# The impact of current and future policies on energy related $CO_2$ emissions in the domestic transport sector
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# A comparison of the USA and the People's Republic of China with the Climate Action Tracker

**Master thesis for the Energy Science master programme at Utrecht University**

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# Abstract

There is increasing awareness around the world of the influence of $CO_2$ on climate change. In 2009, domestic transportation accounted for 27% of global final energy consumption and the USA had the largest $CO_2$ emissions with 1.6 Gt, followed by China with 456 Mt. Both countries pledged under the Copenhagen Accord to reduce their $CO_2$ emissions until 2020. The target of the USA is to reduce emissions by 17% under 2005 levels. China plans a reduction of 40-45% below 2005 levels per unit of GDP. This study focuses on these two countries and assesses the $CO_2$ reduction potential of current and planned policies in the domestic transport sector in 2020 and whether the reduction is in line with the pledges. Further, it compares the policy strategies of the two countries and identifies gaps in the current policy strategies with the help of the Climate Action Tracker model. The Climate Action Tracker model uses evaluation against best practice and was further developed during the research. Both countries show similarities in their policy strategies, having fuel economy standards for passenger vehicles and focusing on high speed rail and electric vehicles. Current and planned policies in China have a reduction potential of 68 Mt $CO_2$ in 2020. Filling the policy gaps has a reduction potential of 420 Mt $CO_2$. The corresponding values for the USA are 268 and 949 Mt $CO_2$. With a conservative assumption for the Chinese GDP development, the upper end of the target range of the pledge (45%) is exceeded by 2% without further policy action. The policy impact exceeds the pledge by 7%, the reduction potential by 31%. Policies in the USA lead to a reduction of 21% below 2005 levels by 2020. The reduction potential is 58% below the 2005 levels. To fulfil the pledge under the Copenhagen Accord, this gives the other sectors a little buffer.

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# Exchange rate

To convert Chinese Yuan Renminbi to US Dollar, the exchange rate of 10.10.2012 was used (XE 2012).

1 Yuan (RMB) = $0.158731
$1 = 6.29996 Yuan (RMB)

# Glossary

| | |
|---|---|
| AEO | Annual Energy Outlook |
| AFV | Alternative fuel vehicle |
| AIF | Actual impact factor |
| ARRA | American Recovery and Reinvestment Act |
| B10 | Diesel with a share of 10% biodiesel |
| BAU | Business as usual |
| BRT | Bus rapid transit |
| BTS | Bureau of Transportation Statistics |
| CAFE | Corporate average fuel economy |
| CAT | Climate Action Tracker |
| CMAQ | Congestion Mitigation and Air Quality Improvement |
| CNG | Compressed natural gas |
| cpl | cents per litre |
| CPS | Current policies scenario |
| DOE | Department of Energy |
| DOT | Department of Transportation |
| E10 | Gasoline with a share of 10% ethanol |
| EPA | Environmental Protection Agency |
| EREV | Extended range electric vehicle |
| EV | Electric vehicle |
| FAA | Federal Aviation Administration |
| FCEV | Fuel cell electric vehicle |
| FCV | Fuel cell vehicle |
| FRA | Federal Railroad Administration |
| FHWA | Federal Highway Administration |
| FTA | Federal Transit Administration |
| GDP | Gross Domestic Product |
| HEV | Hybrid electric vehicle |
| HOT | High-occupancy toll lanes |
| HOV | High-occupancy vehicle lane |
| IEA | International Energy Agency |
| IMF | International Monetary Fund |
| IRS | Internal Revenue Service |
| ISIC | International Standard Industrial Classification |
| LNG | Liquefied natural gas |
| LPG | Liquid petroleum gas |
| MIF | Maximum impact factor |
| mpg | miles per gallon |
| NGV | Natural gas vehicle |
| NEDC | New European driving cycle |
| NRDC | National Development and Reform Commission |
| PHEV | Plug-in hybrid electric vehicles |
| pkm | Person kilometre |
| tkm | Tonne kilometre |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WEO | World Energy Outlook |

# 1 Introduction

## 1.1 Background

There is increasing awareness around the world of the influence of $CO_2$ on climate change (IPCC 2007a). In the Copenhagen Accord, the parties agreed that global warming should be limited to 2° C. To reach this goal, deep cuts in emissions are needed (UNFCCC 2010). The Bridging the Emissions Gap report by the UNEP quantifies this with 14-20 Gt $CO_2$ for 2020 (UNEP 2011). China and the United States of America (USA) have pledged under the Copenhagen Accord to reduce their emissions on a voluntarily basis. In 2010, the USA emitted about 5.7 Gt $CO_2$ (UNFCCC 2012); Chinese emissions are reported at 7.6 to 9 Gt $CO_2$ (Guan et al. 2012). The USA has an absolute $CO_2$ reduction target of 17% below 2005 levels by 2020 (UNFCCC 2011a), which is "in line with final U.S. energy and climate legislation" (The White House 2009, paragraph 2). In China, the Executive of the State Council target to lower $CO_2$ emissions by 40-45% per unit of GDP below 2005 levels by 2020 (UNFCCC 2011b, State Council 2009). For China the net reduction is hard to quantify, because it also depends on the development of the GDP. If the GDP increases faster than emissions, then no real reduction would be achieved.

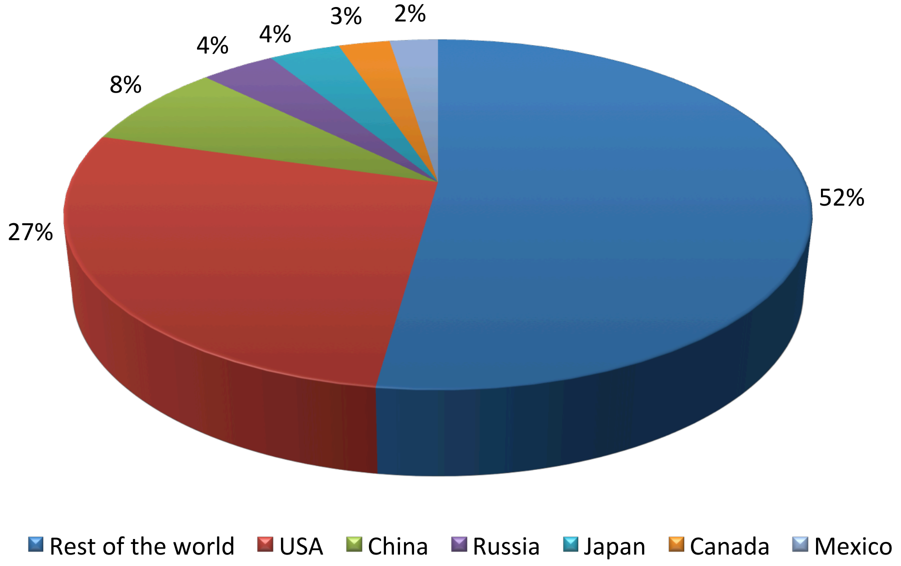

**Figure 1: Share of $CO_2$ emissions by country from fossil fuel combustion in the domestic transport sector, excluding $CO_2$ from electricity production, in 2009. Data from the IEA 2011 balances (IEA 2011b, IEA 2011a), is converted to $CO_2$ emissions with IPCC factors (IPCC 1995).**

In 2009, transportation accounted for 27% of global final energy consumption (IEA 2011a). Based on divisions 49-51 of the International Standard Industrial Classification, the transportation sector covers air, land, pipeline and water transport (UNSD 2012). For air and water transport with departure or arrival in a different country, there are special categories: world marine and aviation bunkers (IEA 2011c). These two categories are not included in the domestic transport sector. Military transport is not included in the IEA energy balances (IEA 2011b).

Figure 1 shows the breakdown of worldwide $CO_2$ emissions in the domestic transport sector by country in 2009. $CO_2$ emissions from electricity are excluded because they are accounted for in the power supply sector. The USA had the largest $CO_2$ emissions with 1.6 Gt (IEA 2011b), followed by China[1] with 456 Mt (IEA 2011a). Six countries accounted for 48% of worldwide $CO_2$ emissions in the domestic transport sector in 2009. The USA leads by far. China's emissions are twice as big as Russia's and Japan's, who share third place (IEA 2011a, IEA 2011b). The UNEP Bridging the Emissions Gap report quantifies the required cuts from transportation at 1.7-2.5 Gt $CO_2$ (UNEP 2011).

Table 1 shows the final energy consumption of the domestic transport sector of the USA and China in 2009 per mode of transport. In total, the final energy consumption of the USA was 3.6 times higher than that of the Chinese. Transport accounted for 40% of the total final energy consumption in the USA and 12% in China. Final energy consumption is estimated using Equation 1 (Blok 2007).

Final energy consumption = Net available energy - Input to own conversion processes + Output of own conversion processes (Eq. 1)

**Table 1: Final energy consumption per mode of transport in 2009 (IEA 2011a, IEA 2011b).**

| Unit: PJ | **China** | **USA** | **World** |
|---|---:|---:|---:|
| **Domestic aviation** | 488 | 1,999 | 4,007 |
| **Domestic navigation** | 558 | 148 | 1,705 |
| **Non-specified transport** | 51 | 32 | 360 |
| **Rail transport** | 490 | 366 | 2,020 |
| **Pipeline transport** | 5 | 582 | 2,292 |
| **Road transport** | 5,514 | 21,062 | 71,481 |
| **Total: Transport** | 7,106 | 24,189 | 81,865 |
| **Share: Transport** | 12% | 40% | 27% |

Table 1 indicates that the USA and China are the largest consumers of the global final energy consumption in the domestic transport sector. The USA consumed about half of the global final energy consumption from domestic aviation in 2009. Road transport is the largest energy consumer in both countries with a share of 78% and 87% in China and the USA, respectively. The rankings of the other modes of transport differ. This is mainly due to infrastructure and intensity. To provide an indication of differences in infrastructure, Table 2 shows the lengths of pipelines, rail, road and waterways and the

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[1] In the following paragraphs, "China" always refers to Mainland China. This excludes the special administrative regions of Hong Kong and Macau.

number of airports in the USA and China. Table 3 shows the difference of activity levels of different modes of transport.

**Table 2: Transport infrastructure in China and the USA. The number in brackets indicates the reference year (CIA 2012).**

| | China | USA |
|---|---:|---:|
| Airports | 497 (2012) | 15,079 (2010) |
| Pipelines [km] | 75,742 (2010) | 793,285 (2010) |
| Railways [km] | 86,000 (2008) | 224,792 (2007) |
| Roadways [km] | 3,860,800 (2007) | 6,506,204 (2008) |
| Waterways [km] | 110,000 (2011) | 41,009 (2012) |

**Table 3: Activity levels in 2009 of different modes of transport in China and the USA (China statistical yearbook 2011, BTS 2012).**

| [100 million] | pkm[2] | | tkm[3] | |
|---|---:|---:|---:|---:|
| | China | USA | China | USA |
| Dom. aviation | 3,375 | 8,828 | 126 | 192 |
| Dom. navigation | 69 | 6 | 57,557 | 7,634 |
| Rail | 7,879 | 577 | 25,239 | 24,515 |
| Road | 13,511 | 67,862 | 37,189 | 20,224* |
| Pipeline | - | - | 2,022 | 10,087** |

* 2003 value

** 2008 value

The USA not only consumes four times more final energy in air transport than China (Table 1) but also has more airports (Table 2). The amount of pkm was 162% higher in the USA than in China, the amount of tkm was 52% higher (Table 3).

China has more waterways than the USA (Table 2). This is also reflected in the fact that navigation is the second largest final energy consumer in China, while it is in fifth place in the USA (Table 1). Activity levels of domestic navigation for passenger and freight transport are a lot higher in China than in the USA. The amount of pkm was 1,089% higher in China than in the USA, the amount of tkm was 654% higher (Table 3).

With fewer railways (Table 2), China consumes more energy in rail transport (Table 1). National statistics show that the activity levels in China in 2009 were higher than in the USA for both pkm and tkm. The amount of pkm was 1,266% higher in China than in the USA, the amount of tkm was 3% higher (Table 3).

The USA has almost double the roadways than China (Table 2) and consumes four times more energy (Table 1). The amount of pkm is 402% higher in the USA than in China. For

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[2] pkm: person kilometre – travelled distance of a vehicle multiplied by the number of passengers

[3] tkm: tonne kilometre – travelled distance of a vehicle multiplied by the amount of freight [t]

tkm the latest available data of the USA is from 2003. Back then, the amount was 185% higher than the Chinese (7,100 × 100 million tkm).

Six times the total final natural gas consumption explains the difference in final energy consumption by pipelines (Table 1). The USA had a total final natural gas consumption of 13 EJ in 2009, while China consumed 2 EJ (IEA 2011a, IEA 2011b). Activity data for the USA is only available for 2008. It was 173% higher than in China (Table 3).

These values show that the countries are different in regards to the transport sector. Rail and water transport are more important in China than in the USA. The following chapter provides additional information on the development, projections and mitigation potential of the domestic transport sector of the two countries.

## 1.2 Development, projections and mitigation potential of the domestic transport sector

Several studies and reports have projections of the future energy demand and $CO_2$ emissions of the transport sector. The following sections compare the development of the Chinese and American domestic transport sector and projections from various studies.

### 1.2.1 Development of the domestic transport sector between 1990 and 2009

Between 1990 and 2007, final energy consumption of the domestic transport sector increased in both countries. From 2007 on, the beginning of the financial crisis, a decreasing trend in the USA can be observed at a rate of 4% per year. In China there was a continued increasing trend for the whole period (Figure 2).

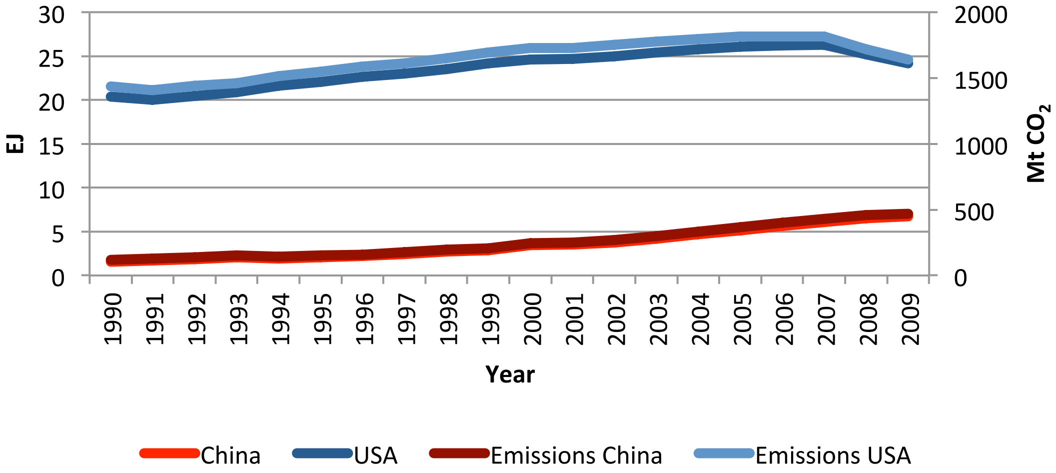

**Figure 2: Final energy consumption and $CO_2$ emissions development of the domestic transport sector in the USA and China between 1990 and 2009 (IEA 2011a, IEA 2011b).**

The following subchapters give insight into the development of individual modes of transport and the changes of final energy demand, activity levels and vehicle stock.

#### *1.2.1.1 Development in China between 1990 and 2009*

Between 1990 and 2009, the final energy consumption of all modes of transport in China increased, except for rail (Figure 3). The large increase of the final energy consumption of rail transport between 1996 and 1998 and the decrease between 1999 and 2000 cannot explained by an increase of locomotives, freight or activity level (China statistical yearbook 2011), pointing out towards a statistical error.

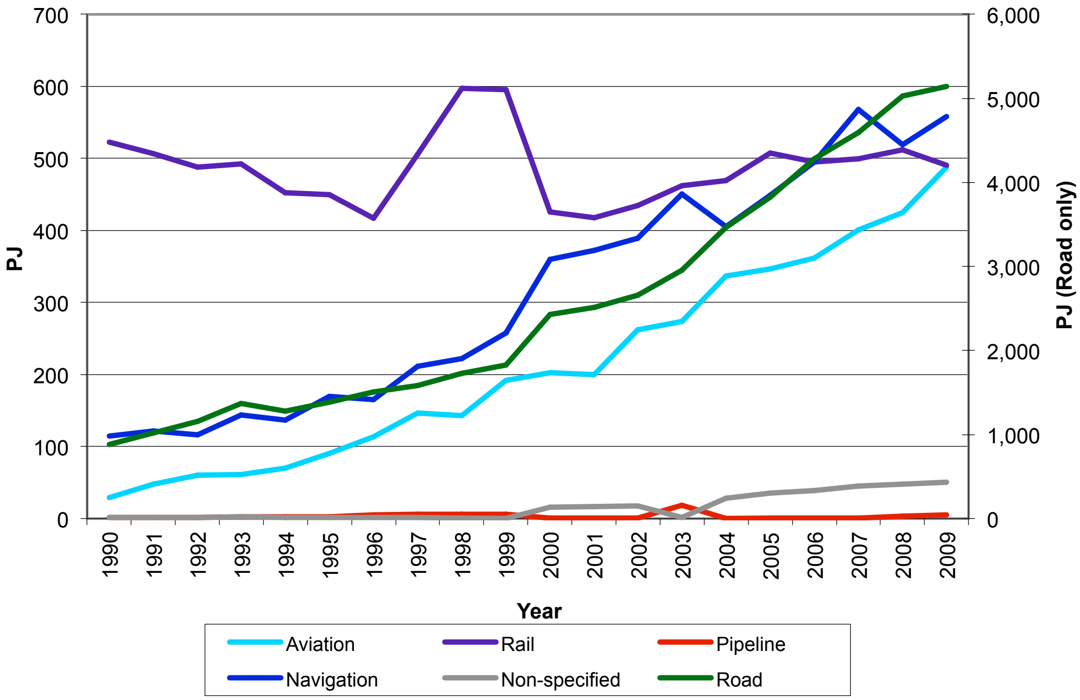

**Figure 3: Final energy consumption per mode between 1990 and 2009 in China (IEA 2011a).**

- **GDP development**

To understand the growth of the domestic Chinese transport sector, the gross domestic product (GDP) development needs to be considered. The GDP is "the sum of the gross values added of all resident institutional units engaged in production" (OECD 2001, paragraph 1).

Figure 4 shows the GDP development between 1990 and 2011 and the projections until 2020. Between 1990 and 2011 it increased by 698% with an average annual growth rate of 10.4%. The International Monetary Fund has conservative projections until 2017 of 8.6% per year, continued until 2020 for the graph (IMF 2012c). This growth is important for the policy analysis of this thesis, as the Chinese reduction target is per unit of GDP.

Hu & Khan explain the GDP increase with an increased rate of productivity and more efficient labour. After economic reforms in 1978 the productivity rate increased by 3.9%

until 1994. Between 1953 and 1978, the annual increase was 1.1%. The economic reforms also allowed foreigners to invest in China. Foreign investment built factories and created jobs (Hu, Khan 1997).

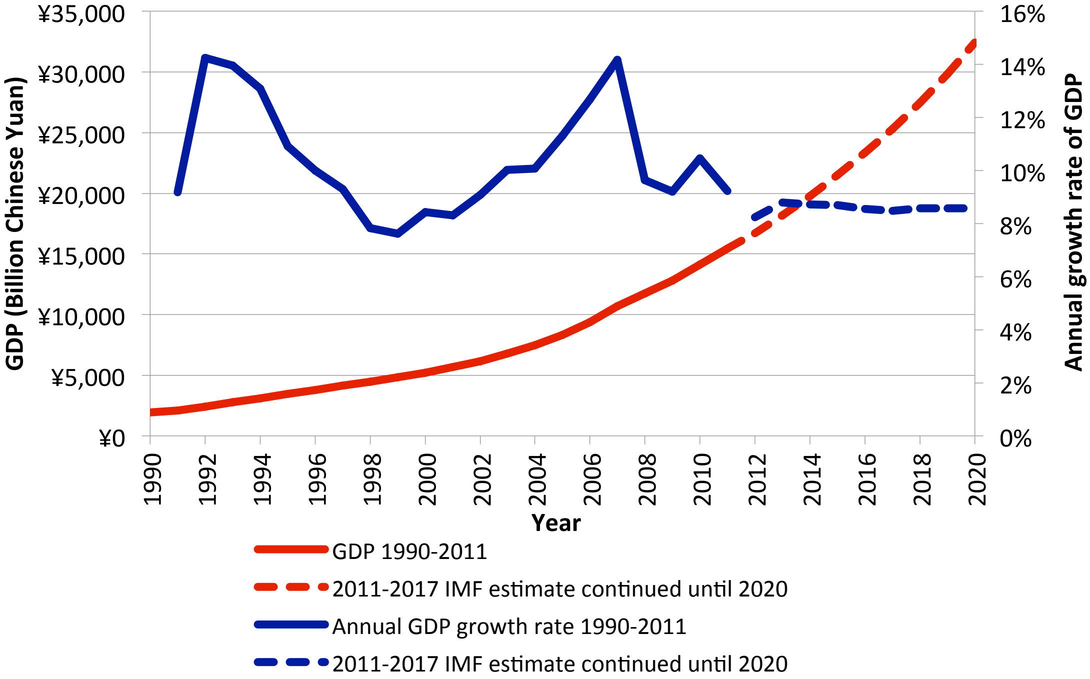

**Figure 4: GDP development of China between 1990 and 2011 and estimate until 2020 (IMF 2012c).**

- **Domestic aviation**

The final energy demand of domestic aviation increased from 29 PJ to 488 PJ (IEA 2011a). Passenger transport activity increased from 23 to 338 billion pkm and freight transport activity from 1 to 13 billion tkm. Parallel to this, the number of aeroplanes increased from 503 to 2,405 (China statistical yearbook 2011).

- **Domestic navigation**

Domestic water transport increased its final energy demand by 387% from 115 PJ to 558 PJ (IEA 2011a). The number of boats and vessels decreased from 408,370 to 176,932. Passenger transport activity decreased from 17 to 7 billion pkm, while freight transport activity increased by 397% from 1,159 to 5,758 billion tkm. The length of navigable inland waterways increased by 13% from 109,200 km to 123,700 km (China statistical yearbook 2011). As the other modes of transport had an increase in passenger activity, this indicates a modal shift.

- **Pipeline**

The pipeline network length increased between 1990 and 2009 from 16,000 to 69,100 km (China statistical yearbook 2011). Between 1990 and 2009, the final energy consumption increased by 171% from 1.8 to 5 PJ (IEA 2011a). The activity increased by 223% from 63 to 202 billion tkm (China statistical yearbook 2011).

