agenda than is the development of low-carbon vehicle technologies. A long-term policy framework to decrease carbon dioxide emissions from transport will provide stakeholders with a degree of certainty about carbon reduction in relation to other objectives.

2. The EU needs to take a leadership role to achieve international agreements for reducing emissions from aviation and shipping. A global strategy is the most effective, but also the most difficult approach in reducing emissions from these transport modes. It involves including international aviation and maritime transport in an emission-trading scheme with the objective to tighten targets over time and to allocate rights through auction and not allocation. It would mean a more effective emission trading scheme than the current EU-wide scheme, and would also include shipping. If a global trading system is not possible in near future, then an effective EU-wide scheme needs to be in place as a first step towards such a global system.
3. A great deal of R&D is being done in the private sector and EU initiatives are needed to strengthen efforts to identify emerging and promising technology, such as batteries and other energy storage technologies. Support is needed to bring these technologies to market. In this respect, partnerships with vehicle manufacturers may be particularly useful, giving them a stake in developing and commercialising new technologies. In addition, substantial R&D needs to be stimulated and financed on bio-kerosene (third-generation biofuels). Furthermore, effective carbon pricing is needed to support innovative low-carbon transport technologies, such as biofuels for heavy-duty road transport and maritime transport. This approach will yield new technologies that could become future standards in developing countries and in transition countries which are having difficulties in meeting low-carbon goals.
4. With restricted worldwide capacity for biomass production, bioenergy needs to be concentrated where it can contribute most to mitigating carbon dioxide emissions, and where there are few options available. Technology development of bio-fuels could best be aimed at advanced bio-diesels for shipping and trucks and bio-kerosene for airplanes such as FT diesel or algae-based fuels. To achieve this, the current renewable energy directive needs to be aligned with a long-term vision on transport in the EU. Cost-effectiveness of EU transport policies can be improved by closely linking current biofuel targets with EU vehicle-efficiency targets. King (2008) suggests that this could be achieved by establishing a carbon-intensity obligation for all fuels, such as in the California's Low-Carbon Fuel Standard where carbon-intensity of fuels is reduced through a system of tradable credits, also applicable to

biofuels. EU could also set up a wider road transport obligation which links carbon intensity of fuels to vehicle efficiency, possibly through tradable credits. Ultimately, road transport could be covered by a 'cap and trade' scheme such as the current ETS.

5. Given the size of allocated budgets for Trans-European transport infrastructure, revising TEN-T transport policies is a priority in the short term. Infrastructure built in the coming decade will still be operational in 2050 and beyond. A key issue is to provide a stronger link between TEN-T policy planning, development, and climate goals, as proposed in the Green Paper on future TEN-T policy. The implication is that the EU would co-finance only those projects with a proven economic rationale and with environmental benefits, thus shifting investment from road to rail infrastructure.

5.9 Conclusions

Low-carbon transport presented in the vision for 2050 significantly reduces carbon dioxide emissions from transport, makes EU transport systems better able to adapt to future changes in energy supply and climate, improves robustness and resilience and increases long-term competitiveness of the EU economy. It will also trigger cleaner and quieter cities in Europe. A decarbonised energy sector and international agreements in shipping and aviation are crucial.

The current economic crisis is affecting transport more than most other activities, and this creates opportunity for changing business models and for the emergence of a new long economic cycle with different dynamics. But as yet, this is not substantiated. Given the longevity of transport infrastructure and spatial patterns, betting on the benign effects of such a paradigm is a risky strategy. Setting incentives to adjust transport to a long-term sustainability path is crucial, for instance, to reduce the transport intensity of freight transport. Rather than pushing investment in a crisis phase, a long-term sustainability strategy for infrastructure development is needed, because infrastructure built in the coming decade will still be operational in 2050.

Considerable doubt remains whether a sufficient decrease in carbon dioxide emissions from transport is feasible without a broad, frontal approach to achieve policy coherence, EU-wide. Such doubts are generated by the feasibility of carbon reduction options, projected steep growth in transport demand – passenger and freight transport – and the scarcity of evidence that this trend can be reversed at the level of the economy as a whole. Thus, establishing a broadly supported ambition to achieve low-carbon transport is on the critical path, including leadership to allocate responsibilities to vehicle manufacturers, fuel companies, and consumers. It also needs to enforce clear accountability and put in place the policies and frameworks to allow and enable others to fulfil their roles.