- **Rail**

Rail transport decreased the final energy demand by 6% from 523 to 491 PJ (IEA 2011a). Meanwhile, the number of locomotives increased by 31% from 13,592 to 17,825. Passenger transport activity increased by 202% from 261 to 788 billion pkm and freight transport activity by 138% from 1,062 to 2,524 billion tkm. The length of railway tracks increased by 48% from 58,000 km to 86,000 km (China statistical yearbook 2011).

While the number of locomotives, passenger and freight activity increased, the final energy consumption decreased. This is because 99% of the 6,279 steam powered locomotives were retired between 1990 and 2009. Meanwhile the number of diesel powered locomotives increased by 91% from 5,680 to 10,844 and electricity powered locomotives by 322% from 1,633 to 6,898 (China statistical yearbook 2011). Coal consumption decreased by 68%, diesel and electricity consumption increased by 171% and 449% (IEA 2011a).

- **Road**

Final energy consumption of road transport increased by 484% from 880 to 5,140 PJ (IEA 2011a), while passenger transport activity increased by 416% from 262 to 1,351 billion pkm and freight transport activity by 1,007% from 336 to 3,718 tkm (China statistical yearbook 2011).

While in 1990 the motor gasoline consumption was six times higher than diesel, in 2009 it was only 4% larger, with shares of 50% (motor gasoline) and 48% (diesel) of the final consumption. Alternative fuels like LPG and natural gas were introduced in 1997. In 2009, their share of the final consumption was below 1%. The same applies for biogasoline and biodiesel, which were introduced in 2006.

The number of vehicles per 1,000 people increased from 15 (2003) to 47 (2009) (World Bank 2012). The number of passenger vehicles increased by 4,034% from 2 to 87 million, of which 98% are small cars and the number of trucks increased by 398% from 4 to 21 million. The Chinese standard of living is gradually increasing and thereby enabling more people to own cars (Yanli et al. 2012).

Furthermore, the length of the highway network increased by 275% from 1 million km to 3.9 million km (China statistical yearbook 2011). Large investments by the Chinese government in infrastructure, combined with the increase in car registrations enables more Chinese people to travel and is, together with the increase of the standard of living, the driving trend behind the increase in pkm and tkm.

- **Non-specified**

Final energy demand of non-specified transport increased by 4,235% from 1 to 51 PJ (IEA 2011a). No further information is available.

#### *1.2.1.2 Development in the USA between 1990 and 2009*

Between 1990 and 2009, the total final energy consumption of the domestic transport sector in the USA increased from 20.4 to 24.2 EJ, with the maximum in 2007 with 26.3 EJ, before the financial crisis (IEA 2011b) Figure 5 shows the development per mode of transport.

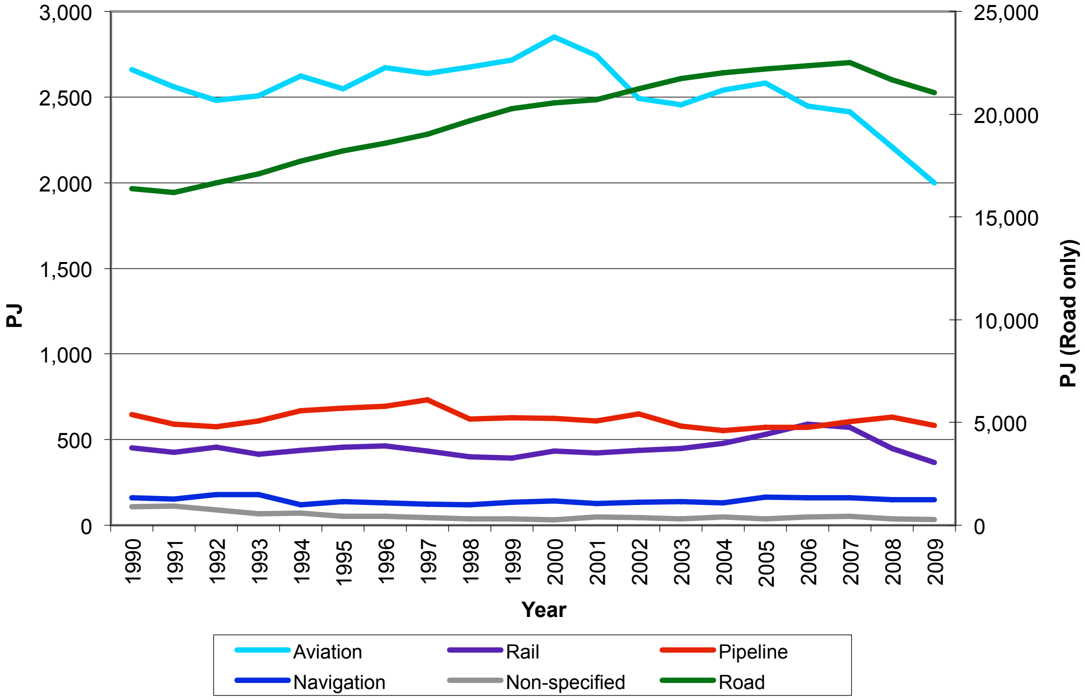

**Figure 5: Final energy consumption per mode between 2000 and 2009 in the USA (IEA 2011b).**

- **GDP**

Figure 6 shows the GDP development between 1990 and 2011 and the projections until 2020. Between 1990 and 2011 it increased by 66% with an average annual growth rate of 2.4%. The International Monetary Fund has projections until 2017 with an average growth of 2.9% per year. The graph was extrapolated with this average growth rate until 2020 (IMF 2012b).

There are two significant drops in the GDP development. The first one is between 2000 and 2001: the growth rate dropped by 3%. One significant event during this time period was the 9/11 attacks (IATA 2011). The second significant drop is between 2007 and 2009. The growth rate dropped by 5.3% and became even turned into recession after the start of the financial crisis (IATA 2011). Similar changes can be observed in the development of final energy consumption statistics (Figure 5).

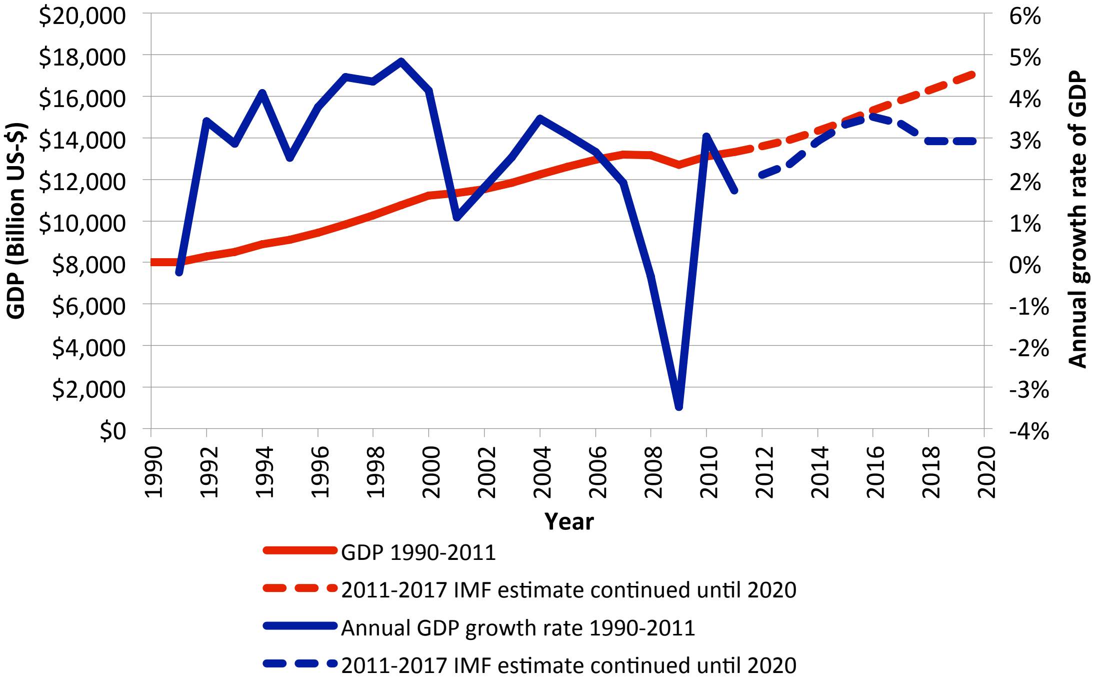

**Figure 6: GDP development of the USA between 1990 and 2011 and estimate until 2020 (IMF 2012b).**

- **Aviation**

The final energy consumption of domestic aviation decreased by 25% from 2,661 PJ to 1,999 PJ. In 2000, the final energy consumption was at its peak with 2,851 PJ (IEA 2011b). The number of aeroplanes increased by 22% from 6,083 to 7,431. The biggest year in terms of active aeroplanes was 2001 with 8,497. Passenger transport activity increased by 60% from 553 to 823 billion pkm with the peak in 2007 with 972 billion pkm. Energy intensity of passenger transport decreased from 3,252 to 1,933 kJ/pkm. Freight transport activity increased by 33% from 15 to 19 billion tkm with the peak in 2004 with 23 billion tkm (BTS 2012).

Several U.S. airlines filed for bankruptcy between 1990 and 2009, amongst these were Delta Air Lines and U.S. Airways (Sturm 2010). The attacks of 9/11 (2001) had a large impact on the whole aviation industry. Fuel prices increased and account for 30% of an airline’s costs today, compared to 13% prior to 2001. Domestic flight demand in the USA declined after the attacks and stabilised in 2003. It increased until 2008 and the financial crisis (IATA 2011).

- **Navigation**

Domestic water transport decreased its final energy consumption by 8% from 161 PJ to 148 PJ (IEA 2011b). The number of vessels decreased by 5% from 42,469 to 40,305. Passenger transport activity increased by 28% from 458 to 583 million pkm, while freight transport activity decreased by 26% from 1,334 to 763 billion tkm. The length of navigable channels decreased by 3% from 41,600 to 41,512 km (BTS 2012).

- **Pipeline**

The pipeline network length increased by 8% in the USA between 2001 and 2008 (BTS 2012). Between 1990 and 2009, the final energy consumption decreased by 10% from 645 to 582 PJ (IEA 2011b). The freight activity level increased by 8% from 935 to 1,008 billion tkm until 2008 (BTS 2012).

- **Rail**

Rail transport decreased the final energy demand by 19% from 452 to 366 PJ (IEA 2011b), while the number of locomotives increased by 27% from 19,153 to 24,319 (BTS 2012). As the consumption of diesel decreased from 437 EJ to 338 EJ and electricity consumption increased from 15 to 28 EJ, the share of electricity powered locomotives must have increased. There are unfortunately no detailed statistics about locomotive types.

The long-distance railway length decreased by 20% from 230,000 km to 184,000 km. For rail transit the railway length increased by 79% from 9,500 to 17,000 km. Passenger transport activity increased by 43% from 40 to 58 billion pkm and freight transport activity by 48% from 2,346 to 1,654 billion tkm. The energy intensity for passenger transport decreased from 1,362 to 1,169 kJ/pkm and for freight transport from 276 to 191 kJ/tkm. Rail transport is the only mode of transport with an increase of passenger activity after 2007 (BTS 2012). This indicates a modal shift of commuters, corresponding to the increase in rail transit.

- **Road**

Final energy consumption of road transport increased by 29% from 16,386 to 21,062 PJ. The highest consumption was in 2007 with 22,519 PJ (IEA 2011b).

The number of passenger cars increased by 29% from 182 to 234 million and the number of trucks increased by 83% from 6 to 11 million. After 2007, the number of passenger vehicles decreased by 1.2 million. The number of trucks continued to increase after 2007.

Passenger transport activity decreased by 19% from 5,698 to 6,786 billion pkm, but decreased by 15% since 2007. Freight transport activity increased by 48% from 1,366 to 2,022 tkm. The data for tkm is only available until 2003.

Energy intensity of passenger vehicles decreased from 2,513 to 2,308 kJ/pkm. Fuel economy of passenger vehicles increased by 10% from 8.5 to 7.6 L/100 km. For trucks it also increased by 10% from 11.4 to 10.3 L / 100km (BTS 2012). An increase of vehicle kilometres outweighed the improvements (EPA 2012c).

The number of vehicles per 1,000 people increased from 796 (2003) to 820 (2007) and decreased to 802 (2009) (World Bank 2012). Together with the decreased activity level of passenger transport and number of passenger vehicles, this also indicates the modal shift to rail transport, especially for commuters, after the beginning of the financial crisis.

- **Non-specified**

Final energy demand of non-specified transport increased by 3% from 31.6 to 32.5 PJ (IEA 2011a). No further information is available.

### 1.2.2 Comparison

Overall, the Chinese domestic transport sector grew at a faster pace than the American between 1990 and 2009. In 1990, the final energy consumption of the domestic transport sector of the USA was 13.2 times higher than the Chinese. In 2009, this was only 3.6 times higher. The Chinese final energy consumption increased by 335%, the American only by 18% (IEA 2011a, IEA 2011b).

China increased the length of all transportation routes, especially highways, while in the USA only the highway and pipeline length increased. Except for waterways, all transportation routes are longer in the USA (Table 4).

**Table 4: Transport infrastructure changes in the USA and China between 1990 and 2009 (BTS 2012, China statistical yearbook 2011).**

| [km] | **USA 1990** | **USA 2009** | **Change** | **China 1990** | **China 2009** | **Change** |
|---|---:|---:|---:|---:|---:|---:|
| **Highways** | 6,187,082 | 6,481,147 | 5% | 1,028,300 | 3,860,800 | 275% |
| **Pipeline** | 2,032,598 | 2,463,858 | 21% | 15,900 | 69,100 | 335% |
| **Railways** | 239,556 | 201,217 | -16% | 57,900 | 85,500 | 48% |
| **Waterways** | 41,600 | 40,512 | -3% | 109,200 | 123,700 | 13% |

Besides vessels, the vehicle population of cars, trucks, locomotives and aeroplanes increased in both countries. The car population in China increased by remarkable 4,034%. In 1990, there were 87 times more cars in the USA than in China. By 2009, there were only 3 times more cars in the USA. Trucks have the largest by percentage increase of all vehicles in the USA. In 1990, there were more trucks in the USA than in China: by 2009, there were more trucks in China. The number of aeroplanes increased by 378% in China, but by 2009 there were still 2.5 times less aeroplanes than in the USA in 1990 (Table 5).

**Table 5: Vehicle population changes in the USA and China between 1990 and 2009 (BTS 2012, China statistical yearbook 2011).**

| | USA 1990 | USA 2009 | Change | China 1990 | China 2009 | Change |
|---|---|---|---|---|---|---|
| **Cars** | 181,975,051 | 234,467,679 | 29% | 2,093,100 | 86,534,200 | 4,034% |
| **Trucks** | 6,195,876 | 10,973,214 | 77% | 4,259,600 | 21,220,000 | 398% |
| **Vessels** | 42,469 | 40,305 | -5% | 408,370 | 176,932 | -57% |
| **Locomotives** | 19,153 | 24,319 | 27% | 13,592 | 17,825 | 31% |
| **Aeroplanes** | 6,083 | 7,771 | 28% | 503 | 2,405 | 378% |

Figure 7 shows the difference of the growth of final energy consumption of selected modes of transport. In China, only one mode of transport shows negative growth of final energy consumption between 1990 and 2009. Rail transport replaced 99% of inefficient steam powered locomotives with diesel and electricity powered locomotives (China statistical yearbook 2011), while the length of railways increased by 48% (Table 4). All other modes of transport increased their final energy consumption by more than 100%.

In the USA, road transport had the largest growth of final energy consumption in the time period with 29%. Together with the vehicle population, the amount of vehicle kilometres increased by 38% from 3.4 to 4.7 trillion (BTS 2012). All other modes of transport consumed less final energy in 2009 than in 1990, even though the vehicle population increased, except for vessels. As the vehicle kilometres of all modes of transport increased, this indicates increased efficiency.

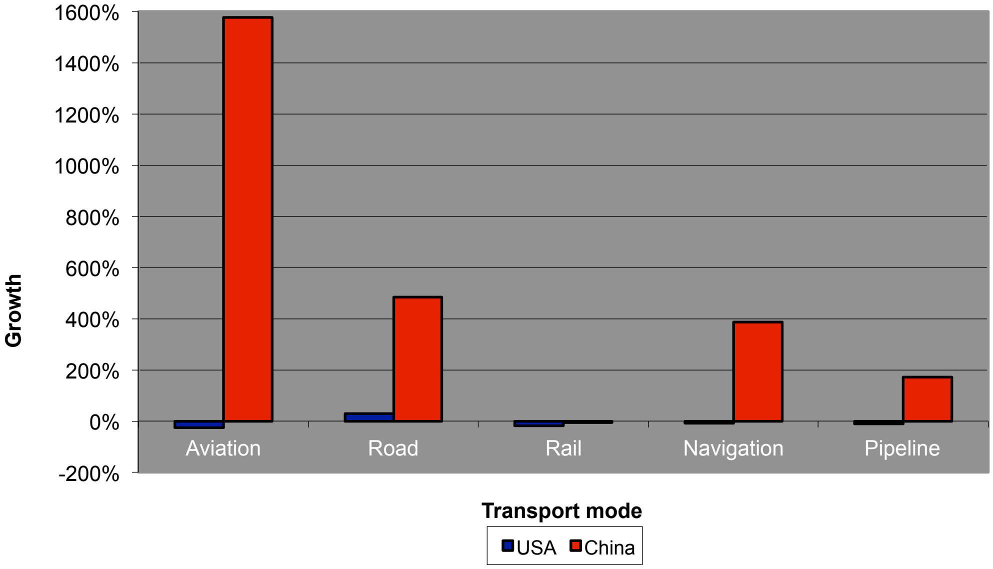

**Figure 7: Comparison of growth of final energy demand between 2000 and 2009 per mode of transport (IEA 2011a, IEA 2011b).**

Passenger and freight transport activity growth looks similar (Figure 8 and Figure 9). Only the decrease of passenger transport activity of water transport in the USA was smaller than the Chinese. The amount of pkm in China was still 12 times higher than in the USA in 2009, but there is a modal shift to other modes of transport, as the infrastructure is better today than it was in 1990 (Table 4).

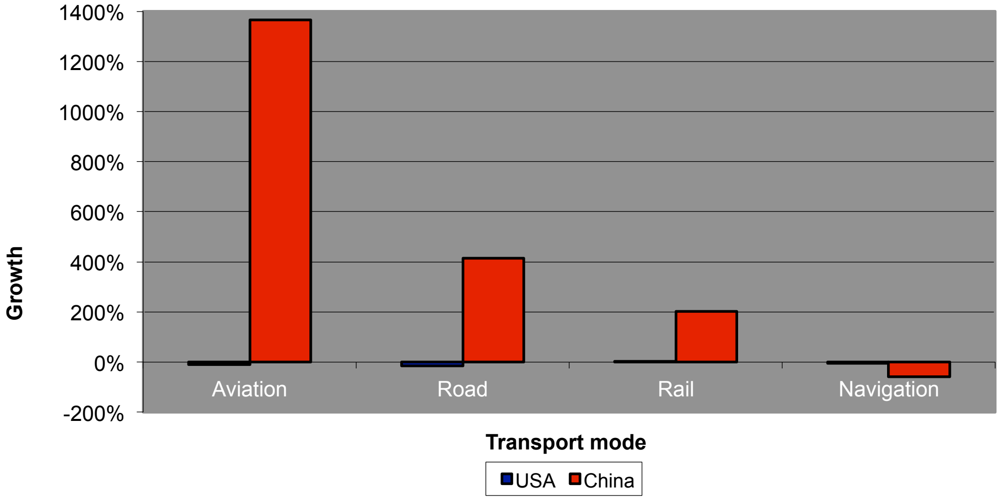

**Figure 8: Comparison of growth of passenger transport activity between 2000 and 2009 per mode of transport (IEA 2011a, IEA 2011b).**

Comparing passenger and freight activity (Figure 8 and Figure 9) shows that the Chinese have growth rates larger than 100%, except for passenger transport through domestic navigation. With the better infrastructure of other modes of transport (Table 4), less people use domestic navigation for travel.

Except for rail transport, all passenger activity levels decrease in the USA. Increasing fuel prices are one driving trend behind this modal shift (EPA 2012c). Domestic navigation is the only mode of transport with a decrease of freight activity. As the other modes of transport have increasing freight activity levels, this indicates a modal shift.

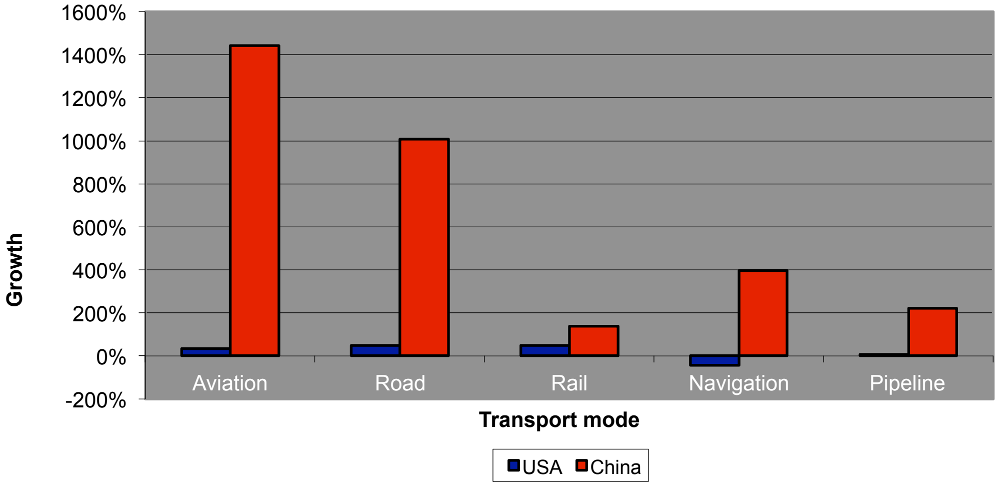

**Figure 9: Comparison of growth of freight transport activity between 2000 and 2009 per mode of transport (IEA 2011a, IEA 2011b).**

The total amount of pkm in 2009 was three times higher in the USA than in China. The amount of pkm from road transport was even five times higher in the USA. Only rail and water transport had a larger amount of pkm in China than in the USA. For water transport the amount was 12 times larger in China than in the USA. For rail transport, the amount of pkm was 14 times larger in China.

In regard of tkm, there was two times more activity in China than in the USA. Water transport is the main mode of transport for freight in China, followed by road and rail transport. The USA only transports more freight via aviation and pipelines.

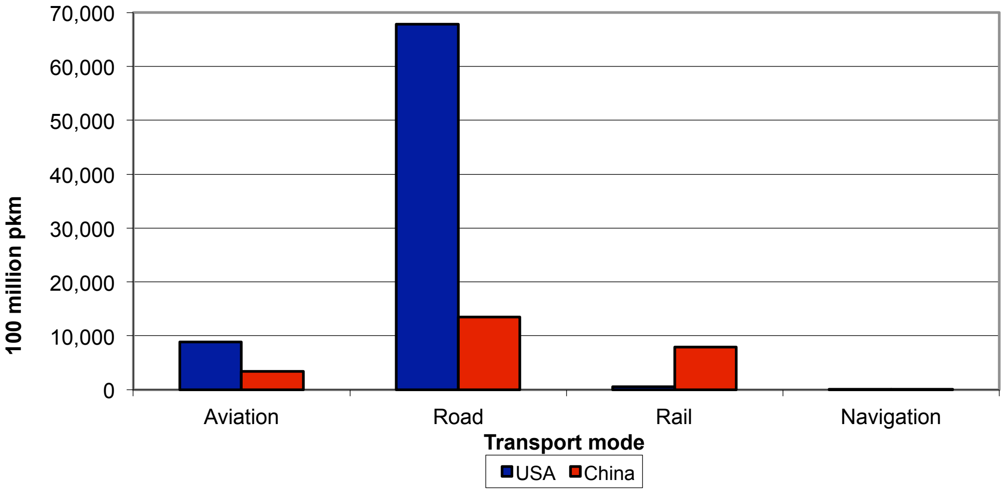

**Figure 10: Person km in 2009 in the USA and China (BTS 2012, China statistical yearbook 2011).**

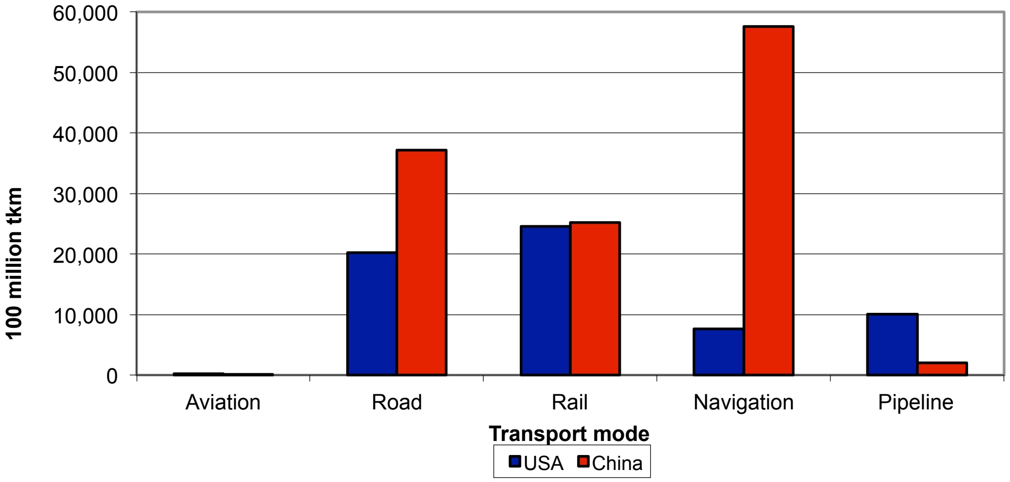

**Figure 11: Tonne km in 2009 in the USA and China (BTS 2012, China statistical yearbook 2011).**

Improvement of living standards (Yanli et al. 2012), economic growth and improved transport infrastructure supported the growth of Chinese transport activity. The financial crisis had so far no impact on growth (China statistical yearbook 2011).

In the USA, several events stopped the growth of the transport sector. For aviation, the attacks of 9/11 had a strong impact (IATA 2011). The financial crisis with increasing fuel prices had an impact on road and air transport (EPA 2012c). Rail transport, especially rail transit, profits from this, as more people use the train for commuting now (BTS 2012).

### 1.2.3 Projections and mitigation potential

The 2011 World Energy Outlook (WEO) report has energy demand projections for both countries. It projects that the energy demand of the transport sector will reach 25.1 EJ in the USA by 2020. Base year is 2009 with 24.2 EJ. In China, it projects 14 EJ by 2020 in the Current Policies Scenario (CPS). Base year is 2009 with 6.7 EJ. This scenario includes all policies as of mid-2011 and assumes that there will be no additional policies in the future. The WEO does not explicitly define whether the transport sector includes international aviation and navigation and does not split the growth projections by mode of transport (IEA 2011e).

#### *1.2.3.1 China*

The WEO projections from 2011 are in line with those published by Zhang et al. (2009). The authors aim to forecast the energy demand of China's transport sector. They use the period 1990 to 2006 to calibrate their model, which is based on a partial least square regression method and projects a consumption of 13-14 EJ by 2020. This is 2.3-2.5 times the demand of 2006, which is 5.5 EJ (Zhang et al. 2009).

The ERI projected the energy demand of different modes of transport in 2005. Values are given in Table 6. Even though both studies refer to the same source, total consumption differs by 3.2 EJ by 2020. Unfortunately the original report seems not to be available online anymore and therefore it cannot be checked whether it includes also single growth rates per energy carrier.

**Table 6: Transport energy consumption by mode in China (Hu et al. 2010).**

| Unit: EJ | 2004 | 2010 | 2015 | 2020 | Growth 2010-2020 |
|---|---|---|---|---|---|
| **Waterways** | 0.8 | 0.9 | 1.0 | 1.1 | 25% |
| **Civil aviation** | 0.3 | 0.7 | 0.9 | 1.2 | 77% |
| **Railways** | 0.7 | 1.0 | 1.2 | 1.4 | 41% |
| **Highways** | 3.0 | 3.9 | 5.1 | 6.6 | 68% |
| **Total** | 4.7 | 6.5 | 8.1 | 10.3 | 59% |

Zhang et al. refer to the baseline scenario of the Energy Research Institute (ERI), which projects 13.5 EJ by 2020. Their assumptions on GDP growth and urbanization rate are alike (Table 7).

For domestic aviation, one study calculated the $CO_2$ emissions for the year 2010. The result of 38 Mt $CO_2$ (Fan et al. 2012) is close to the calculated 37 Mt $CO_2$ from the IEA balances (IEA 2011a).

No further studies in English concerning future energy demand of aviation, navigation and rail transport were found. For road transport the following studies are available.

Yanli et al. calculated the energy demand of road transportation by 2020 to be 179 million tonnes of fuel, 1.6 times higher than in 2010 (109 million tonnes of fuel). The main factor in the increase of energy demand is an increase of activity levels (Table 7). The authors assume that fuel consumption of a single automobile will decrease by 53% by 2020 compared to 2004, based on the fuel consumption developments between 1990 and 2004 (Yanli et al. 2012).

He et al. forecasts the future trends in oil consumption of the road transport sector. Based on different assumptions of the fuel economy (Table 7), the authors expect that the 2020 energy consumption will be between 191 and 227 million tonnes of oil. This is 1.5 to 1.8 times higher than the 2010 demand of 125 million tonnes of oil (He et al. 2005).

Ou et al. perform a scenario analysis for alternative fuels and vehicles. They estimate the $CO_2$ emissions from road transportation to reach 1,200 Mt by 2020 when no additional policies are taken by the government. This is 2.5 times as much as 2009 emissions from the whole domestic transport sector. They conclude that future policies should focus on sustainable biofuels, electric vehicles with a high efficiency and coal-to-liquids (CTL) with CCS. The main drivers are oil security and GHG emission reduction. They report as the major barriers for development the biofuels versus food issue and the high resource usage for CTL production. Finally, they indicate that CCS technology also needs more development (Ou et al. 2010).

There is a difference of 12-48 million tonnes of fuel demand in the studies of Yanli et al. and He et al., which can be explained by different assumptions on fuel economy improvements (Table 7). All studies project growth of the Chinese final energy demand from (road) transportation.

**Table 7: Energy demand and $CO_2$ reduction forecasts of the Chinese transport sector.**

| Scenario | Information about assumptions of the authors | Energy consumption/$CO_2$ emissions | Source |
|---|---|---|---|
| 2011 WEO<br>CPS<br>Transport | Assumes that no new policies are added after mid-2011.<br>Includes 12th Five-Year-Plan policies and targets.<br>Average annual growth of GDP: 7% (Delegation of the European Union in China 2011)<br>Urbanization rate: 4% growth every five years; 51.5% in 2015 (Delegation of the | 2009: 7 EJ<br>2020: 14 EJ | IEA 2011e |

| | | | | |
|---|---|---|---|---|
| | European Union in China 2011) | | | |
| Zhang et al.<br>Transport sector<br>Scenario 1 | **GDP growth p.a.**<br>2006-10: 8.1%<br>2010-15: 7.5%<br>2015-20: 6.8% | **Urbanization rate**<br>2010: 49%<br>2015: 54%<br>2020: 58% | 2006: 5.5 EJ<br>2020: 12.7 EJ | Zhang et al. 2009 |
| Scenario 2 | 2006-10: 8.1%<br>2010-15: 8.2%<br>2015-20: 7.7% | 2010: 49%<br>2015: 54%<br>2020: 58% | 2006: 5.5 EJ<br>2020: 13.7 EJ | |
| ERI Baseline<br>Transport sector | 2001-10: 8.6%<br>2011-20: 6.5% | 2010: 49%<br>2015: 54%<br>2020: 58% | Start not given<br>2020: 13.5 EJ | Zhang et al. 2009 |
| Yanli et al.<br>Road transport | No information about GDP growth.<br>53% less average fuel consumption of single automobiles by 2020 compared to 2004.<br>**Activity increase p.a.:**<br>pkm 2004-2010: 7.3%<br>pkm 2010-2020: 5.8%<br>tkm 2004-2010: 5.8%<br>tkm 2010-2020: 3.8% | | 2010: 109 million tonnes of oil<br>2020: 179 million tonnes of oil | Yanli et al. 2012 |
| He et al.<br>Road transport | No fuel economy improvement.<br>No information about GDP growth. | | 2010: 125 million tonnes of oil<br>2020: 227 million tonnes of oil | He et al. 2005 |
| | 46% fuel economy improvement over 11 years.<br>No information about GDP growth. | | 2020: 208 million tonnes of oil | |
| | 87% fuel economy improvement over 11 years.<br>No information about GDP growth. | | 2020: 191 million tonnes of oil | |
| Ou et al.<br>Road transport | No additional action from the government. EV the only alternative fuel vehicle (AFV).<br>0.6% EV shares in vehicle sales by 2020<br>224 million vehicles by 2020<br>No information about GDP growth. | | 2010: 5.5 EJ<br>2020: 15.5 EJ | Ou et al. 2010 |
| Wang et al.<br>Road transport | **Scenario 1**<br>Conservative projection scenario<br>- Fuel Economy level remain in 2000 level<br>- No information about GDP growth | | 2020: 785 Mt $CO_2$ | Wang et al. 2007 |
| | **Scenario 2**<br>Recent Policy<br>2000-2005 Policies<br>- Environmental protection issues considered<br>- Implementation of fuel efficiency limits<br>- No information about GDP growth | | 2020: 727 Mt $CO_2$ | |
| | **Scenario 3** | | 2020: 430 Mt $CO_2$ | |

|  |  |  |  |
|---|---|---|---|
|  | New Policy<br>Mitigation options<br>- Sustainable development and climate change issues emphasized<br>- A lot of advanced technologies<br>- Less consideration of financing or technical barriers<br>- No information about GDP growth |  |  |
| Yan & Crookes Road transport | **Baseline**<br>- No implemented measures to reduce energy demand<br>- No information about GDP growth | 2005: 255 Mt $CO_2$<br>2030: 1,304 Mt $CO_2$ | Yan & Crookes 2009 |
|  | **Best case**<br>includes a series of policy measures:<br>- Private vehicle control<br>- Fuel economy regulation<br>- Promotion of diesel and gas vehicles<br>- Fuel tax<br>- Biofuel promotion<br>- No information about GDP growth | 2030: 783 Mt $CO_2$ |  |

Wang et al. calculated a reduction of 355 Mt $CO_2$ by 2020 compared to their reference case (Table 7). They conclude that there is a large reduction potential in China. Their reference scenario has 2.2 times higher emissions by 2020 compared to 357 Mt $CO_2$ in 2006 (Wang et al. 2007).

Yan and Crookes report the status of China's road transport sector. Their review adopted and proposed strategies for reducing energy demand and emissions, such as fuel economy regulation, tailpipe emission control, alternative fuels and vehicles, and economic incentives. They conclude that China is in a rare position to be able to choose the road vehicle fuel/propulsion systems before being locked into an internal combustion fleet. Strategic planning and early acting are the keys in tackling these challenges (Yan & Crookes 2010). According to them, there are no detailed statistics for the past. They also calculated reduction potentials of energy demand and GHG emissions in China's road transport sector, reaching 521 Mt $CO_2$ by 2030 compared to their BAU scenario. Table 7 shows the assumptions of the best case scenario. They conclude that fuel tax, fuel economy regulation and private vehicle control are the most effective measures (Yan & Crookes 2009).

The mitigation potentials of Wang et al. and Yan and Crookes are similar with a reduction of 45% (Wang) and 40% over their BAU scenarios. The results of the literature review indicate that China's transport sector will continue to grow at a fast pace and can contribute a large share of the required emission reduction from transportation (UNEP 2011).

### *1.2.3.2 USA*

The Annual Energy Outlook (AEO) 2012 includes energy demand projections of other studies for comparison. These results are presented below, together with projections of other literature, also for single modes of transport.

**Table 8: Energy demand and $CO_2$ reduction forecasts of the American transport sector.**

| **Scenario** | **Information about assumptions of the authors** | **Energy consumption/$CO_2$ emissions** | **Source** |
|---|---|---|---|
| 2011 WEO<br>CPS<br>Transport | Assumes that no new policies are added after mid-2011.<br>2015 oil price: \$0.67<br>2020 oil price: \$0.74<br>Economic growth 2010-20: 2.6% p.a. | 2009: 24.1 EJ<br>2020: 25.1 EJ | IEA 2011e |
| AEO 2012<br>Transport | 2015 oil price: \$0.74<br>2020 oil price: \$0.80<br>Economic growth 2010-20: 2.5% p.a. | 2010: 29.1 EJ<br>2020: 28.1 EJ | EIA 2012a |
| INFORUM 2012<br>Transport | 2015 oil price: \$0.58<br>2020 oil price: \$0.67<br>Economic growth 2010-20: 3.1% p.a. | 2010: 28.9 EJ<br>2020: 30.6 EJ | EIA 2012a |
| IHSGI 2011<br>Transport | 2015 oil price: \$0.62<br>2020 oil price: \$0.46<br>Economic growth 2010-20: 2.5% p.a. | 2010: 28.1 EJ<br>2020: 28.9 EJ | EIA 2012a |
| Exxon Mobil 2012<br>Transport | Tax on $CO_2$ emissions<br>Economic growth 2010-20: 2.7% p.a. | 2010: 28.5 EJ<br>2020: 29.5 EJ | EIA 2012a |
| BP 2012<br>Transport | Tax on $CO_2$ emissions | 2010: 24.1 EJ<br>2020: 22.2 EJ | EIA 2012a |
| DOT<br>Transport | Reference (2009 AEO)<br>Reductions through strategies below 2030 levels (if all implemented) | 2030: 2,171 Mt $CO_2$<br>Max: 61%<br>Min: 19% | DOT 2010b |
| Andress et al.<br>Road transport | AEO Reference case<br>Ethanol success<br>Ethanol and HEV[4] success<br>PHEV[5] success<br>FCEV[6] success<br>FCEV and F-T[7] diesel success | 2020: 23.6 EJ<br>2020: 23.4 EJ<br>2020: 23.4 EJ<br>2020: 23.2 EJ<br>2020: 22.9 EJ<br>2020: 23.2 EJ | Andress et al. 2011 |
| Ross Morrow et al.<br>Road transport | Reference (2009 AEO)<br>**$CO_2$ tax scenario**<br>30\$/t $CO_2$ in 2010; 60 \$/t $CO_2$ in 2030<br>**Transportation tax scenario:**<br>0.5\$/gallon diesel or gasoline in 2010<br>3.36\$/gallon diesel or gasoline in 2030<br>**Increased CAFE scenario:**<br>Continuing increased CAFE standards | 2030: 2,171 Mt $CO_2$<br>2030: 2,018 Mt $CO_2$<br><br>2030: 2,000 Mt $CO_2$<br><br><br>2030: 1,946 Mt $CO_2$ | Ross Morrow et al. 2010 |

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[4] Hybrid electric vehicle

[5] Plug-in hybrid electric vehicles

[6] Fuel cell electric vehicle

[7] Fischer-Tropsch

| | | | |
|---|---|---|---|
| | through 2030<br>**Performance-based tax credit scenario:** Tax credit for AFVs | 2030: 1,857 Mt $CO_2$ | |
| Winchester et al. Aviation | Economy-wide cap-and-trade policy on U.S. aviation.<br>Four scenarios with assumptions on $CO_2$ price, demand change and fuel price. | Base scenario 2020: 300 Mt $CO_2$<br>Scenarios 2020: 282-297 Mt $CO_2$ | Winchester et al. 2011 |
| Schipper et al. Rail | Scenario 1: 98 of 1405 billion pkm shifted<br>Scenario 2: 156 of 890 billion pkm shifted | 10.5 Mt $CO_2$ reduction<br>5.7 Mt $CO_2$ reduction | Schipper, Kosinski 2010 |

The data show variations in the projections. The IEA, INFORUM, IHSGI and Exxon Mobil forecasts expect an annual growth between 3 and 6% while the AEO and BP expect a decrease between 1 and 8%. The different assumptions that were available are shown in Table 8.

The AEO includes military transport, international aviation and navigation (EIA 2012a). The other studies do not explicitly state whether they include military transport, international aviation and navigation in their projections. This could explain the large differences between the AEO, INFORUM, IHSGI and Exxon Mobil forecasts with the BP and IEA data. The AEO includes all policies up to June 2012, IEA projections up to mid-2011. For the other studies it is unknown whether they include the latest policy updates.

The 2012 AEO also includes growth rates per energy carrier per mode of transport (Table 9).

**Table 9: Annual growth rates of energy carriers by mode in the domestic transport sector of the USA between 2010 and 2035 from the 2012 AEO (EIA 2012a).**

| Mode of transport | Energy carrier | Growth |
|---|---|---:|
| Light-Duty Vehicles | Motor Gasoline | -0.6% |
| | E85 | 27.0% |
| | Compressed/Liquefied Natural Gas | 1.1% |
| | Liquefied Petroleum Gases | 0.5% |
| | Electricity | 21.6% |
| | Liquid Hydrogen (from 2015 on) | 166% |
| | Distillate Fuel Oil (diesel) | 10.9% |
| Commercial Light Trucks | Motor Gasoline | 0.0% |
| | Distillate Fuel Oil (diesel) | 0.9% |
| Freight Trucks | Motor Gasoline | -0.2% |
| | Distillate Fuel Oil (diesel) | 0.8% |
| | Compressed/Liquefied Natural Gas | 7.0% |
| | Liquefied Petroleum Gases | 0.4% |
| Freight Rail | Distillate Fuel Oil (diesel) | 0.6% |

| | | |
|---|---|---|
| Domestic Shipping | Distillate Fuel Oil (diesel) | 0.5% |
| | Residual Oil | 0.5% |
| Air Transportation | Jet Fuel | 0.4% |
| | Aviation Gasoline | -0.1% |
| Rail Transportation | Intercity Rail (electricity) | 1.2% |
| | Intercity Rail (diesel) | 1.2% |
| | Transit Rail (electricity) | 1.1% |
| | Commuter Rail (electricity) | 1.1% |
| | Commuter Rail (diesel) | 1.2% |
| Recreational Boats | Gasoline | 0.5% |
| | Distillate Fuel Oil (diesel) | 0.1% |
| Total consumption | All | 0.1% |

**Mitigation scenarios**

Mitigation scenario studies conclude that deep cuts in emissions from the domestic transport sector are possible by 2030 and 2050 (Yang et al. 2009, McCollum, Yang 2009, EPA 2010a, Greene 2011), but without social, political and cultural change in the near term, the U.S. will never meet its international obligations (Rajan 2004).

Winchester et al. evaluated the impact of economy-wide cap and trade on aviation in the USA. In four scenarios with different assumptions on $CO_2$ and fuel prices and demand change, they calculated that by 2020 a cap would reduce emissions by 1-6% compared to the BAU emissions of 300 Mt $CO_2$ (Table 8) (Winchester et al. 2011).

Schipper assessed the potential of high speed rail to reduce emissions until 2050. A shift from air and road transport to high speed rail can reduce emissions by 5.7 to 10.5 Mt $CO_2$ by 2050 (Table 8) (Schipper, Kosinski 2010).

Andress et al. compared possible reduction potentials for 2060 of different options (Table 8). Their scenarios achieve a reduction of up to 32% by 2060 compared to the AEO reference case they use, mainly through light-duty vehicles. By 2020, the reductions reach 3%. The decrease accelerates after 2030. Heavy-duty transport needs a different strategy, as diesel will be the main fuel for this mode of transport. As an alternative to biodiesel, the authors propose Fischer-Tropsch diesel (Andress et al. 2011).

Bianco et al. assess whether the regulatory framework of federal agencies and state actions are sufficient to meet the reduction target of the Obama administration (see page 9). They cover road transport and aviation in the transport sector, but their analysis covers also other key sectors, such as industry and power supply. All their reduction scenarios fall short of the pledge. The most ambitious scenario only reaches a reduction of 14% below 2005 levels, 3% below the pledge (Bianco, Litz 2010).

Ross Morrow et al. share the conclusion of Bianco (2010). They analysed the impact of $CO_2$, performance and transportation tax and increased fuel economy standards on reduction of oil consumption and greenhouse gas emissions, using the U.S. EPA's National Energy Modeling System (NEMS). All scenarios achieved a reduction lower than 14% below 2005 levels by 2020 (Ross Morrow et al. 2010).

The U.S. Department of Transport (DOT) analysed different strategies and policy options with their GHG reduction potentials (Table 8). The strategies are the introduction of low-carbon fuels and an increase of vehicle fuel efficiency amongst others. The DOT concluded that the current policy actions and strategies need to be expanded. The increase of vehicle fuel efficiency has meanwhile been implemented as the new fuel economy standards for passenger and heavy-duty vehicles (see section 3.3.2.1) (DOT 2010b).

The reviewed literature indicates that deep cuts in $CO_2$ emissions from transport are possible, where road transport has the largest $CO_2$ emission reduction potential due to its large share of final energy consumption. Like China, the USA can contribute a large share of the required cuts of $CO_2$ emissions (UNEP 2011).

#### *1.2.3.3 Conclusion*

The literature review shows that road transport has received the most attention in studies. Especially studies that perform a policy analysis mostly focus on road transportation. Therefore, in most cases 23% of the $CO_2$ emissions have not received attention in the studies concerning the transport sector in China (13% in the USA). This gap accounts for 105 Mt of $CO_2$ in China and 206 Mt in the USA in 2009 (IEA 2011a, IEA 2011b).