References

- AEA Energy & Environment (2007) Low carbon commercial shipping. AEA Didcot
- Banister D (2009) Getting in the right lane. Low carbon European transport beyond 2050. Paper. Transport Studies Unit, Oxford University, Oxford
- Buhaug Ø, Corbett JJ, Endresen Ø, Eyring V, Faber J, Hanayama S (2008) Updated study of greenhouse gas emissions from ships. Phase 1 Report, International Maritime Organisation, London (Cited in Christ P (2009) Greenhouse gas emissions reduction potential from international shipping. Discussion paper No. 2009-11, Joint Transport Research Centre, Paris)
- Christ P (2009) Greenhouse gas emissions reduction potential from international shipping. Discussion paper No. 2009-11, Joint Transport Research Centre of the OECD and International Transport Forum, Paris
- Committee on Climate Change (2008) Building a low-carbon economy – the UK's contribution to tackling climate change. HMSO, Norwich
- De Lange R, Verbeek R, Passier G, Kattenwinkel H (2008) Mogelijkheden tot CO₂ normering en brandstof differentiatie voor het vrachtverkeer. MON-RPT-033-DTS-2008-02646, TNO Industrie en Techniek, Delft
- de Vries HJM, van Vuuren DP, den Elzen MGJ, Janssen MA (2001) The TIMER iMAGE Energy Regional (TIMER) model. National Institute for Public Health and the Environment (RIVM), Bilthoven, pp. 188
- Dornburg V, Faaij A, Verweij P, Banse M, van Diepen K, van Keulen H, Langeveld H, Meeusen M, van de Ven G, Wester F, Alkemade R, ten Brink B, van den Born GJ, Van Oorschot MMP, Ros J, Smout F, Van Vuuren DP, van den Wijngaart R, Aiking H, Londo M, Mozzaffarian H, Smekens K, Lysen E, van Egmond S (2008) Biomass Assessment – Assessment of the global biomass potentials and their links to food, water, biodiversity, energy demand and economy: inventory and analysis of existing studies. PBL, Bilthoven
- EEA (2009) Transport at a crossroads. TERM 2008: indicators tracking transport and environment in the European Union. EEA Report No. 1/2008, European Environment Agency, Copenhagen
- European Commission (2009) TEN-T: a policy review. Towards a better integrated trans European transport network at the service of the common transport policy. Green Paper, COM(2009) 44, Commission of the European Communities, Brussels
- Fargione J, Hill J, Tilman D, Polasky S, Hawthorne P (2008) Land clearing and the biofuel carbon debt. *Science* 319(5867):1235–1238
- Hanschke CB, Uytterlinde MA, Kroon P, Jeeninga H, Londo HM (2009) Duurzame innovatie in het wegverkeer – Een evaluatie van vier transitiepaden voor het thema Duurzame Mobiliteit. ECN, Petten
- IEA (2008) Energy technology perspectives. Scenarios and strategies up to 2050. International Energy Agency, Paris
- King J (2008) The King Review of low-carbon cars. Part II: recommendations for action. HMSO, London
- Lensink SM, De Wilde HPJ (2007) Kostenefficiëntie van (technische) opties voor zuiniger vrachtverkeer. ECN-E-07-003. ECN, Petten
- OECD (2008) OECD Environmental Outlook to 2030. OECD, Paris
- PBL (2008) Lessons from global environmental assessments. Netherlands Environmental Assessment Agency (PBL), Bilthoven, 2008
- Petersen MS, Enci R, Hansen CO, Larrea E, Obisco O, Sessa C, Timms PM, Uljed A (2009) Report on Transport Scenarios with a 20 and 40 Year Horizon. Final Report TRANSvisions. Tetraplan A/S, Copenhagen
- Rothengatter W (2009) European transport in a competitive economy. Paper for Netherlands Environmental Assessment Agency Karlsruhe

- Schippl J, Leisner I, Kaspersen P, Madsen AK (2008) *The future of European long distance transport. European Technology Assessment Group, Karlsruhe*
- Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, Fabiosa J, Tokgoz S, Hayes D, Yu T-H (2008) Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science* 319(5867):1238–1240
- Smeets EMW, Bouwman AF, Stehfest EE, van Vuuren DP, Posthuma A (2009) Contribution of N₂O to the greenhouse gas balance of first-generation biofuels. *Glob Change Biol* 15(1):1–23
- van Ruijven B, Hari L, van Vuuren DP, de Vries B (2008) The potential role of hydrogen in India and Western Europe. *Energy Policy* 36(5):1649–1665
- van Vuuren DP, van Ruijven BJ, Hoogwijk MM, Isaac M, de Vries HJM (2006) TIMER 2.0. Model description and application. In: Bouwman AF, Hartman MPM, Klein Goldewijk CGM (eds) *Integrated modelling of global environmental change. An overview of IMAGE 2.4.* Environmental Assessment Agency (MNP), Bilthoven, Netherlands
- van Vuuren DP, van Vliet J, Stehfest E (2009) Future bio-energy potential under various natural constraints. *Energy* 37(11):4220–4230
- van Vuuren DP, Bellefleur E, Kitouss A, Isaac M (2010) Bio-energy use and low stabilisation scenarios. *Energy J* 31:193–222
- WBGU (2009). *World in Transition – Future Bioenergy and Sustainable Land Use.* Berlin, German Advisory Council on Global Change