While in China all BAU scenarios lead to an increase of final energy consumption and emissions, in the USA this is not the case for all studies. The AEO and BP studies project a decrease of final energy consumption. Nevertheless, for both countries studies project a large emission reduction potential.

Two studies (Bianco and Ross & Morrow) concluded that the United States would not meet their pledge in 2020 with the different policy options they proposed. The other reviewed studies did not relate their results to the pledge. Considering the growth rates from the 2011 WEO differ from the 2010 WEO and also the AEO, which is used as the reference case by most studies, a new analysis might show different results. For China, no study (in English) was found which examined the pledge.

A direct comparison of the strategies of the two largest $CO_2$ emitters in the domestic transport sector to reduce emissions does not exist in English literature, although this is very interesting, as the countries had different development in the domestic transport sector (see section 1.2.2) and also the projections for both countries differ. In China, final energy consumption is projected to increase by 59% between 2010 and 2020 (Hu et al. 2010). In the USA, numbers vary between a decrease of 1 to 8% and an increase between 3 and 6% in the same time period (Table 8).

## 1.3 Research questions

The aim of the research is to perform a comparative policy analysis of the USA and China concerning energy related $CO_2$ emissions from the domestic transport sector and the corresponding reduction potential of current and future policies. This leads to the following research questions:

- How large is the $CO_2$ emission reduction potential in the domestic transport sector in 2020, taking into account current and planned policies? Are the reductions in line with the countries' pledges under the Copenhagen Accord?
- Where do China and the USA show similarities in their policy strategies, where are differences?
- Where are gaps in the current policy strategies and what additional $CO_2$ reduction potential exists?

## 1.4 Choice of methodology

The literature research identified several methodologies to perform a policy analysis of the transport sector to calculate $CO_2$ emission reductions. This section gives an overview of different methodologies, pointing out their key characteristics. After a comparison, based on the criteria for this thesis, one methodology is chosen for the analysis.

### 1.4.1 Overview of identified methodologies

Five different methodologies were identified, of which four have been used for policy analyses of China and the USA.

#### *1.4.1.1 Bottom-up, top-down economic and hybrid approach*

Bottom-up and top-down are two approaches that are widely used in energy modelling. The main characteristic of the top-down approach is the macroeconomic view with a small level of technological detail, while the bottom-up approach has a high level of technological detail (Dittmar 2006). Table 10 shows the main features of the top-down and bottom-up approach (OECD 1998).

**Table 10: Main features of top-down and bottom-up modelling approaches (OECD 1998, page 19).**

| Criteria | Top-Down | Bottom-Up |
|---|---|---|
| ***Level of disaggregation*** | • low: 1-10 sectors or activities represented | • high: a range of energy end uses |
| ***Behaviour representation*** | • comprehensive, but few energy-relevant details | • detailed (at end use level) but not comprehensive |
| ***Representation of technologies*** | • based on macro input-output or econometric analysis<br>• production functions determine substitution | • based on engineering and cost data<br>• description of physical flows |

| | | |
|---|---|---|
| | possibilities | |
| ***Technological change*** | - price and income effects<br>- exogenous technical progress (AEEI[8]) | - assumptions on market shares or optimisation<br>- projections of technological efficiency<br>- learning curves |
| ***Methodological approach*** | - Econometrics or calibration based on a single year<br>- Economic growth estimated or exogenous | - spread-sheet analysis (for descriptive reasons)<br>- simulation/optimisation models |
| ***Efficiency gap*** | - no energy efficiency gap except in case of energy subsidies<br>- all markets are fully competitive | - energy markets are not efficient<br>- potential for cost-effective energy savings |
| ***Assumptions about market barriers and hidden costs of new technologies*** | - costs of adopting new technologies are reflected in observed behaviour | - significant market barriers prevent adoption of new technologies<br>- hidden costs tend to be low |
| ***Transaction costs of removing market barriers and imperfections*** | - high | - low |

A combination of the top-down and bottom-up approach is called hybrid (Dittmar 2006). The features of a hybrid model depend on which particular features of the bottom-up and top-down approach were selected by the creator of the model (see Table 10). Examples of hybrid models are the Long-range Energy Alternatives Planning System (LEAP) (SEI 2012), National Energy Modeling System (NEMS) (EIA 2012d) and VISION (Argonne National Laboratory 2012).

The top-down, bottom-up and hybrid approach were used for analyses of the USA and China. The bottom-up approach was used by Hao et al. (2011); hybrid by Yan & Crookes (2009) and Ou et al. (2010) for China. NEMS was used by Ross Morrow et al. (2010) and EIA (2012a); VISION by Bianco & Litz (2011) and Andress et al. (2011) for the USA.

### *1.4.1.2 Climate Action Tracker*

The Climate Action Tracker (CAT) is a relatively new method for policy analysis and has not been used for an analysis of China and the USA yet. It has been used twice so far for analyses of Australia and Mexico (Höhne et al. 2011b, Höhne et al. 2012). The Excel-based model covers five sectors of an economy, of which one is the transport sector. It is applicable for the short term until 2020 and reflects the complex policy landscape in a detailed way. For the five sectors it contains 70 policy packages for evaluation against best practice.

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[8] Autonomous Energy Efficiency Improvement

#### *1.4.1.3 Kaya identity*

The Kaya identity has been used as methodology for policy analyses of both countries (Wang et al. 2007, McCollum, Yang 2009, Yang et al. 2009, Greene 2011). This method decomposes $CO_2$ emissions into the following factors, of which policies can address the latter (IPCC 2007b):

- Population
- GDP per capita
- Energy intensity
- Carbon intensity

### 1.4.2 Criteria for this thesis

Based on the research question, the following aspects are important for the methodology:

- **Time scale:** The emission reduction targets are set for 2020 (UNFCCC 2011a, UNFCCC 2011b), so the methodology must allow for short-term evaluation.
- **Policy areas:** Several sub-sectors in the transport sector (see section 1.2) use different modes of transport (for example passenger cars, planes, trains, trucks). Some policies might affect all modes of transport; some might affect just one or a few. The methodology should be able to reflect a large variety of policies for the different modes of transport, targeting different elements, for example energy efficiency, carbon intensity or activity levels.
- **Quantification of $CO_2$ emission reductions per policy:** This shows the effectiveness of policies and enables the identification of policy gaps and quantification of remaining emissions. It enables to assess, whether the country is on the right path towards the reduction target. As some policies just target certain energy carriers (for example subsidies for biofuels), this requires a high resolution of input data.
- **Transparency:** The analysis must be reproducible and understandable by others, so transparency of the calculations is important (Blok 2007).
- **Applicability for both countries:** For the comparison, just the input data should be country specific. The model should be applicable for both countries with no other specific modifications.

### 1.4.3 Evaluation of the methodologies based on the criteria

The evaluation of the methodologies based on the criteria (section 1.4.2) showed that not all methodologies are suitable for this thesis.

The VISION model comes with a reference case for the USA, but it can be calibrated for other countries. However, it only reflects highway vehicle technologies (Argonne National Laboratory 2012).

NEMS is the national model for the USA and was created by the U.S. Energy Information Administration (EIA) of the Department of Energy (DOE). The EIA states that due to complexity and high software costs, the model is not used widely outside the DOE (EIA 2012d). This prevents the use of this methodology for this thesis, because the results must be reproducible.

Top-down approaches are more suitable for the long-term rather than the short-term. Due to the macroeconomic view on the whole economy, technologies cannot be included as detailed as in bottom-up approaches (Dittmar 2006). The LEAP model, a hybrid, is also a method for the long-term (SEI 2012).

This leaves the bottom-up approach, the Kaya identity and the Climate Action Tracker as a choice for the methodology.

The rich technological detail of bottom-up models enables a broad policy analysis (Dittmar 2006). The policies can target individual technologies of sub-sectors or whole sub-sectors of the transport sector. However, the high level of technological detail comes at cost of transparency. Also, a model with rich technological detail is sometimes individual per country and not suitable for the use for other countries. The bottom-up approach therefore only partly fulfils the criteria for this thesis.

The Kaya identity is transparent, simple and allows evaluating policies towards energy and carbon intensity (IPCC 2007b). McCollum & Yang (2009) developed one equation for each sub-sector of the transport sector and summed all emissions up. The method has been used for several countries and allows for short-term evaluation (see section 1.4.1.3). One disadvantage is that the impact of policies must be quantified externally (Greene 2011).

The CAT has also been used for different countries and allows for short-term evaluation. The calculations in the Excel model are transparent and enable the quantification of emission reductions per policy (section 1.4.1.2). However, the origin of some factors within the model is not clear. Policies are evaluated against best practice, so the impact does not have to be quantified externally (Höhne et al. 2011a). Another disadvantage is that the best practice policies of the model may be exceeded by other policies that were not considered during the design of the model.

Table 11 shows a comparison of the three methodologies based on the criteria.

**Table 11: Comparison of the bottom-up approach, Kaya identity and Climate Action Tracker, based the criteria.**

| **Criterion** | **Bottom-up** | **Kaya** | **CAT** |
|---|---|---|---|
| Time scale | 🟩 | 🟩 | 🟩 |
| Policy areas | 🟩 | 🟨 | 🟩 |
| Quantification | 🟩 | 🟩 | 🟩 |
| Transparency | 🟨 | 🟩 | 🟨 |
| Applicability | 🟨 | 🟩 | 🟩 |

**Legend:**

| | |
|---|---|
| 🟩 | Fulfils criteria. |
| 🟨 | Partly fulfils criteria. |
| 🟥 | Does not fulfil criteria. |

All three methodologies fulfil the time scale criterion and can quantify the emission reduction per policy. The Kaya identity can only evaluate policies in terms four factors: GDP, population, energy and carbon intensity, so all integrated technologies can only use the latter two factors. For that criterion, the other two methodologies have more possibilities, such as activity levels or efficiency. The bottom-up approach lacks transparency after a certain technological detail, when for example the whole electricity production needs to be modelled. Also, a bottom-up model is not always applicable for all countries due to the technological detail. In this regard, the CAT is less complex and more transparent.

Although the CAT has deficits in regard of transparency, because the origin of some factors in the model is not clear, it fulfils all the other criteria and is therefore used for this thesis.

# 2 Methodology

This chapter critically assesses the CAT model and its transport section to identify strengths and weaknesses for specific adjustments prior to the analysis.

## 2.1 Critical assessment of the CAT model and its transport sector part

The CAT model is an Excel-based tool to evaluate the potential impact of actions of countries to reduce GHG emissions until 2030. In this context, the term *actions* includes policies and strategies. A policy determines decisions and actions, in this case of a government. With the right strategy these policy targets can be achieved. The model can be used for every country (Höhne et al. 2011a).

A detailed methodology and the model are both available from the CAT website[9]. The following sections are all based on the official methodology and previous analyses (Höhne et al. 2011a, Schubert 2012).

### 2.1.1 Sectors and transport sector definition

The model covers five sectors: agriculture, forestry and other land use (AFOLU), buildings, electricity production and industry and transport. The CAT defines the transport sector as: “All energy used in transport, including all modes. Includes also agricultural energy consumption as much of it is caused by transport” (Höhne et al. 2011a, page 9).

This definition differs from the one given in the introduction. The IEA includes agricultural highway use in the transport data of the balances. The agriculture data, which the CAT includes in the transport sector, includes not only off-highway traction but also power and heating (IEA 2011c). Therefore, agriculture data should be included in the AFOLU instead of transport sector. For this thesis, agriculture data is not included in the transport sector.

### 2.1.2 Policy areas

The CAT model covers five policy areas (Table 12). Within a sector, a policy area represents a *segment* of the analysis (Figure 12).

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[9] http://www.climateactiontracker.org/

**Table 12: Definitions of the policy areas (segments) in the CAT model (Höhne et al. 2011a).**

| Policy area | Definition |
|---|---|
| Changing activity | Covers policies targeting energy demand. |
| Energy efficiency | Covers policies targeting energy used per unit of activity. |
| Renewable energy | Covers policies targeting the fuel mix, aiming to increase the share of renewable energy. |
| Low carbon | Covers policies targeting the fuel mix, except renewables, aiming to decrease the carbon intensity. |
| Non-energy | Covers emissions that are not directly linked to energy, such as emissions from land-use and processes in industry. |

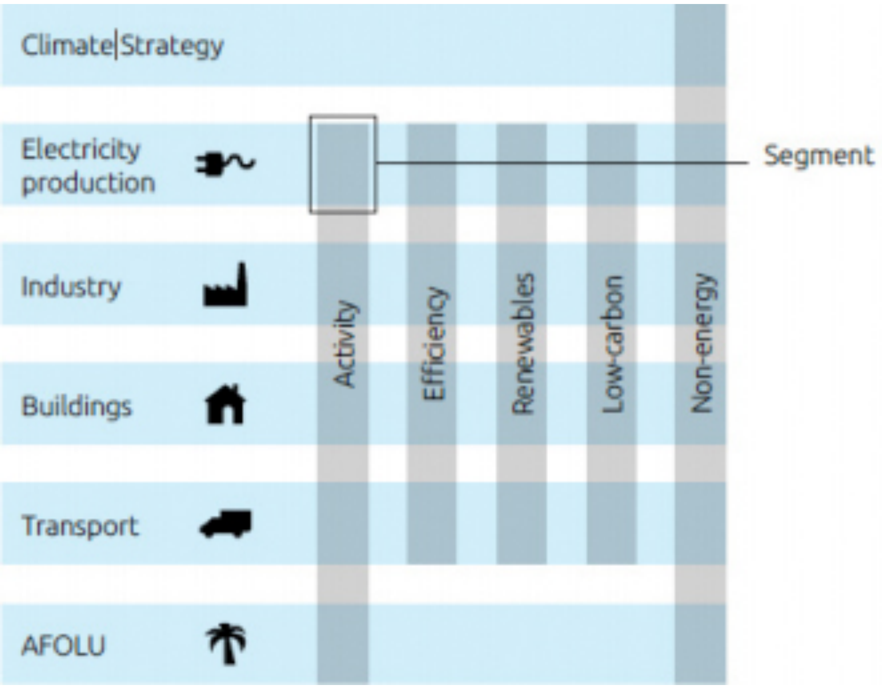


**Figure 12: Dimensions of the general CAT analysis - definition of segments (Höhne et al. 2011a).**

The CAT defines emissions and carbon intensity as follows (Höhne et al. 2011a):

$CO_2$ emissions = (activity × efficiency × carbon intensity) + non-energy - removals (Eq. 2)

Emissions [kg CO2] are a product of activity levels, for example the amount of km driven, efficiency [energy/km] and carbon intensity. Carbon intensity is the amount of emissions per unit of energy (see Eq. 3). In the agriculture sector, the CAT adds the $CO_2$ equivalent of $CH_4$ emissions and removes $CO_2$ emissions through plant growth. In the power supply sector CCS is also removing emissions.

Carbon intensity = $CO_2$ emissions / final energy consumption (Eq. 3)

The policies from the five areas (Table 12) can target individual elements of these equations.

### 2.1.3 Policy evaluation

Based on low carbon scenarios (Table 13) that followed the 2007 IPCC report to reach the 2° C target (UNFCCC 2010), the CAT team developed a "framework vision of a low carbon future" (Höhne et al. 2011a, page 11), which is the basis for the general CAT analysis.

**Table 13: Low carbon scenario studies (Höhne et al. 2011a, page 11).**

| **Study** | **Author** |
|---|---|
| The Energy report: 100% renewable Energy in 2050 | The Energy Report 2011 |
| World Energy Outlook 2010 | IEA 2010 |
| Energy technology perspectives 2010 | OECD 2010 |
| The Economics of Low Stabilization: Model Comparison of Mitigation Strategies and Costs | Edenhofer et al. 2010 |
| ADAM 2-degree scenario for Europe | Jochem 2009 |
| Meeting the 2 degree target | van Vuuren et al. 2009 |
| International, U.S. and E.U. Climate Change Control Scenarios: Results from EMF 22 | Clarke, Böhringer 2009 |
| Energy [r]evolution scenario | Teske 2010 |
| IMAGE and MESSAGE Scenarios Limiting GHG Concentration to Low Levels | Rao et al. 2008 |
| Report on first assessment of low stabilisation scenarios | Knopf et al. 2008 |

As no single policy is able to achieve the required emission reductions, the CAT combines single policy measures into packages for the evaluation. The heart of the general CAT analysis is a defined *low carbon policy package*, which "contains the policies necessary to reach a low carbon economy" (Höhne et al. 2011a, page 13).

Those necessary policies are called *incentives*. They lead to less $CO_2$ emissions and therefore support the vision of a low carbon future. The model also includes policy packages, which lead to additional $CO_2$ emissions. These are called *barriers* and must not be disregarded in the analysis.

Table 14 shows an example for the definition of a policy package in the electricity production sector. The policy package is neutral of policy instruments and based on a target and technical and behavioural options.

**Table 14: Policy package example from the electricity production sector (Höhne et al. 2011a, pages 13-14).**

| | |
|---|---|
| **Target** | For the electricity supply sector the target would be, for example, an electricity generation system that is 100% emission free by 2050. |
| **Technical or behavioural options** | For electricity supply the technical solution is to provide 100% generation from carbon free sources by 2050, supported by appropriate grid infrastructure and system integration. |
| **Low carbon policy package with neutral policy instruments** | For the electricity sector, this would include sufficient and stable support for renewable electricity generation for a diverse set of technologies. It would not prescribe whether this support would be generated through e.g. a feed in tariff or a renewable energy obligation. |

Figure 13 shows an example of a segment in the CAT. This example segment consists of four policy packages, of which three are incentives and one is a barrier. For the evaluation, each policy package has further elements. These are *benchmarks*, an *assessment*, a *weighting factor*, a *score*, a *maximum impact factor* (MIF) and an *actual impact factor* (AIF). The following paragraphs define each of the elements and section 2.1.3.2 critically assesses each transport policy package and the corresponding elements.

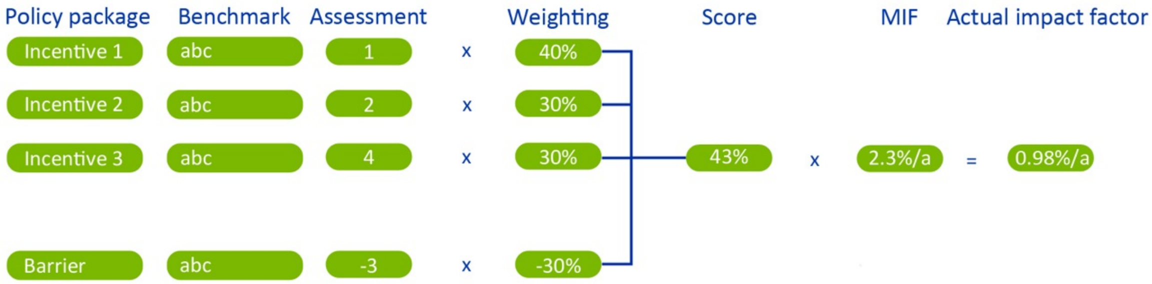


**Figure 13: Example of a segment in the CAT.**

### *2.1.3.1 Assessing a policy package*

A *policy package* is either a barrier or an incentive. There are two different systems for the assessments of both types.

The scale for *assessments* of incentives goes from 0 to 4, where 0 is the lowest assessment an incentive can get and 4 the highest. The scale for barriers goes from -4 to 0, where -4 is the lowest assessment a barrier can get and 0 the highest.

The *benchmarks* are either descriptive or include a quantified expected result of the analysis of the policy package. The benchmark that is connected to the highest assessment (4 or 0) includes the highest expected result. Each policy package has a set of up to five benchmarks, one for each assessment. There are only few exemptions with fewer benchmarks than assessments (see section 2.1.3.2).

The value of the quantified expected result decreases with each benchmark that is connected to a lower assessment. Table 15 shows an example. The benchmarks are the same for every country analysis.

**Table 15: Benchmark example of a policy package.**

| Benchmark and connected assessment | Decrease of quantified expected result |
|---|---|
| Benchmark for an assessment of 4 | 100% of quantified expected result |
| Benchmark for an assessment of 3 | 75% of quantified expected result |
| Benchmark for an assessment of 2 | 50% of quantified expected result |
| Benchmark for an assessment of 1 | 25% of quantified expected result |
| Benchmark for an assessment of 0 | 0% of quantified expected result |

This scaling system was chosen by the CAT team to reduce complexity (Markus Hagemann 6/09/2012). In principal, the scaling system could also be from 0 to 10 or 0 to 100, but that would require more benchmarks.

Each policy package has a *weighting factor*, which was chosen by the CAT team, based on the importance of the policy package (Höhne et al. 2011a). However, the methodology does not provide a rationale for the selection of the importance and corresponding individual weights. They are therefore subject to a sensitivity analysis. Within a segment, the weights of all incentives sum up to 100%.

Barriers have *negative weighting factors* and therefore reduce the score of a segment. Like the weighting factors for incentives, the factors are based on importance. Again, no rationales for the values are in the methodology.

For the comparison of analysed countries, the model aggregates the *score* of each segment through the single policy packages. The maximum score a segment can get is 4, which equals 100%. This score is multiplied with the *MIF*, a factor that represents the maximum impact the connected policy packages can achieve. The MIFs are based on previous analyses (Schubert 2012). Values and units of the MIFs are in section 2.1.3.2 at the corresponding policy package or segment. The result is the *AIF*, which has an impact on the final energy consumption calculations and therefore emissions.

The following equations illustrate the calculation of the score from Figure 13.

Score from incentives: $((1 \times 40\%) + (2 \times 30\%) + (4 \times 30\%)) / 4 = 55\%$ (Eq. 4)

Discount from barrier: $(-3 \times -30\%) / -4 = -23\%$ (Eq. 5)

The example corresponds to 55% out of a maximum score of 4. To get the final segment score, the score from the incentives needs to be reduced by the discount from barriers.

Segment score: Score from incentives × (1+Discount) (Eq. 6)

This results in 43%. In Figure 12, the unit of the MIF is not specified. For this example it is an annual 2.3% reduction of fossil fuel use. Multiplied with the score of 43%, the actual impact is an annual 0.98% reduction of fossil fuel use.

#### *2.1.3.2 Transport sector policy packages*

The CAT model has 11 policy packages for the transport sector. Ten policy packages are incentives and one is a barrier. The following sections assess the elements (Figure 13) of each policy package. As the CAT does not split the transport sector by mode, all policy packages have an impact on the total data of all modes. The policy packages in the model are numbered. The first transport policy package is number 49.

Most benchmarks and MIFs come from previous research (Schubert 2012).

##### *2.1.3.2.1 Changing activity segment*

There are four policy packages in this policy area, of which policy package 52 (Fiscal or other incentives which promote higher fuel use in transport) is the barrier. They all share one MIF, because their weighting factors sum up to 100%. The MIF decreases the final consumption of diesel and motor gasoline by 2.3% per year and is based on the *Transportation Petroleum Reduction Plan* of the U.S. Virgin Islands (USVI). The USVI aim to reduce their petroleum product use by 60% compared to 2025 projections (Johnson 2011).

There is a conflict with this segment and emerging countries. The policy packages assume that there is the possibility of switching to non-motorised transport or low carbon modes of transport. However, changing activity can also be the other way round. In emerging countries, like China, increasing welfare (Yanli et al. 2012) can cause a switch to motorised transport, which increases final energy consumption. In this case it is assessed whether this growth is already incorporated in the BAU scenario or if an individual solution is required.

- **Policy package 49: Strategies to avoid traffic and to move to non-motorised transport**

This policy package concerns non-motorised transport. Table 16 provides additional information, the benchmarks and the weighting factor.

The benchmarks are based on the plan of the USVI. The question arises whether it is practical to use a policy of a small country as the benchmark for all countries? As the introduction showed, $CO_2$ emissions need to be reduced by large amounts. If one country – no matter what size it is – shows the highest efforts to reduce emissions, then there is no reason why it should not serve as benchmark.

They plan a vehicle mile reduction of 20% to reduce final energy consumption by a switch to non-motorised transport (bike, walking) and increased use of public transport, through an expansion of the routes, and ride sharing. This accounts for 34% of the total reduction of the USVI (Johnson 2011). The CAT does not prescribe what to do to reach the benchmark. The row with additional information in Table 16 shows the examples the model provides for the user what kind of policies and measures apply to this policy package.

There is no information concerning the assumed weighting factor in the official methodology.

**Table 16: Additional information, benchmarks and weighting of policy package 49.**

| | |
|---|---|
| Additional information | Strategies include amongst others:<br>- urban planning (short distances to work and shopping)<br>- traffic management systems to prevent traffic jams<br>- route optimization tools for freight<br>- promotion of walking and biking<br>- investment in infrastructure for biking |
| Benchmarks | 4: 20% less vehicle miles/kilometres by 2020<br>3: 15% less vehicle miles/kilometres by 2020<br>2: 10% less vehicle miles/kilometres by 2020<br>1: 5% less vehicle miles/kilometres by 2020<br>0: no change |
| Weighting | 40% |

- **Policy package 50: Strategies for modal shift to low carbon modes of transport**

  This policy package concerns a modal shift from cars to public transport. Table 17 provides additional information, the benchmarks and the weighting factor. Like the previous case, the benchmarks are based on the plan of the USVI. By 2020 they intend to increase their capacity of public transport by 20%, by increasing the length of routes and vehicle fleet (Johnson 2011).

There is no information concerning the weighting factor in the official methodology.

**Table 17: Additional information, benchmarks and weighting of policy package 50.**

| | |
|---|---|
| Additional information | Strategies include amongst others:<br>- investment in public transport infrastructure (railway lines, trains, buses, bus lanes)<br>- increasing frequency of public transport/ improvement of coverage (esp. bus lines)<br>- pricing/other incentives for low carbon modes |
| Benchmark | 4: 20% increase of passenger capacity of public transport by 2020<br>3: 15% increase of passenger capacity of public transport by |

| | |
|---|---|
| | 2020<br>2: 10% increase of passenger capacity of public transport by 2020<br>1: 5% increase of passenger capacity of public transport by 2020<br>0: stagnation or negative development |
| Weighting | 30% |

- **Policy package 51: Level of energy and/or $CO_2$ taxes for transport fuels**

This policy package deals with an energy tax or a $CO_2$ tax for transport fuels or both, if they exist. Table 18 shows the benchmarks and weighting factor.

The rationale behind this policy package is that fuel has low price elasticity, so a tax has to be large in order to be effective (Höhne et al. 2011a). Greene says that the elasticity of travelled distance by vehicles to the fuel price is close to -0.1. He does not limit the elasticity to a single vehicle type (Greene 2011).

Ross Morrow confirms that taxes decrease the driven distance of vehicles and increase sales of vehicles with better fuel efficiency, when the fuel price increases (Ross Morrow et al. 2010). Taxes are not the only element that influence the fuel price, but can account for a significant amount of it (Hu et al. 2010). The fuel price also depends on the crude oil price (Kilian 2010).

Compared to most other policy packages, there is only a benchmark for the assessments of 4 and 0, where for the assessment of 4 the tax has to be “increased by 100% of energy price by 2020” (Höhne et al. 2011a, page 72) and the assessment of 0 is awarded for no existing tax.

With the unclear formulation of the benchmark for assessment 4, four questions arise:

1. Does a tax have to be increased to twice the amount of the energy price for a rating of 4, so it is 100% more expensive than the fuel without a tax?
2. If more than one tax exists (the title refers to a carbon and/or energy tax), is the assessment of 4 awarded if only one tax is increased?
3. Do the assessments 1-3 follow the procedure described in Table 15?
4. If a tax exists but no increase is planned, which is the assessment? ‘No tax’ does not apply.

Assuming for this thesis that the assessments 1-3 follow the procedure described in Table 15, the words ‘Or no increase’ should be added to the benchmark for rating 0. Otherwise there is no assessment for a tax that does not change.

The weighting factor is 30%. The official methodology does not provide a rationale for the value.

**Table 18: Additional information, benchmarks and weighting of policy package 51.**

| | |
|---|---|
| Additional information | - |
| Benchmark | 4: tax is increased by 100% of energy price by 2020<br>0: no tax |
| Weighting | 30% |

- **Policy package 52: Fiscal or other incentives which promote higher fuel use in transport**

This policy package covers incentives, which promote higher fuel consumption. Table 19 provides additional information, the benchmarks and the weighting factor.

The benchmarks do not have a quantified value and there are no benchmarks for the assessments of -1 to -3. This makes it hard to judge for the user of the model. The assessment of -4 speaks of *strong incentives* and *various areas*, but there is no explanation of what is strong and what is not. Maybe *area* is the wrong term and should be replaced by *different modes of transport*, as the additional information part in Table 19 includes aviation and road transport. That list should be enhanced, because it may be possible that in some countries navigation and rail transport also receive subsidies for diesel and motor gasoline.

There is no information concerning the weighting factor in the official methodology.

**Table 19: Additional information, benchmarks and weighting of policy package 52.**

| | |
|---|---|
| Additional information | Barriers include:<br>- subsidies/tax breaks on company cars<br>- subsidies/tax breaks on commuting by car<br>- car taxation that is not linked to emissions (in cases where this leads to bigger cars being favoured)<br>- subsidies/tax breaks for airlines, flight kerosene |
| Benchmark | 0: no negative incentives<br>-4: strong incentives in various areas |
| Weighting | -30% |

#### *2.1.3.2.2 Energy efficiency segment*

There are three policy packages in this policy area. Two focus on fuel economy of passenger and heavy-duty vehicles from road transport and one on taxes. Besides the weighting factor, the tax policy package equal to policy package 52. The double appearance is legitimate, as taxes also influence the energy efficiency besides consumer activity (Ross Morrow et al. 2010, Hu et al. 2010). The double appearance is not double counting. If the model had a different structure, the policy package could appear only once and affect several segments.

Together, the policy packages have one MIF, because their weightings sum up to 100%. The MIF is based on the benchmarks and weightings of policy packages 53 and 54. It leads to an annual 1.8% decrease of final energy demand of diesel and motor gasoline.

- **Policy package 53: Level of incentive to reduce new car emissions per kilometre**

This policy package concerns fuel economy in cars. The term *fuel economy* refers to fuel efficiency, which is the relationship between consumed fuel and travelled distance (EPA 2010b). Table 20 provides additional information, the benchmarks and the weighting factor.

The EU target of 95 g $CO_2$/km by 2020 for cars and vans is the most ambitious fuel economy target worldwide (An, Earley 2011) and the basis for the benchmark. For the MIF, it was calculated with Eurostat data that to reach the EU target, an improvement of 34% is required, compared to 2009 values of 145.7 g $CO_2$/km (Eurostat 2012a). Under the consideration that every year more vehicles are registered than deregistered (Eurostat 2012b) and with the assumptions of a vehicle lifetime of 15 years and 15,000 annual vehicle kilometres (VKM), the improvement of 34% will lead to a fuel consumption reduction of 23% by 2020, compared to 2009 levels. The annual reduction is 2% and since 2010 is the base year for the calculations in the CAT, this leads to 20% less fuel consumption for the fraction of cars.

The following equation was used to calculate the emissions of the years 2010 and 2020 with the data mentioned above:

$$\text{Emissions}_a \left[\text{Mt CO}_2\right] = \sum_{n=a}^{n-lifetime} \frac{\text{Sales}_n \times \text{average CO}_2 \text{ emissions per km}_n \left[\text{g CO}_2 \text{ km}^{-1}\right] \times \text{VKM}_n \left[\text{km}\right]}{1{,}000{,}000{,}000{,}000 \left[\text{g / Mt}\right]} \qquad \text{(Eq. 7)}$$

Fuel economy standards in the USA use miles per gallon (mpg) as unit. Average emissions were converted from mpg values to g $CO_2$/km with the formula (An, Earley 2011):

$$\text{g CO}_2\text{/km} = (1/\text{mpg})*6{,}180 \qquad \text{(Eq. 8)}$$

The weighting factor is 60%. The official methodology does not provide a rationale for the value. However, because this policy package only affects a fraction of a transport sub-sector (road transport), the weighting factor can be used to affect only the fraction of cars. This requires a country specific modification of the factor.

**Table 20: Additional information, benchmarks and weighting of policy package 53.**

| | |
|---|---|
| Additional information | Incentives include:<br>- regulation on maximum emissions for new cars<br>- tax incentives<br>- investment in research & development<br>- voluntary agreements with car producers |
| Benchmark | 4: 20% less fuel consumption by cars in 2020 compared to 2010<br>3: 15% less fuel consumption by cars in 2020 compared to 2010<br>2: 10% less fuel consumption by cars in 2020 compared to 2010<br>1: 5% less fuel consumption by cars in 2020 compared to 2010<br>0: no incentives |
| Weighting | 60% |

- **Policy package 54: Level of incentive to reduce new freight vehicles emissions per kilometre**

This policy package concerns fuel economy in heavy-duty vehicles. Table 21 provides additional information, the benchmarks and the weighting factor.

Fuel economy standards for heavy-duty vehicles exist in Japan and the USA. Other countries have standards that aim at other GHGs than $CO_2$. The *Euro* and *China* standards aim at CO, HC, NOX and PM (DieselNet 2012).

In Japan, the current target for 2015 (370 g $CO_2$/km) increases the fuel economy by 11% over 2002 levels (415 g $CO_2$/km) (DieselNet 2012).

According to the U.S. Environmental Protection Agency (EPA), fuel economy standards for heavy-duty vehicles in the USA will lead to an emission reduction of up to 23% for affected vehicles due to decreased fuel consumption compared to 2010. On average, the standards will lead to a 15% fuel consumption reduction per diesel vehicle when implemented (EPA 2011).

This value is higher than the Japanese reduction and therefore used for the benchmarks. The values of benchmarks 1-3 follow the procedure from Table 15.

The weighting factor is 20%. Again, there is no rationale in the official methodology.

**Table 21: Additional information, benchmarks and weighting of policy package 54.**

| | |
|---|---|
| Additional information | Incentives include:<br>- regulation on maximum emissions for new trucks<br>- tax incentives<br>- investment in research & development<br>- voluntary agreements with truck producers |
| Benchmark | 4: 15% less diesel consumption by heavy-duty vehicles in 2020<br>3: 11.25% less diesel consumption by heavy-duty vehicles in 2020<br>2: 7.5% less diesel consumption by heavy-duty vehicles in 2020<br>1: 3.75% less diesel consumption by heavy-duty vehicles in 2020<br>0: no policies in place |
| Weighting | 20% |

- **Policy package 55: Level of energy and/or $CO_2$ taxes for transport fuels**

As mentioned in the introduction of this segment, this policy package is equal to package 52, except for the weighting factor. Instead of 30% the value is 20%. As for all other weighting factors, no rationale for the value is provided.

### *2.1.3.2.3 Renewables segment*

There is one policy package in this policy area.

- **Policy package 56: Sufficient incentives to increase renewable energy sources in transport (biofuels)**

This policy package concerns renewable fuels in the transport sector. It includes biogasoline, biodiesel and other liquid biofuels. Table 23 provides additional information, the benchmarks and the weighting factor.

The benchmark for the best assessment is based on the share of renewable fuels in the Brazilian transport sector. It was 23% in 2009 and is higher than the targets of other countries for 2020 (IEA 2011a) and therefore the benchmark. The current biofuel mandate of Brazil is E20-25 (IEA 2011d). This means that motor gasoline needs to have a share of between 20 and 25% of ethanol.

The quantification of the benchmarks differs from the example in Table 15. It does not follow the procedure that the quantified value of benchmark 3 has 75% of the benchmark 4 and so on. This is because it would lead to numbers (17%/11.5%/6%) that are no common targets (Table 22).

Many countries have different blending mandates for motor gasoline and diesel, which often, but not always, only affect road transport. India’s target for example is not restricted to road transport (Whitaker, Heath 2009). Table 22 lists the countries with mandates and targets larger than 10%. The mandates only define the share of renewables in a fuel, not the total fuel consumption (IEA 2011d).

**Table 22: Countries with more than 10% biofuel targets and mandates (IEA 2011d).**

| Country | Target/Mandate | Year |
|---|---|---|
| Brazil | E20-25 | Now |
| Bolivia | B20 | 2015 |
| Costa Rica | B20 | Now |
| Dominican Republic | E15 | 2015 |
| India | E20, B20 | 2017 |
| Indonesia | E15, B20 | 2025 |
| Jamaica | 12.5% renewable<br>20% renewable | 2015<br>2030 |
| Paraguay | E24 | Now |

In regard of the proposed split of modes of transport, this policy package should be split into biodiesel and biogasoline for a more detailed analysis. Also, since in some countries the targets and mandates only affect road transport (IEA 2011d), policy packages for other modes of transport should be added to account for this.

The weighting factor is 100%. This means that no other policy package influences the MIF, which is connected to this policy package. The MIF leads to the share of the benchmark that corresponds to the assessment.

**Table 23: Additional information, benchmarks and weighting of policy package 56.**

| | |
|---|---|
| Additional information | Incentives include:<br>- regulation on minimum use of biofuels<br>- tax incentives<br>- information campaigns |
| Benchmark | 4: 23% until 2020<br>3: 20% until 2020<br>2: 15% until 2020<br>1: 10% until 2020<br>0: no target |
| Weighting | 100% |

#### *2.1.3.2.4 Low carbon segment*

There are two policy packages in the low carbon segment. The first focuses on electricity while the second on alternative fuels as energy carrier. Both policy packages only affect road transport.

- **Policy package 58: Support for fuel switch from oil to natural gas or other low carbon technologies**

This policy package focuses on fuel switch from oil products to natural gas or other low carbon technologies, in road transport, such as LPG or hydrogen. Table 24 provides additional information, the benchmarks and the weighting factor.

As no targets for shares of vehicles were found, the IEA balances were used to find a value for the benchmarks. First, an assessment was made of which low carbon fuel has the highest share in countries' final energy consumption from road transport. As a second step, it was assessed through literature research whether policies exist in the corresponding countries that caused the high share of the fuel or whether the share was achieved without policies (Schubert 2012). Natural gas is the low carbon fuel with the highest share and Bangladesh is the country with the largest share caused by policies (IEA 2011a, Wadud 2011).

The weighting is 100%, as the MIF increases the share of natural gas consumption to the corresponding share of the assessment by 2020 for the road transport sector. With the introduction of LPG as a new energy carrier, a new policy package should be added. Hydrogen is not part of the energy carriers in the IEA balances (Table 50, page 132).

**Table 24: Additional information, benchmarks and weighting of policy package 58.**

| | |
|---|---|
| Additional information | Incentives include:<br>- investment in infrastructure for gas mobility<br>- tax incentives<br>- information campaigns |
| Benchmark | 4: share of 35% natural gas/low carbon fuel in road transport energy consumption in 2020<br>3: share of 26% natural gas/low carbon fuel in road transport energy consumption in 2020<br>2: share of 17.5% natural gas/low carbon fuel in road transport energy consumption in 2020<br>1: share of 9% natural gas/low carbon fuel in road transport energy consumption in 2020<br>0: no plans |
| Weighting | 100% |

- **Policy package 59: Incentives for electric mobility**

This policy package focuses on electric mobility in road transport. Table 25 provides additional information, the benchmarks and the weighting factor. Electric mobility is an option to reduce the dependence on oil products. When using renewable energy, it is $CO_2$ neutral (Helms, Lambrecht 2011).

The benchmarks are based on targets of countries for the share of electric vehicles (plug-in hybrids, extended range electric vehicles and all other electric vehicles) in 2020.

Ireland targets a share of 10% by 2020 (Department of Transport 2012). France has a target of 2 million EVs by 2020, which will represent a share of 4.5%. Germany has a target of 1 million EVs by 2020, which will represent a share of 2% (Schubert 2012).

The weighting is 100%, as the MIF increases the share of electricity consumption to the corresponding share of the assessment by 2020. The question is whether by 2020 also heavy-duty vehicles will also use electricity instead of oil products. Otherwise, the weighting should be set to the share of passenger vehicles.

**Table 25: Additional information, benchmarks and weighting of policy package 59.**

| | |
|---|---|
| Additional information | Incentives include:<br>- investment in infrastructure for electric mobility<br>- investment in research & development<br>- cooperation agreements with producers of cars, batteries, etc.<br>- tax incentives<br>- information campaigns |
| Benchmark | 4: share of 10% electric cars in 2020<br>3: share of 7.5% electric cars in 2020<br>2: share of 5% electric cars in 2020<br>1: share of 2.5% electric cars in 2020<br>0: no plans |
| Weighting | 100% |

### 2.1.4 Data input and BAU scenario

The bases for the calculation of the emission reduction are inputs of historical final energy consumption data and projections. Connected, the historical data and projections create a business as usual (BAU) scenario. Sources for historical data and projections can either be national inventories or "established international sources such as the IEA" (Höhne et al. 2011a, page 21).

The CAT does not subdivide the historical data input of the transport sector into different modes of transport. The model uses the following energy carrier categories from the IEA balances as inputs. Note that the names below are the original names from the IEA balances. Waste for example is not consumed by the transport sector, but the name is used for it. Definitions of the categories and included energy carriers are the appendix (page 132).

- Coal and coal products
- Oil products
- Natural gas
- Biofuels and waste
- Electricity

The model uses emission factors suggested by the IPCC (IPCC 1995, Table 49 on page 132) to calculate resulting emissions and assumes that biofuels are $CO_2$-neutral. If available, the analysis uses country specific emission factors.

The model aggregates electricity emissions in the electricity production sector. However, it uses the emission factor of motor gasoline for the whole category of oil products, which amongst others includes diesel and jet fuel (see Table 50 for definitions). These energy carriers have higher emission factors than motor gasoline, so with the current data structure the model's $CO_2$ emission calculations are too small.

According to the IEA balances (IEA 2011a), the different modes of transport use the energy carriers shown in Table 26. Adding them to the model will lead to more precise emission calculations.

**Table 26: Energy carriers used by modes of transport (IEA 2011a, IEA 2011b).**

| Aviation | Navigation | Rail | Road |
|---|---|---|---|
| Kerosene type jet fuel[10] | Diesel | Biodiesel | Diesel |
| | Motor gasoline | Coal | Biodiesel |
| | Fuel oil | Diesel | Biogasoline |
| | | Electricity | LPG |
| | | | Motor gasoline |
| | | | Natural gas |
| | | | Electricity |

Based on the shares of the total final consumption of the different modes (Table 1), the data input is split into the modes shown in Table 26. The definitions of the modes are in Table 27. Final consumption by pipeline and non-specified transport should also be included in the model for a realistic BAU scenario.

**Table 27: Definitions of the modes of transport from the IEA balances (IEA 2011b, page 16).**

| Mode | Definition |
|---|---|
| Domestic aviation | Includes deliveries of aviation fuels to aircraft for domestic aviation - commercial, private, agricultural, etc. It includes use for purposes other than flying, e.g. bench testing of engines, but not airline use of fuel for road transport. The domestic/international split should be determined on the basis of departure and landing locations and not by the nationality of the airline. Note that this may include journeys of considerable length between two airports in a country (e.g. San Francisco to Honolulu). For many countries this incorrectly includes fuel used by domestically owned carriers for outbound international traffic; |
| Domestic | Includes fuels delivered to vessels of all flags not engaged in international |

---

[10] From now on referred to as "Jet fuel".

| | |
|---|---|
| navigation | navigation (see international marine bunkers). The domestic/international split should be determined on the basis of port of departure and port of arrival and not by the flag or nationality of the ship. Note that this may include journeys of considerable length between two ports in a country (e.g. San Francisco to Honolulu). Fuel used for ocean, coastal and inland fishing and military consumption are excluded; |
| Pipeline | Includes energy used in the support and operation of pipelines transporting gases, liquids, slurries and other commodities, including the energy used for pump stations and maintenance of the pipeline. Energy for the pipeline distribution of natural gas or coal gases, hot water or steam (ISIC Rev. 4 Division 35) from the distributor to final users is excluded and should be reported in energy industry own use, while the energy used for the final distribution of water (ISIC Rev. 4 Division 36) to household, industrial, commercial and other users should be included in commercial/public services. Losses occurring during the transport between distributor and final users should be reported as losses. |
| Rail | Includes quantities used in rail traffic, including industrial railways; |
| Road | Includes fuels used in road vehicles as well as agricultural and industrial highway use. Excludes military consumption as well as motor gasoline used in stationary engines and diesel oil for use in tractors that are not for highway use;” |
| Non-specified | Includes all transport not elsewhere specified. |

### 2.1.5 Strengths and weaknesses of the model

Based on chapter 2.1, strong and weak points are identified.

**Strengths**

The model has a simple and transparent structure. The data input and evaluation are straightforward (see section 2.1.3.1). The calculations can easily be modified in case of adjustment or enhancement (see section 2.1.4).

The main strength is the detailed policy evaluation part, which reflects different policy areas (see section 2.1.2). The model can be used for every country.

**Weaknesses**

The transport section of the model has several weaknesses. It includes agriculture, which should not be included by the definition of the IEA balances (see section 2.1.1). For this thesis, disregarding agriculture data in the data input solves this problem.

The transport sector is not split by mode (see section 2.1.4). This is a problem, as some policy packages only affect a certain mode of transport, such as policy packages 58 and 59.

The following example concerns policy package 59: Electricity consumption by other modes of transport than road can influence the calculations without a split of the data by mode of transport. In Russia, electricity accounted for 8% of the final energy consumption of the whole transport sector in 2009, but the share of road transport of the 8% was 0% (IEA 2011a). Without a split of the data input by mode of transport, the model assumes the share of the benchmark is already reached for assessments 1-3 and does not calculate the policy impact correctly.

Splitting the data input per mode solves this problem. The calculations can be modified that only certain data of the corresponding mode of transport is affected.

The split of the data by mode of transport leads to another problem: lack of coverage for other modes of transport than road (see section 2.1.3.2). There is no policy package for aviation and navigation, except for the general renewable fuel policy package. The modal shift policy package partly affects rail transport. This problem can be solved by the introduction of new policy packages in the policy evaluation part.

In terms of energy carriers, the model is not detailed enough. It uses the emission factor of motor gasoline for all oil products (see section 2.1.4). This leads to too small emissions, as jet fuel and diesel have higher emission factors than motor gasoline. Introducing new emission factors and energy carriers into the model solves this problem.

There are no rationales for the weighting factors. The origin of the weighting factors is not documented (see section 2.1.3.1). This is a lack of transparency and the weighting factors are therefore an object for a sensitivity analysis.

The policy packages for taxes and fossil fuel subsidies have unclear benchmarks, which make the assessments difficult.

## 2.2 Model adjustments and improvement

Based on the identified weaknesses from section 2.1.4, the following parts of the model were adjusted:

- Data input
- Policy packages

The following sections give insight into the changes, which will improve the calculation results of the model.

### 2.2.1 Data input adjustments

**Modes of transport**

Based on Table 26, the data input is split into the following modes of transport:

- Aviation
- Navigation
- Rail
- Road
- Other

The category *Other* includes *non-specified transport* and *pipeline transport* from the IEA balances. No policy package has an impact on this category. This category accounts for 2.5% of the American and 0.8% of the Chinese final energy consumption of 2009 (IEA 2011a, IEA 2011b). Definitions are given in Table 27.

**Energy carriers**

The energy carrier *Oil products* is split into the following energy carriers:

- Diesel
- Jet fuel
- LPG
- Motor gasoline
- Fuel oil

The category *Biofuels and waste* is broken down into single energy carriers that are used by the transport sector (IEA 2011b, IEA 2011a):

- Biodiesel
- Biogasoline

Definitions are given in Table 50 (page 132). Emission factors come from the IPCC (see Table 49, page 132).

**Emission factors**

Country specific emission factors are available for the USA (EIA 2012b). In a national communication, China states that a lot of work needs to be done to obtain data for emission factors, which reflect actual conditions. In the inventory submitted to the UNFCCC, China often uses default factors from the IPCC (The People's Republic of China 2004). Table 28 shows the difference between the country specific and IPCC emission factors. For the USA, the country specific emission factors are added to the model. For China IPCC values are used.

**Table 28: Difference between country specific emission factors of the USA (EIA 2012b) and IPCC emission factors (IPCC 1995).**

| Unit: kg $CO_2/GJ_{LHV}$ | USA | IPCC |
|---|---|---|
| **Motor gasoline** | 71 | 69 |
| **Liquefied Petroleum Gas** | 63 | 63 |
| **Jet Fuel** | 71 | 74 |
| **Diesel** | 73 | 74 |
| **Natural gas** | 53 | 56 |
| **Fuel oil** | 79 | 77 |

### 2.2.2 New policy packages

Policy packages 50 and 52 also include other modes of transport than road, but the MIF affects only road transport. All other policy packages with their MIFs affect road transport as well. It is therefore necessary to create new policy packages for the new modes of transport, which have their own weighting factors and MIFs.

The following sections provide descriptions of the new policy packages for other modes of transport than road with the corresponding benchmarks and MIFs.

Some modes of transport receive a biofuel policy package, which is based on the same policy, because it does not prescribe a certain mode of transport. This does not necessarily lead to the share of the policy in all modes of transport, because one single mode of transport can exceed the target. This reduces the requirements for the other modes to achieve the overall target. This enables the model to be flexible in regard of evaluation.

The calculations of the model for all MIFs lead to the corresponding value of the benchmark by 2020. Exemptions are indicated in the text. Because the impact of each policy package is directly used for the calculations without sharing a MIF, like in the changing activity segment (see section 2.1.3.2.1), the weighting factor of each policy package is 100%.

#### *2.2.2.1 Aviation*

Aviation uses jet fuel. Several airlines have already successfully tested bio jet fuel in the Netherlands, Germany and the United Kingdom (KLM 2011, Lufthansa 2011, Virgin Atlantic 2008). Lufthansa in Germany used a ratio of 50:50 on one engine. The airline does not report why usage of bio jet fuel did not continue after the successful test over six months (Lufthansa 2011). KLM has stopped the use of bio jet fuel due to high prices (KLM 2011).

China is currently the only country with a target for the use of bio jet fuel in aviation. By 2020, the country aims to have a share of 30% of bio jet fuel (Yan 2012). Therefore, this value is the used for the best benchmark.

Based on the Chinese target, with the procedure from Table 15 the benchmarks are as follows:
4: 30% share of bio jet fuel in the final energy consumption of domestic aviation by 2020
3: 22.5% share of bio jet fuel in the final energy consumption of domestic aviation by 2020
2: 15% share of bio jet fuel in the final energy consumption of domestic aviation by 2020
1: 7.5% share of bio jet fuel in the final energy consumption of domestic aviation by 2020
0: no bio jet fuel by 2020

#### *2.2.2.2 Navigation*

Several abatement options exist (Strandmyr Eide, Endresen 2010), but there are no direct governmental policies aiming to reduce $CO_2$ emissions from domestic navigation.

Emission standards for rail and navigation exist but concern emissions other than $CO_2$, such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides ($NO_X$) or particulate matter (PM). Actions to reduce some of these emissions however result in increased fuel consumption and therefore increased $CO_2$ emissions (Strandmyr Eide, Endresen 2010). To reduce $NO_X$ emissions, water can be added in different ways (for example as direct injection or emulsified in the fuel), but this reduces the thermal engine efficiency (DNV 2012a). To reduce $SO_X$ emissions, a scrubber can be retrofitted to ships, which requires energy when operating (DNV 2012b). It is therefore important to reduce fuel consumption and $CO_2$ emissions through other measures.

At the international level, there is no GHG regulation for navigation at the moment (European Commission 2011). Some companies have own voluntary targets, which are not mandated by the government, for example MAERSK. MAERSK is currently testing a biodiesel blend of 5-7% and aims to reduce emissions by 20% until 2017 per container moved (MAERSK 2010).

Table 22 shows biofuel targets and mandates of several countries. The Indian biofuel target is not restricted to road and rail transport (Whitaker, Heath 2009) and also includes a target for biogasoline (E20) (IEA 2011d). With this information, two new policy packages for biofuels in navigation can be added. One is for biogasoline, the other for biodiesel. Both motor gasoline and diesel are used in domestic water transport (IEA 2011a, IEA 2011b).

The benchmarks for the biodiesel policy package are based on the B20 targets mentioned above (Table 22):
4: Share of biodiesel in the final diesel consumption of domestic navigation is 20% in 2020
3: Share of biodiesel in the final diesel consumption of domestic navigation is 15% in 2020

2: Share of biodiesel in the final diesel consumption of domestic navigation is 10% in 2020
1: Share of biodiesel in the final diesel consumption of domestic navigation is 5% in 2020
0: No biodiesel in 2020

The benchmarks for the biogasoline policy package are analogue and based on the Indian E20 target (IEA 2011d).

#### *2.2.2.3 Road*

LPG is a new energy carrier in the model and requires a policy package. The split of the biofuels policy package requires a new policy package for biodiesel, because the old policy package is based on a biogasoline target.

- **Biodiesel**

Biodiesel is already in use in many countries (IEA 2011b, IEA 2011a). The benchmarks for the biodiesel policy package are based on the B20 targets mentioned in Table 22:

4: Share of biodiesel in the final diesel consumption of road transport is 20% in 2020
3: Share of biodiesel in the final diesel consumption of road transport is 15% in 2020
2: Share of biodiesel in the final diesel consumption of road transport is 10% in 2020
1: Share of biodiesel in the final diesel consumption of road transport is 5% in 2020
0: No biodiesel target for 2020

- **LPG**

The most common policy for LPG is a fuel tax exemption or rebates. Some countries also offer vehicle tax rebates and grants for conversions (World LP Gas Association 2005). Targets for LPG were not found. Therefore the current situation was assessed with the IEA balances.

In 2009, LPG had a share larger than 10% in the final energy consumption of road transport in five countries. Turkey had the largest share with 19%, followed by Korea (17%), Bulgaria (15%), Lithuania (14%) and Poland (12%) (IEA 2011a). Except for Korea, all countries have fuel tax exemptions for LPG or rebates. Korea supports vehicle conversions. Table 29 shows how much LPG costs as percentage of the motor gasoline and diesel price. Highest savings compared to diesel are in Lithuania, compared to motor gasoline in Poland (World LP Gas Association 2005).

**Table 29: LPG pump price, including all taxes, as percentage of motor gasoline and diesel (World LP Gas Association 2005).**

| | Diesel | Motor gasoline |
|---|---:|---:|
| **Turkey** | 66% | 53% |
| **Korea** | 73% | 49% |
| **Bulgaria** | 67% | 57% |
| **Lithuania** | 52% | 48% |
| **Poland** | 54% | 46% |

Based on the highest found shares in the IEA balances by 2009 (Turkey), the benchmarks for the LPG policy package are as follows:
4: Share of LPG in the final energy consumption of road transport is 19% in 2020.
3: Share of LPG in the final energy consumption of road transport is 14% in 2020.
2: Share of LPG in the final energy consumption of road transport is 10% in 2020.
1: Share of LPG in the final energy consumption of road transport is 5% in 2020.
0: No LPG in 2020

#### *2.2.2.4 Rail*

The rail sector uses coal, diesel and electricity as energy carriers. Coal is being phased out (IEA 2011a, see section 1.2.1.1 for China), so there are new policy packages for biodiesel and electricity.

- **Biodiesel**

Companies in the USA and United Kingdom have tested biodiesel in the past but did not continue usage after the testing period (Amtrak 2011, Virgin Trains 2012). Amtrak in the USA indicated that cost and availability play an issue in constant use, compared to ultra low-sulphur diesel (Amtrak 2011). Virgin Trains stopped the use of biofuels because of over-sourcing and economic impacts (Virgin Trains 2012).

The benchmarks for the biodiesel policy package are based on the B20 targets mentioned above in Table 22. For the Indian target, rail transport was explicitly included (Whitaker, Heath 2009):
4: Share of biodiesel in the final diesel consumption of rail transport is 20% in 2020
3: Share of biodiesel in the final diesel consumption of rail transport is 15% in 2020
2: Share of biodiesel in the final diesel consumption of rail transport is 10% in 2020
1: Share of biodiesel in the final diesel consumption of rail transport is 5% in 2020
0: No biodiesel in 2020

- **Electrification of railways**

Increased electrified railways enable the use of electric and hybrid instead of diesel or steam locomotives on more routes. The technical potential allows for a 100% share of electricity in the final energy consumption of rail transport. Policy decisions can stimulate the use of this potential. Based on the diesel and electricity prices and availability of electrified railways, a fuel switch from diesel to electricity can occur.

China and India have policies to increase the electrification of railways. While in China, the 5-Year-Plans call for railway development (Delegation of the European Union in China 2011), in India the Government wants to increase the amount of electrified railways from 20,000 to 33,000 before 2020 (Ministry of Railways 2011).

In India, 20,000 km of electrified railways accounted for 31% of the tracks in 2010. The target of 33,000 km will account for 51%, if no additional tracks are constructed. Between 2002 and 2010, the amount of railways only increased by 852 km (1%) (Ministry of Statistics & Programme Implementation 2012). In that case, the share of electrified railways will increase by 20% (Ministry of Railways 2011).

In China, the amount of electrified railways increased from 14,864 km (25%) in 2000 to 32,717 km (49%) in 2010, while the total length of railways increased from 58,656 to 66,239 km. The increase of 24% over 10 years (China statistical yearbook 2011) is larger than the Indian and therefore used for the benchmark.

The benchmarks are as follows:
4: 24% increase of electrification of railway tracks until 2020
3: 18% increase of electrification of railway tracks until 2020
2: 12% increase of electrification of railway tracks until 2020
1: 6% increase of electrification of railway tracks until 2020
0: No actions to increase the share of electricity.

The maximum impact factor decreases the growth rate of diesel by one tenth of the value of the benchmark and adds it to electricity, so it represents a fuel switch. For some countries this policy package could lead to a full fuel switch.

## 2.3 Data input and BAU scenarios

To create BAU scenarios for the evaluation, data input of final energy consumption from the past and growth rates are required. The CAT has a hierarchy of sources for growth rates. Governmental sources are preferred, followed by recognized international organizations, such as the IEA or World Bank (Höhne et al. 2011a).

**Consumption data**
The IEA balances provide final energy consumption data by mode of transport for both countries (IEA 2011a, IEA 2011b). For the USA, the Annual Energy Outlook (AEO) is another option (EIA 2012a). As it is one source, the IEA balances allow for a better comparison of both countries, because the data has been aggregated with the same methodology and definitions (see Table 50). Different definitions between different aggregation methods make a comparison difficult.

**Growth rates**

For growth rates, there are two sources for each country, following the hierarchy.

For China, there are growth rates from the government from 2005 per mode of transport, but not per energy carrier (Hu et al. 2010, see Table 6). The projected final energy consumption of 2010 was already exceeded by 0.2 EJ in 2009 (IEA 2011a). While the final energy consumption of navigation, aviation and railways was below the projections, the road transport consumption was 1.2 EJ higher than projected. Table 30 shows the values of the projection and consumption.

**Table 30: Final transport energy consumption by mode in China – 2005, 2009 consumption (IEA 2011a) and 2010 projections from 2005 (Hu et al. 2010).**

| Unit: EJ | 2005 consumption | 2009 consumption | 2010 projection |
|---|---|---|---|
| **Aviation** | 0.3 | 0.5 | 0.7 |
| **Navigation** | 0.4 | 0.6 | 0.9 |
| **Rail** | 0.5 | 0.5 | 1.0 |
| **Road** | 3.8 | 5.1 | 3.9 |
| **Total** | 5.0 | 6.7 | 6.5 |

The gap between the final energy consumption of aviation, navigation and rail transport of 2009 and the projections for 2010 is too large to be closed within one year. Aviation increased the final energy consumption by 0.2 EJ between 2005 and 2009; navigation increased the final energy consumption by 0.3 EJ between 1999 and 2009 and rail transport's final energy consumption has not increased by 0.5 EJ since 1990, due to the retirement of steam and replacement by diesel and electric locomotives (IEA 2011a, China statistical yearbook 2011). More recent governmental growth rates probably exist, but are not public (Christian Ellermann 5/04/2012).

Another source for both countries is the WEO. It provides growth rates, but not at the same detailed level as the AEO (Table 9). It does not split the growth rates by mode of transport. Table 31 shows the 2011 WEO growth rates from the Current Policies Scenario. The growth rates apply from 2009 until 2035. Diesel, jet fuel, motor gasoline and LPG share one growth rate (*Oil*). So do biodiesel and biogasoline (*Biofuels*); coal and natural gas (*Other fuels*) (IEA 2011e).

**Table 31: Annual growth rates from the 2011 WEO (IEA 2011e).**

| | China | USA |
|---|---|---|
| **Oil** | 4.6% | -0.3% |
| **Electricity** | 7.1% | 3.6% |
| **Biofuels** | 9.2% | 4.2% |
| **Other fuels** | 0.3% | 1.4% |

The WEO growth rates are from the Current Policies Scenario (CPS), which include all policies until mid-2011 (IEA 2011e).

For the USA, the AEO provides growth rates per mode of transport for each energy carrier. This is the most detailed available level of all growth rates. Values from the 2011 reference case are in Table 32, broken down to modes of transport used in this analysis, because the IEA data is not as detailed as the AEO data (EIA 2012a). The 2011 reference case was chosen because it is from the same year as the latest available WEO growth rates.

**Table 32: Annual growth rates from the AEO 2011 reference case (EIA 2012a).**

| **Mode of transport / Energy carrier** | **Annual growth rate** |
|---|---:|
| **Aviation** | |
| Jet fuel | 0.6% |
| **Navigation** | |
| Motor gasoline | 0.2% |
| Diesel | 0.9% |
| Fuel oil | 0.9% |
| **Rail transport** | |
| Diesel | 1.2% |
| Electricity | 1.1% |
| **Road transport** | |
| Motor gasoline | -0.1% |
| Diesel | 1.6% |
| LPG | -0.1% |
| Natural gas | 5.3% |
| E85 | 26.0% |
| Electricity | 21.9% |

Due to the differences in the projections of the Chinese government from 2005 and the final energy consumption of 2009, the WEO growth rates are favoured for the China analysis.

For the USA, the AEO growth rates are more detailed and do not have a negative growth rate for every oil product. They are therefore chosen for a more detailed analysis. However, there is only a growth rate for E85 and not for biodiesel in the road transport sector. Also, the IEA data does not go by blend, but total amount, so this large growth rate might not be useful.

## 2.4 Policy inventory and analysis

The policy inventory gathers current and planned transport policies of China and the USA. The collected policies get assigned to the policy packages for the evaluation, according to the benchmark requirements of the policy packages. With the assessments, the model will determine the emission reduction (excepting policies that are already included in the BAU).

The separation of the inventory and analysis also identifies whether the CAT does not cover some policies. With this knowledge the CAT model can be further enhanced.

## 2.5 $CO_2$ reduction potential according to best practice

If an assessment is smaller than 4 (incentives) or smaller than 0 (barriers), a policy gap between current and best practice exists. Closing the policy gap by setting the assessment to the difference between the actual and best assessment quantifies the total $CO_2$ reduction potential according to best practice.

# 3 Results

This chapter first shows the effects of changes in the model, which were made in the previous chapter. Then it presents the BAU scenarios, which are the basis for the analysis, followed by the policy inventories and the policy analyses of both countries with the model. The policy strategies are compared and with the identified policy gaps, the reduction potential according to best practice policies is calculated. The last part of this chapter is a sensitivity analysis.

## 3.1 Effect of changes in the model

Before the modification of the model, all oil products used the emission factor (EF) of motor gasoline. The emissions of the different modes of transport were summed up and presented as one value for the whole domestic transport sector.

Splitting the data input by mode of transport, adding more energy carriers and corresponding IPCC EFs had an impact on results. Figure 14 shows that emissions increased by 73 Mt $CO_2$ (4%) for the USA and 44 Mt $CO_2$ (14%) for China due to the changes, based on the final consumption of 2005. The increase is mainly driven by the introduction of diesel and jet fuel EFs, which are higher than the EF of motor gasoline.

For the USA, country specific EFs are available. Using these factors results in an increase in the emissions by additional 17 Mt $CO_2$. The difference to the original CAT version is 90 Mt $CO_2$ (5%). The increase is due to the high share of motor gasoline (64%) of the final energy consumption (IEA 2011b), of which the EF increased by 2 kg $CO_2/GJ_{LHV}$, compared to the IPCC factors (Table 28). No country specific EFs were available for China.

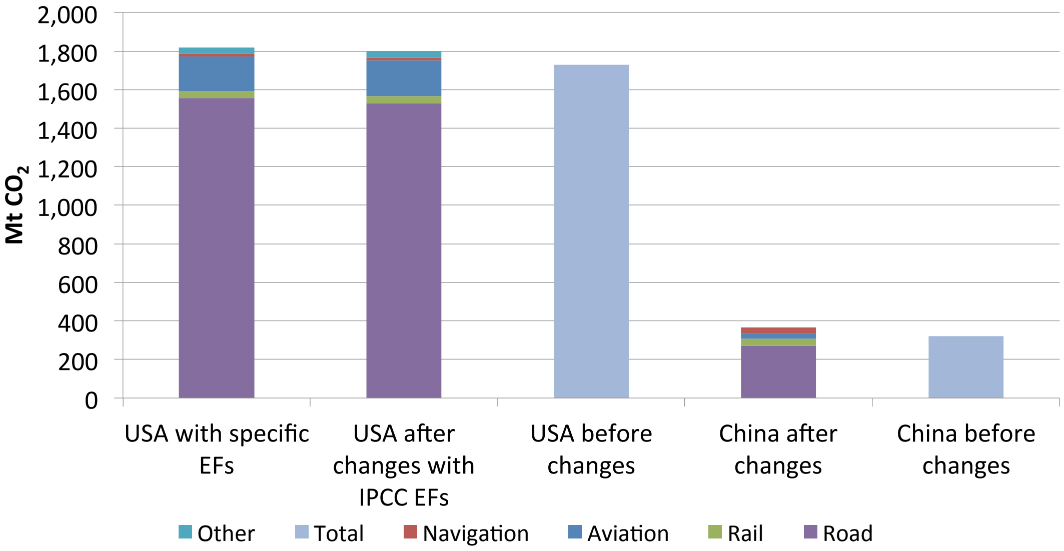


**Figure 14: Impact of changes in the model on 2005 emissions.**

## 3.2 BAU scenarios

The BAU scenarios are technically frozen policy scenarios. They use the growth rates from the CPS from the 2011 WEO for China and 2011 AEO for the USA, which include all policies until mid-2011 (EIA 2012a, IEA 2011e).

For the USA, the growth rates are at a very detailed level, split by energy carrier per mode of transport (Table 32). For China, the growth rates are per energy carrier and not split per mode of transport (Table 31). Table 33 shows which growth rate is used for each energy carrier.

**Table 33: Growth rates of energy carriers - China.**

| Energy carrier | Annual growth rate |
|---|---|
| Biodiesel | 9.2% (Biofuels) |
| Biogasoline | 9.2% (Biofuels) |
| Coal | -5% (Individual) |
| Diesel | 4.6% (Oil) |
| Electricity | 7.1% (Electricity) |
| Fuel oil | 4.6% (Oil) |
| Jet fuel | 4.6% (Oil) |
| LPG | 4.6% (Oil) |
| Motor gasoline | 4.6% (Oil) |
| Natural gas | 0.3% (Other fuels) |

The growth rate for coal in China differs. Statistics show that the amount of coal is decreasing by 5% per year (IEA 2011a). Instead of using the positive growth rate of *Other fuels* (0.3%) for coal, the decrease is continued with -5% per year.

For each country there is one graph showing $CO_2$ emissions by fuel and mode. The growth rates apply from 2010 on.

### 3.2.1 China

The model accounts electricity emissions in the electricity production sector and regards all biofuels (see Table 50on page 132 for definitions) as carbon neutral. In total, emissions increase by 106% between 2005 and 2020 from 366 to 756 Mt $CO_2$ (Figure 15).

Diesel has the largest share of emissions. The share increases by 3% between 2005 and 2020 to 50%, followed by motor gasoline with 40% and an increase of 1% from 2005 on. Jet fuel's share stays constant at 7%. Coal's share of 4% decreases to 1%, fuel oil's share decreases from 3% to 2%. LPG's share decreases from 0.4% to 0.2%. The share of natural gas stays constant at 0.1%.

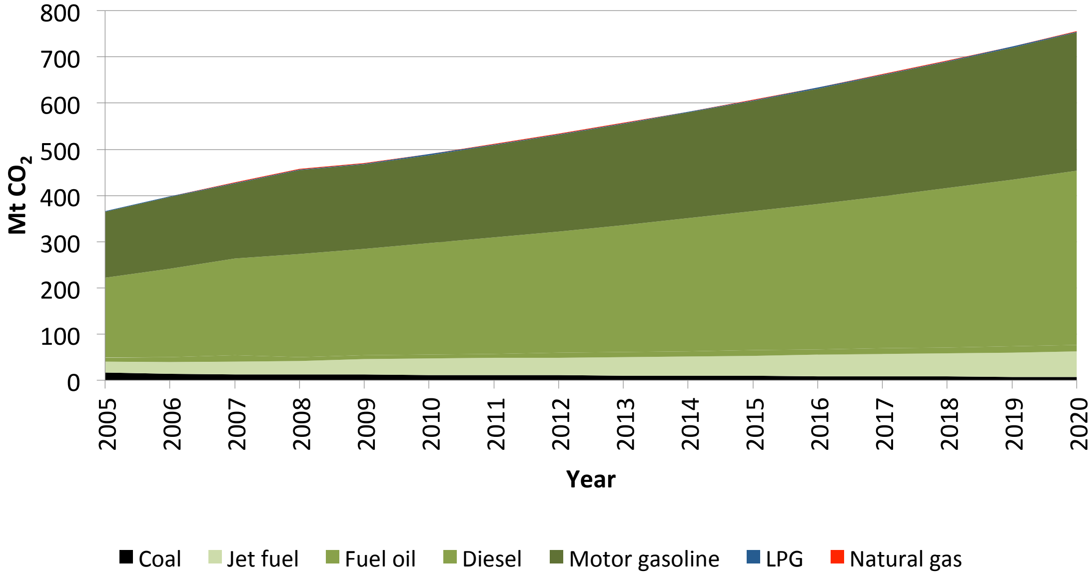


**Figure 15: BAU emissions by energy carrier: China.**

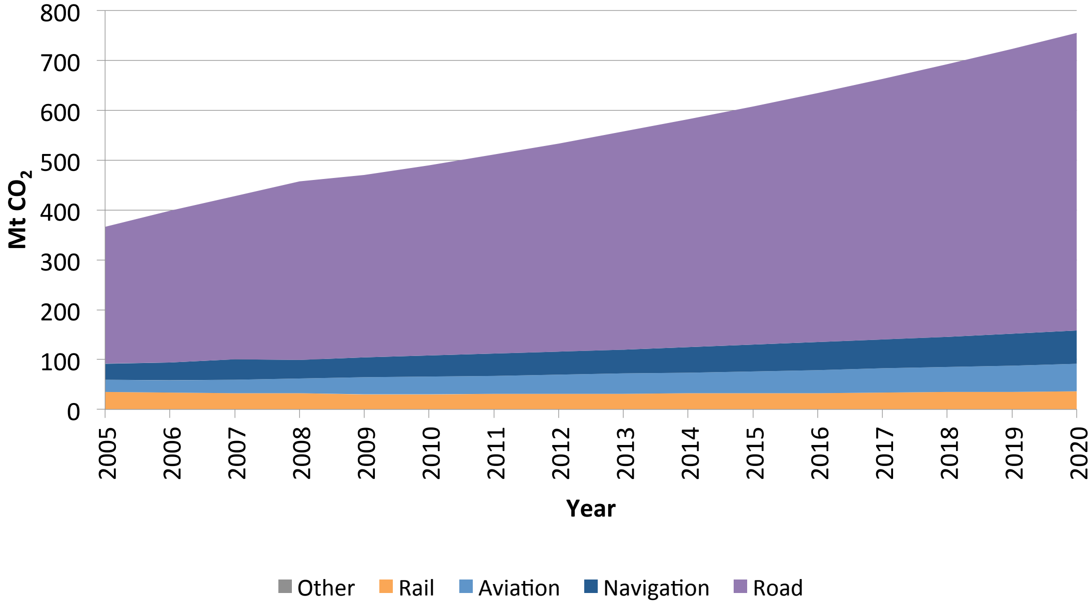


**Figure 16: BAU emissions by mode of transport: China.**

Road transport stays with the largest emissions, which increase by 118%. The share of road transport emissions increases by 7% and reaches 81% in 2020. The share of aviation emissions increases by 1% to 8%, the total emissions by 131%. By 2020, aviation has the second largest share in emissions. Navigation is the third largest source of emissions in 2020 with a share of 6% (-3%). The total emissions increase by 24%. Rail transport's share decreases by 5% to 5% because of a decrease in coal consumption. The total emissions increase by 2%. A large share of rail emissions is accounted for in the electricity supply sector of the model. This value is quantified in section 3.7. Emissions of other modes of transport increase by 1,483%; the share is however smaller than 0.1% during the whole period (Figure 16).

The growth is mainly caused by the expansion of all modes of transport, which is part of the 12th Five-Year-Plan (Delegation of the European Union in China 2011). The Chinese GDP is expected to continue its growth (Figure 4). Welfare and demand for own vehicles and travel in general will continue to increase (Yanli et al. 2012) with this development, causing final energy consumption and emissions to increase. However, emissions of the domestic transport sector are still less than half of those from the USA by 2020 (Figure 17).

### 3.2.2 USA

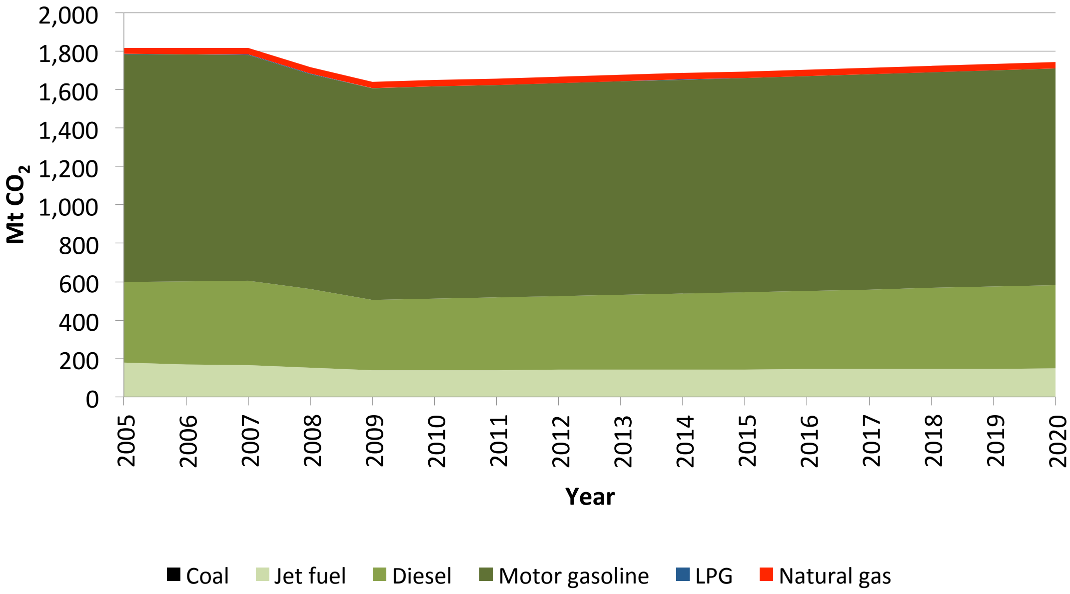


**Figure 17: BAU emissions by energy carrier: USA.**

Between 2005 and 2020, emissions decrease by 6% from 1,818 to 1,708 Mt $CO_2$. The largest reduction took place between 2007 and 2009 (financial crisis, see section 1.2.1.2). In 2009, the emissions were 1,641 Mt $CO_2$ (Figure 17). Between 2010 and 2020, the emissions increase by 4%.

Emissions are mainly dominated by motor gasoline. Motor gasoline emissions account for 64% of the emissions in 2020. That is a decrease of 1% compared to 2005, caused by the negative growth rate. The share of the emission from diesel increases. Diesel reaches 25% in 2020 (+2% compared to 2005). Jet fuel's share drops by 1% to 9%. Natural gas accounts for 2% (no change) of the emissions by 2020. The shares of LPG and fuel oil emissions are below 0.1% at all times.

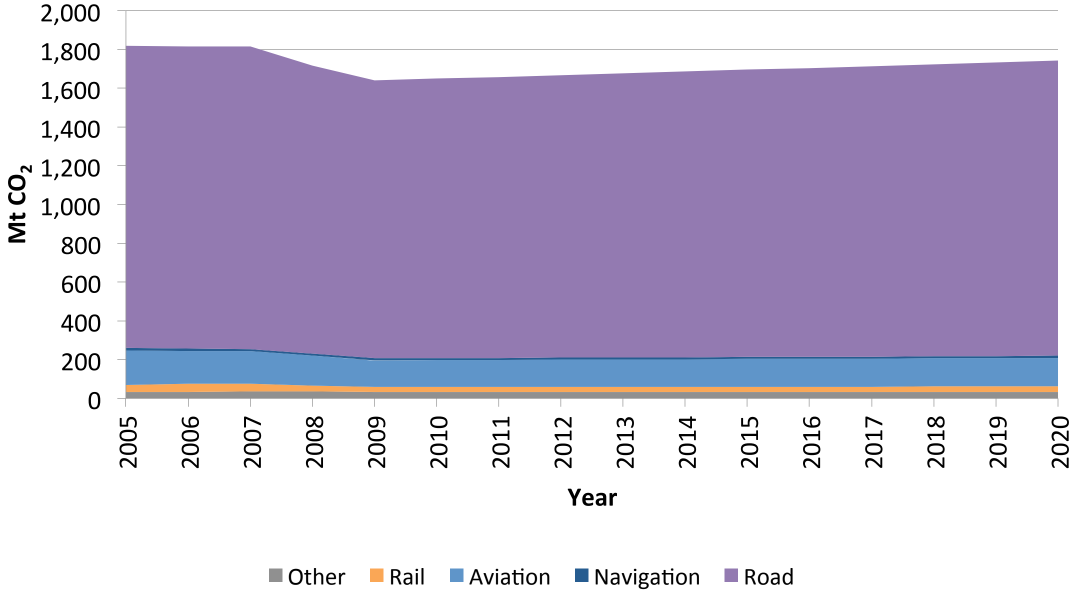


**Figure 18: BAU emissions by mode of transport: USA.**

Road transport has the largest emissions. In total, they decrease by 4%, while the share increases by 1%, reaching 87% in 2020. Aviation is the second largest source of emissions during the whole period. The share decreases by 1% to 9% by 2020. The total emissions decrease by 17%. The share of rail emissions stays constant at 2%, the total emissions decrease by 24%. Navigation has a small share of 0.6% throughout the whole period. The emissions decrease by 9%. Emissions of other modes of transport increase by 1%. The share stays at 2% (Figure 18).

Positive GDP growth projections (Figure 6) are a driving factor behind the growth of final energy consumption and emissions from 2010 on. Without a fuel switch from motor gasoline (negative growth rate, Table 32) to other energy carriers (positive growth rates, Table 32) with fewer emissions intensity, the increase (4%) would be higher. An increase of the motor gasoline growth rate of 0.1% per year results in 12 Mt additional $CO_2$ emissions.

Because of the drop of emissions during the financial crisis, the USA already has a reduction of 6% below 2005 levels by 2020. But this is below the reduction target (see section 1.1). Without additional measures in the domestic transport sector, other sectors will have to reduce emissions even more.

## 3.3 Policy inventories

The Chinese and American transport policies are gathered in an inventory, sorted by the following categories:

- Road
- Rail
- Aviation
- Navigation
- Taxes and subsidies

In the next chapter, the policies are assigned to the policy packages. Calculations that lead to an assessment are provided. The assessments determine the emission reduction and also show where policy gaps and additional potentials are.

## 3.3.1 China

### *3.3.1.1 Road*

Most policies focus on road transport, as it is the biggest source of emissions (Figure 16).

- **Auctioning of license plates**

Beijing, Guangzhou, Guiyang and Shanghai limit the issue of new license plates to limit the growth of the vehicle stock (Wang 2010, Beijing Traffic Management Bureau 2012c). In Beijing, 17,600 license plates have been issued every month since 2011, while over 1 million people apply (Beijing Traffic Management Bureau 2012b). License plates for electric vehicles are not limited (China.org.cn 2011). In 2011, 617,000 fewer vehicles were registered in Beijing than in 2010 (Beijing Traffic Management Bureau 2012a). Since 1994 Shanghai has auctioned license plates. The price of one license plate can amount to 64,637 Yuan ($10,217) (Beijing Traffic Management Bureau 2012d), which forces many residents to register their vehicles in other cities (Wang 2010). In August 2012, Guangzhou limited the number of new license plates to 120,000 per year. Forty per cent of the license plates will be auctioned, 60% issued via a lottery (Beijing Traffic Management Bureau 2012d).

- **Ban of motorcycles from city centres**

Since the late 1990s, over ninety cities have banned motorcycles from city centres. According to People's Daily Online, in 2008 there were 655 cities in China (People's Daily Online 2008), so in about 15% of all cities, motorcycles are banned. This led to them being replaced by electric bicycles. Since 2001, ten cities also have started restrictions for electric bicycles. Restrictions range from a ban from city roads; suspension of issuing licenses or bans from the city centres, among others (Yang 2010). According to Hu, in 2006 there were 37.47 million electric bicycles in China, which are formally non-motorised transport vehicles. Hu estimates that by 2010 the number increased to 50 million (Hu et al. 2010). Despite the ban from some city centres, the number of motorcycles continues to increase. Between 2008 and 2009, 1.7 million new motorcycles were registered in China (Beijing Traffic Management Bureau 2009).

- **Ban of vehicles from city centres on certain days in Beijing**

Each day during the week, one fifth of the registered cars are not allowed to drive inside Beijing, based on the last digit of the license plate. The ban first started in 2008 during the Olympic Games and was continued afterwards, starting each day at 7am and ending at 8pm (Beijing Traffic Management Bureau 2012a). No information about other cities with a vehicle ban on certain days was found.

- **Biofuel target**

Nine provinces currently have an E10 mandate (IEA 2011d). An expansion of the mandate to all 22 provinces is planned by 2020 (Biofuels Digest 2011).

The *Medium and Long-Term Development Plan for Renewable Energy in China* states that by 2020 China plans to have a production capacity of 10 Mt of bioethanol and 2 Mt of biodiesel (GSI 2008), while the overall target is that 15% of the primary energy consumption is covered by renewable energy (NDRC 2007). Biofuel production started in 2000 with a capacity of 200 kt. In 2008, the ethanol production capacity was 1.94 Mt (Li, Chan-Halbrendt 2009). The current biodiesel production capacity was not found.

- **Electric vehicles**

In 2001, the first EV support programme was initiated. Table 34 shows a timeline of Chinese policy support for EV development (Earley et al. 2011).

**Table 34: Electric vehicle policy support in China: A timeline (Earley et al. 2011, page 9). Table modified by adding US$ equivalents.**

| | |
|---|---|
| **2001** | 863 Electric Fuel Cell Vehicles Project – Government investment of RMB 800m ($127 million). |
| **2006** | 863 Energy-Saving and New Energy Vehicles Project – MOST invests RMB 1.1bn ($175 million), setting technology roadmap for EV industry |
| **2008** | MOST, Ministry of Finance (MOF), National Development and Reform Commission (NDRC), Ministry of Industry and Information Technology (MIIT) – *1000 Vehicles, 10 Cities Demonstration Project* |
| **2009** | State Council – *Plan on Adjusting and Revitalizing the Auto Industry* – Planned to invest RMB 3bn ($476 million) to develop key EV technology |
| **2010** | MOST, MIIT and MOF – *Subsidy Standards for Private Purchase of New Energy Vehicle* – selected 5 cities for private EV purchase subsidy with RMB 50,000 ($7,937) maximum subsidy for PHEV RMB 60,000 ($9,524) for BEV. |
| **2010** | *863 Key Technology and System Integration Project for Electric Vehicles* – RMB 738m ($117 million) for battery and EV integration with 42 per cent of funds for battery research |

The target is to put five million electric vehicles on the road by 2020. The interim target is 500,000 by 2015. Plug-in electric vehicles are included in the numbers (China Daily 2012).

- **Fuel economy standard for passenger vehicles**

To promote the reduction of new private car emissions, there is a fuel economy standard, “based on a weight classification system, where vehicles must comply with the standard for their weight class” (An, Earley 2011, page 4). For 2020, plans are to have a fleet average of 116 g $CO_2$/km based on the New European Driving Cycle (NEDC). The average emissions of 2009 models were 180 g $CO_2$/km (An, Earley 2011). This is an improvement of 36%.

- **Fuel standard**

China uses emission standards that are similar to the Euro standards, which focus on other GHGs than $CO_2$, but has no fuel consumption standards for trucks and buses. However, China postponed the introduction of the China IV standard, similar to Euro IV, in 2011 due to lack of availability of clean diesel (Watts 2012). The China V standard, stricter on $NO_X$ emissions, was scheduled to start in Beijing in June 2012. Compared to the China IV standard, it allows 2 instead of 3.5 g $NO_X$/kWh (DieselNet 2012).

- **LPG and LNG support**

Programmes to retrofit public transport and taxis with LPG and LNG exist in 16 provinces and cities. The aim is to improve air quality (The People’s Republic of China 2004). The target is to have three million natural gas vehicles on the road by 2020 (Perkowski 2012). By 2003, 193,000 natural gas-fuelled vehicles were on the road (The People’s Republic of China 2004).

- **Public transport**

Section 3 of the 12th Five-Year-Plan briefly gives priority to public transport expansion via the development of bus rapid transit, urban rail and regulation of the city taxi industry (Delegation of the European Union in China 2011).

#### *3.3.1.2 Rail*

The 12th Five-Year-Plan calls for an accelerated construction of passenger railway lines and development of high-speed railways. The plan set priorities to an expressway network with 45,000 km length that connects cities with a population greater than 500,000 and construction of urban rail traffic networks in some of the larger cities and frameworks in other cities (Delegation of the European Union in China 2011). The Ministry of Railways (MOR) says that by 2020 the target is to have 120,000 km of railways. The total investment is 5 trillion RMB ($793.7 billion) (MoR 2008). In 2009, the track length was 85,500 km (Table 4), so the target of 120,000 km increases the track length by 41%.

#### *3.3.1.3 Aviation*

Air China tested biofuel at a 50:50 blend, based on domestically grown jatropha, on one engine in 2011 but expects development to take a few years (Dingding 2011).

By 2020, China expects to use 12 Mt of aviation biofuels, as an answer to the inclusion of aviation to the European emissions trading. According to the Civil Aviation Administration this amount will represent a share of 30% (Yan 2010).

#### *3.3.1.4 Navigation*

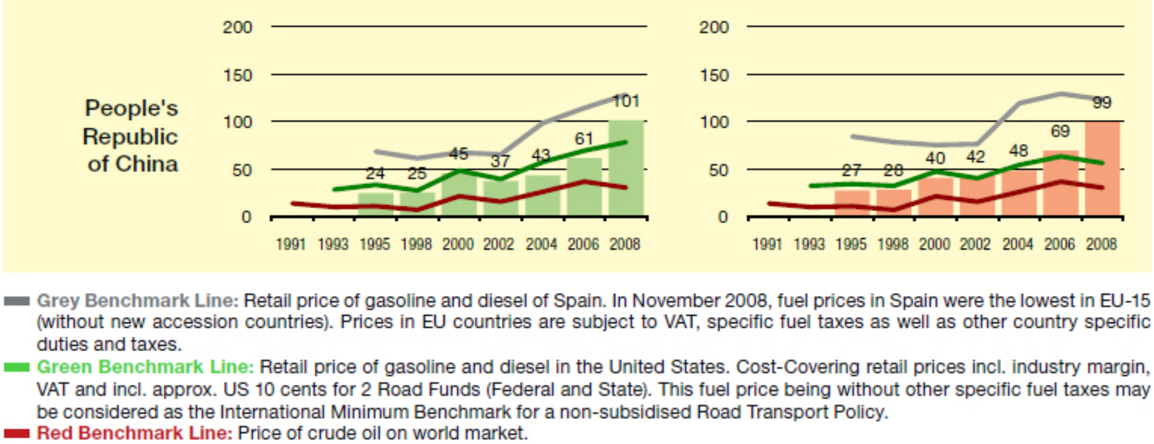
Part of the 12th Five-Year-Plan is "construction of high-grade waterways" (Delegation of the European Union in China 2011, page 13) with no further detail in regard of $CO_2$ emission reduction. No target for biofuel use was found.

#### *3.3.1.5 Taxes and subsidies*

- **Price cap**

The government caps fuel prices for diesel and gasoline, while refineries have to pay the market price when they import oil (GSI 2008). The LPG price does not have a cap (Leung 2011). For the biofuel price no information was found.

According to the International Fuel Prices 2009 report by GTZ (now GIZ), China had a diesel price of 101 US cpl and 99 cpl for gasoline while the price of crude oil on the world market was 30 cpl. The GTZ put China in a category where the retail price is higher than in the USA and lower than in Spain. Spain is a benchmark because it had the lowest fuel prices of the EU-15 countries in November 2008. Figure 19 shows the development of the fuel price from 1991 to 2008. Between 2006 and 2008 prices increased by 66% (diesel) and 43% (gasoline) (Ebert et al. 2009).



▬ Grey Benchmark Line: Retail price of gasoline and diesel of Spain. In November 2008, fuel prices in Spain were the lowest in EU-15 (without new accession countries). Prices in EU countries are subject to VAT, specific fuel taxes as well as other country specific duties and taxes.

▬ Green Benchmark Line: Retail price of gasoline and diesel in the United States. Cost-Covering retail prices incl. industry margin, VAT and incl. approx. US 10 cents for 2 Road Funds (Federal and State). This fuel price being without other specific fuel taxes may be considered as the International Minimum Benchmark for a non-subsidised Road Transport Policy.

▬ Red Benchmark Line: Price of crude oil on world market.

**Figure 19: Fuel price development in China from 1991 to 2008 (Ebert et al. 2009).**

- **Fossil fuel subsidies**

In 2010, China was in fifth place of a fossil-fuel consumption subsidy ranking of the IEA. The country spent a little more than 20 billion dollars on oil, coal and electricity subsidies. The subsidies for coal amounted to 1.6 billion dollars, for oil to 7.6 billion dollars (IEA 2011e). The National Development and Reform Commission (NRDC) raised the gasoline and diesel prices in March 2012 by 6-7%, responding to increasing crude oil prices. The rise is at a slower pace than oil prices though (IEA 2012).

- **Biofuel subsidies**

Ethanol producers receive „consumption tax and value added tax exemption and direct subsidies and low interest loans" (Li, Chan-Halbrendt 2009, page 2). In 2006, subsidies were equal to $73 per tonne of ethanol (Li, Chan-Halbrendt 2009).

- **EV subsidies**

The target of 5 million electric vehicles on the road by 2020 and 500,000 by 2015 receives support from the State Council through subsidies for producers and manufacturers. The annual amount of subsidies for EV production is 2 billion Yuan ($318 million) (China Climate Change Info-Net 2012a).

## 3.3.2 USA

### *3.3.2.1 Road*

As in China, most policies in the USA focus on road transport, as it is the largest source of emissions (see Figure 17).

- **Alternative fuel vehicles (LPG, natural gas, biofuels)**

The Energy Policy Act of 1992 requires the acquisition of AFVs[11] for 75% of the fleet of light-duty vehicles of certain federal agencies. This also includes HEVs[12] and FCVs[13]. There is also a requirement for federal fleets to use dual-fuel vehicles with alternative fuels, except for when there is a lack of availability or a limited budget. Compared to the previous year, federal agencies must increase their use of alternative fuels by 10% per year (DOE 2012d).

Some states have additional incentives, such as High-occupancy toll lanes (HOV) lane exemptions in California (DOE 2012d).

- **Biofuel target**

The USA had a mandate of 9 billion gallons of renewable fuels in 2008. The mandate for 2022 is 36 billion gallons of renewable fuels. For biodiesel the applicable volume for the calendar year 2012 was 1 billion gallons. There is no target for 2022 given in the legislation (110th United States Congress 19/12/2007). The 2008 target in gallons equals 34 billion litres and the 2022 target equals 136 billion litres.

The Energy Independence and Security Act of 2007 did not specify that the biofuel is intended for a specific mode of transport (110th United States Congress 19/12/2007).

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[11] Alternative fuel vehicles

[12] Hybrid electric vehicle

[13] Fuel cell vehicle

- **Congestion Mitigation and Air Quality (CMAQ) Improvement Program**

The CMAQ Improvement Program is one of the major programmes under the Federal-aid Highway Program, which is authorized by the Safe, Accountable, Flexible, Efficient Transportation Equity Act (FHWA 2011). Categories of the programme are amongst others (Pedestrian and Bicycle Information Center 2012):

- Transit
- Shared ride
- Traffic Flow Improvements
- Pedestrian/Bicycle

According to the Pedestrian and Bicycle Information Center, 13% of the CMAQ projects are pedestrian and bicycle projects.

- **Electric vehicles**

The USA has the overall goal of having "one million electric vehicles on the road by 2015" (DOE 2011b, page 2). This also includes plug-in hybrids and extended range electric vehicles (EREVs) (DOE 2011b).

Besides federal tax credits (more in section 3.3.2.5), additional incentives, such as carpool lane access, exemption from sales tax and emissions inspection exist in 28 of the 50 states (Plug In America 2012, DOE 2012d).

- **Fuel economy standards for heavy-duty vehicles**

The National HD[14] programme by the U.S. EPA is the "first-ever program to reduce greenhouse gas (GHG) emissions and improve fuel efficiency of heavy-duty trucks and buses" (EPA 2011, page 1). Starting in 2017, the EPA says that fuel use by affected heavy-duty vehicles will be reduced by 9 to 23% over 2010 baselines, while on average it will be reduced by 15% (EPA 2011).

- **Fuel economy standards for passenger vehicles**

Corporate Average Fuel Economy (CAFE) standards set the maximum fuel consumption for new vehicles sold in the United States. For 2025, an average of 54.5 miles per gallon is the fleet-wide target for all passenger cars (NHTSA 2012). Converting this value to g $CO_2$/km on the NEDC[15], which the CAT uses, corresponds to 112 g $CO_2$/km.

- **High occupancy vehicle and toll lanes and congestion pricing**

On some highways, high-occupancy vehicle lanes (HOV) lanes exist, only allowing vehicles occupied with more than one person to use it. Some of those lanes had been underused and were converted into high-occupancy toll lanes (HOT) lanes, allowing solo drivers to use them after paying a toll. Several projects with toll lanes to prevent

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[14] Heavy Duty

[15] Conversion from CAFE to NEDC (An, Earley 2011): g $CO_2$/km NEDC = g $CO_2$/mile CAFE*0.69

congestion exist and are in a test phase. “Congestion pricing has, where evaluated, helped reduce congestion” (GAO 2012, page 35), so it works rather as an incentive to reduce emissions than as a barrier. In total, there are 41 projects in 12 states, of which 30 projects are completed (Figure 20).

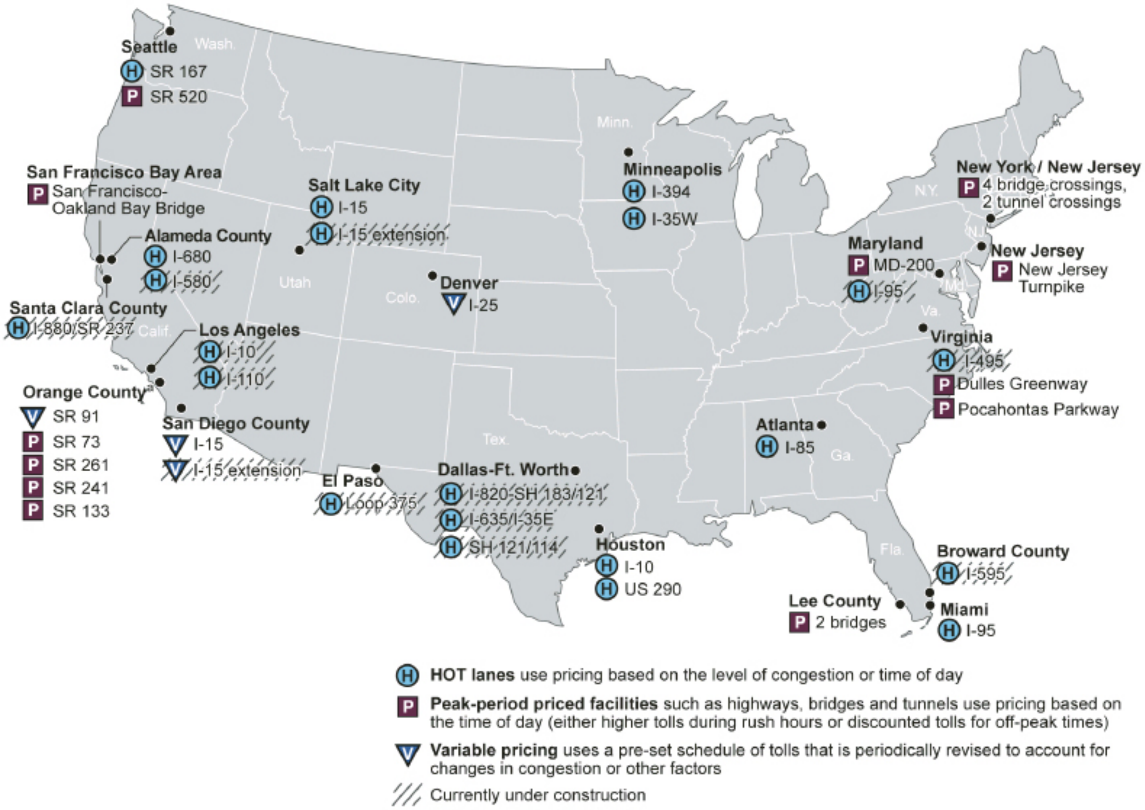

**Figure 20: U.S. congestion pricing projects in operation or under construction (GAO 2012, page 5).**

- **Promotion of non-motorised transport**

The Bicycle & Pedestrian Program by the U.S. Department of Transportation Federal Highway Administration (FHWA) promotes cycling and walking. For the promotion and facilitation of non-motorised transport, each state is required to have a Bicycle and Pedestrian Coordinator in the State Department of Transportation. Projects can be funded from many sources, as long as they are designed for transport and not recreational purposes. The basis in law for this is Section 217 of Title 23 of the U.S. Code (105th Congress 1999).

The FHWA also funds the website of the Pedestrian and Bicycle Information Center (http://www.pedbikeinfo.org/) and other websites[16] to educate citizens about non-motorised transport (FHWA 2012).

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[16] http://www.walkinginfo.org, http://www.bicyclinginfo.org

#### *3.3.2.2 Rail*

- **Transit project grants**

The Federal Transit Administration (FTA) awarded $10.8 billion as funds and grants in 2011 for transit projects all over the United States (FTA 2012). The American Recovery and Reinvestment Act (ARRA) of 2009 provided the following additional funds (111th Congress 17/02/2009):

- $8 billion for high speed rail corridors and intercity passenger rail service
- $1.3 billion for the National Railroad Passenger Corporation (Amtrak) with the restriction that it is not used to subsidize operating losses
- $6.9 billion for public transportation for energy related investments
- $1.5 billion for infrastructure and capital investments

It is not defined in the legal text whether the emphasis of the investments is on $CO_2$ reduction.

- **High-Speed Intercity Rail**

The Federal Railroad Administration (FRA) launched the High-Speed Intercity Passenger Rail Program in 2009 on the framework of The Passenger Rail Investment and Improvement Act of 2008. The goal is to connect population centres that are 100 to 500 miles apart in an efficient way (FRA 2012a). Additional to the $8 billion payment from the ARRA, the 2010 budget proposal of the President requested a high-speed rail grant programme of $1 billion per year (DOT 2010a). The west region receives the largest amount with $2.9 billion of which $2.3 go to California (The White House 2010). A study by the Center for Clean Air Policy from 2006 concluded that diesel trains would most likely be the technology for high-speed trains in the designated corridors (CCAP 2006).

#### *3.3.2.3 Aviation*

As of now, there is no mandate planned for a minimum use of biofuels in the aviation sector. However, the Federal Aviation Administration (FAA) sponsors the Commercial Aviation Alternative Fuels Initiative (CAAFI), which “has sought to enhance energy security and environmental sustainability for aviation by exploring the use of alternative jet fuels” (CAAFI 2012, paragraph 1).

#### *3.3.2.4 Navigation*

There are exhaust emission standards for marine spark-ignition engines and vessels, but they aim at other emissions than $CO_2$ (EPA 2012a, EPA 2012b).

#### *3.3.2.5 Taxes and subsidies*

- **Alternative fuel tax exemption**

Alternative fuels are exempt from federal taxes, depending on the fuel use. Exemptions are: usage “on a farm for farming purposes; in certain intercity and local buses; in a school bus; exclusive use by a nonprofit educational organization; and exclusive use by a state, political subdivision of a state, or the District of Columbia" (DOE 2012d, paragraph 5). While the Energy Policy Act of 1992 defined alternative fuels, the IRS has a different definition. The IRS excludes biofuels from alternative fuels, but has extra tax credits for them (see below) (DOE 2012d).

- **Biofuel grants**

Several financial incentives support biofuel production. Advanced biofuel production grants and loan guarantees exist, supporting development, construction, and retrofitting of bio-refineries for the production of advanced biofuels. There are also improved energy technology loans and advanced energy research project grants, supporting biofuel projects. Fifty per cent of a project can be funded by a maximum amount of $250 million (DOE 2012d).

- **Cellulosic Biofuel Producer Tax Credit**

Because the IRS does not define biofuels as alternative fuels, there is an extra tax credit for biofuels. The tax credit can amount up to $1.01 per gallon (DOE 2012d).

- **Excise tax rate**

The Federal Gasoline Excise Tax Rate is currently at 4.9 $cents per litre (cpl). For diesel it is at 6.4 cpl. On top of that are taxes by the state in which the fuel is bought. For gasoline, New York is the state with the highest taxes with 13.59 cpl. Alaska has the lowest taxes with 2.11 cpl. The median of all states is 6.60 cpl. For diesel, California has the highest taxes (21 cpl). The median is at 12.92 cpl and Alaska again has the lowest with 2.11 cpl (API 2012).

- **Fossil fuel subsidies**

In 2010, subsidies for fossil fuels outside the electricity supply sector were:

- $169 million for coal mining
- $2,165 million for natural gas and petroleum liquids

They accounted for 22.3% of the subsidies outside the electricity supply sector (EIA 2011a).

- **Import Duty for Fuel Ethanol**

The Customs and Border Protection imposes a tariff on imported ethanol intended for fuel use, which is based on the volume of the fuel (DOE 2012d).

- **Tax credit for electric vehicles**

The purchase of an electric vehicle with a capacity of at least 4 kWh qualifies for a credit of $2,500. Every exceeding kWh grants an extra $417 with a maximum credit of $7,500. The credit phases out after 200,000 units are sold (IRS 2009, DOE 2012d).

- **Hydrogen tax credits**

Hydrogen receives certain tax credits for infrastructure (up to $30,000), fuel tax ($0.5 per gallon) and vehicles (up to $4,000) (DOE 2012d).

# 3.4 Transport policy analysis

The following sections provide insight into the calculations for the assessments. The policy packages (sections 2.1.3.2 and 2.2.2) are sorted by segment.

## 3.4.1 Changing activity

### *3.4.1.1 Policy package 49 Strategies to avoid traffic and to move to non-motorised transport*

For an assessment, the amount of vehicle kilometres needs to decrease until 2020 (Table 16).

- **China**

The Chinese living standard is gradually increasing and enables more people to own cars (Yanli et al. 2012). China limits the issue of license plates through lotteries and auctioning, but only in four cities (see section 3.3.1.1).

The ban of motorcycles from city centres did not decrease the number of motorcycles. It continued to increase (Beijing Traffic Management Bureau 2009). Following this policy, Yang states: “the large-scale commercialization of electric two-wheeled vehicles in China cannot be considered a policy success. Indeed, it is a policy accident” (Yang 2010, page 1). Electric two-wheelers are formally non-motorised vehicles (Hu et al. 2010). Because they do not count as motorised vehicles, the increase of electric two-wheelers cannot be integrated in policy package 59, which focuses on electric vehicles.

However, following the development of the vehicle stock of the past (Figure 21), the stock will continue to increase. Huo et al. expect the amount of vehicle kilometres to increase by 7% between 2010 and 2020 (Hu et al. 2010).

The current policies are not strong enough to decrease the amount of vehicle kilometres. As there is an increase rather than a reduction of vehicle kilometres, the policy package receives an assessment of 0.

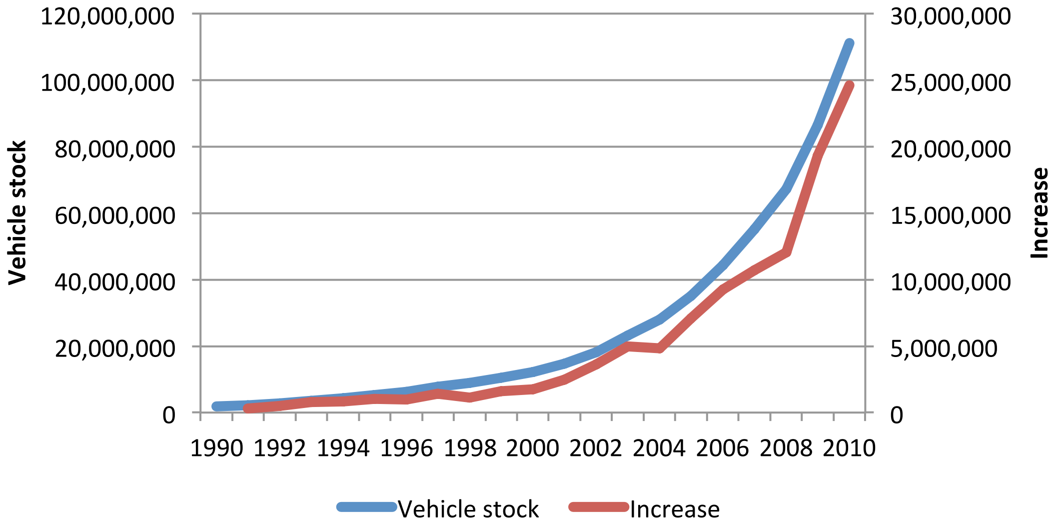

**Figure 21: Passenger vehicle stock development in China between 1990 and 2010 (China statistical yearbook 2011).**

- **USA**

The Bureau of Transportation Statistics (BTS) provides vehicle miles data starting in 1960 (BTS 2012). For the analysis, data from 1990 on was used because this dataset already includes effects of policies presented in section 3.3.2.1.

On average, the total highway vehicle miles increased by 2% per year between 1990 and 2010. Transit vehicle miles, including light, heavy and commuter rail, trolley bus and ferries, increased on average by 3% per year between 1990 and 2010 (BTS 2012).

Continuing with these growth rates until 2020, assuming the policies stay in place, leads to an increase of vehicle miles, which corresponds to an assessment of 0.

#### *3.4.1.2 Policy package 50 Strategies for modal shift to low carbon modes of transport (public transport, freight rail, freight ships)*

A modal shift to public transport increases person kilometres and reduces vehicle kilometres, reducing emissions. For an assessment, public transport passenger capacities need to be increased by at least 5% until 2020 (Table 17).

- **China**

The 12th Five-Year-Plan has the target to increase public transport capacities (see section 3.3.1.1).

The target to have 120,000 km of railways by 2020 relates to an annual increase of 8%, compared to the 66,239 km in 2010. The average growth of passenger coaches was 3% per year between 2000 and 2010 with the smallest growth rate of 2% and largest growth rate of 6%. Continuing with 3% annual growth leads to an increase of 40% by

2020 compared to 2010. Using the same approach for freight wagons leads to an increase of 42% by 2020 compared to 2010 (China statistical yearbook 2011). This increase is larger than the benchmark and will be dealt with in the discussion section.

The passenger capacity of vessels decreased by 3% between 2000 and 2010, while the length of waterways increased from 12,339 km to 12,424 km between 2006 and 2010 (China statistical yearbook 2011, Delegation of the European Union in China 2011). Detailed statistics for buses are not available.

The growth rates lead to an assessment of 4.

- **USA**

The BTS provides detailed vehicle inventory data. Between 2000 and 2010, the stock of public road transport vehicles increased by 15%. In the same period, the amount of Amtrak passenger train cars decreased by 33%, but has increased again since 2007 (BTS 2012). So, the demand for public transport has continuously increased, especially since the beginning of the financial crisis (section 1.2.1.2).

Considering the investments under the ARRA, the Passenger Rail Investment and Improvement Act of 2008, High-Speed Intercity Passenger Rail Program (2009) and grants for transit projects by the FTA (see section 3.3.2.2), it is assumed that the stock of public road transport vehicles will continue to increase with the average growth rate between 2000 and 2010 and the stock of passenger rail cars with the average growth rate between 2007 and 2010. This is a very small period, but if a trend from a longer period was used, the growth would be negative.

In total, this increases the stock of public transport vehicles by 17%. This is not equal to the increase in passenger capacity, which the benchmark requires, because train cars have a higher passenger capacity than buses. Assumptions for average passenger capacities of used public modes of transport are in Table 35.

**Table 35: Passenger capacity assumptions, based on own experience using public transport.**

| **Public mode of transport** | **Assumed average passenger capacity** |
|---|---:|
| Bus/Motor bus/Trolley bus | 60 |
| Light/Heavy/Commuter/Amtrak passenger car | 200 |
| Demand responsive transport | 15 |
| Other[17] | 75 |

Calculating with these values leads to a passenger capacity of 61 million for 2010 and 71 million for 2020. This is an increase of 16%, therefore leading to an assessment of 3.

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[17] Includes: aerial tramway, automated guide way transit, cable car, ferryboat, inclined plane, monorail, and vanpool (BTS 2012).

### *3.4.1.3 Policy package 51 Level of energy and/or $CO_2$ taxes for transport fuels*

For an assessment of 4, the tax must increase by twice the increase of the energy price by 2020. No tax equals a rating of 0 (Table 18).

- **China**

China has no fuel tax (Yan & Crookes 2009), which corresponds to an assessment of 0.

- **USA**

While the federal tax rate has not changed since 1997 (Tax Foundation 2012), the fuel price of gasoline and diesel showed large variations in the past (see Figure 22).

Prices of both fuels more than doubled between 2000 and 2008, while the federal tax rate remained unchanged. Between 2008 and 2009 prices dropped by 50% but now are close to 2008 levels (DOE 2012b).

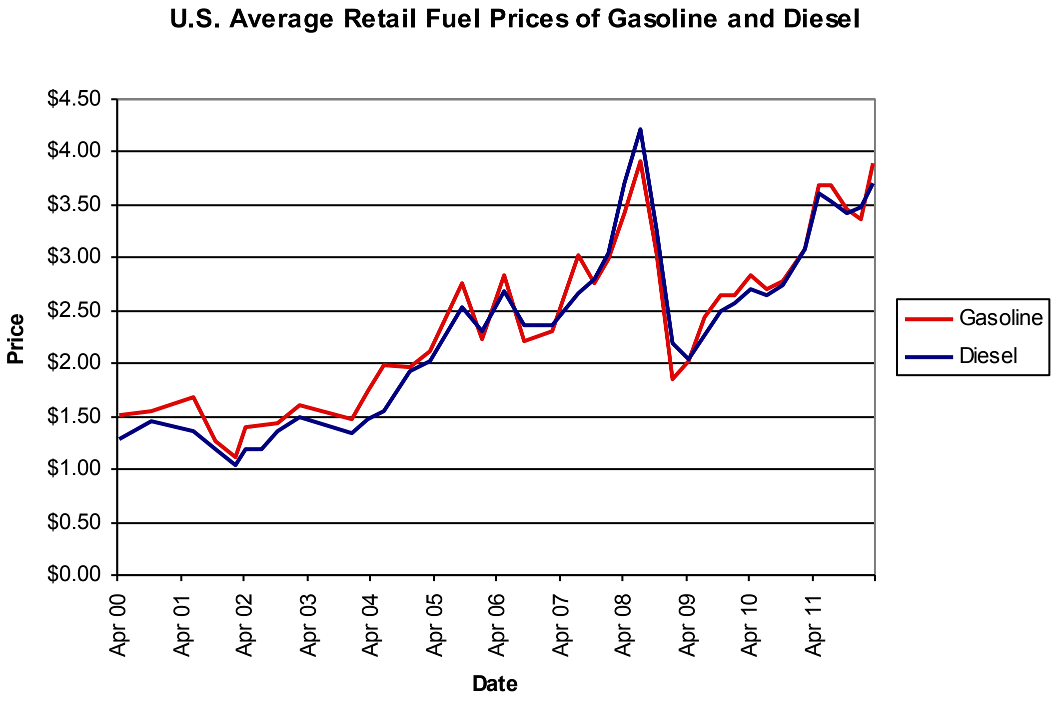

**Figure 22: Price development of gasoline and diesel between 2000 and 2012 in the USA (DOE 2012b).**

In this case, the undefined benchmarks are a problem. An assessment of 0 is awarded, when there is no tax. The assessment of 4 is awarded for a high increase of the tax (Table 18). It is unclear though what the assessment is for a tax that does not remains at the same level?

The tax rate has been unchanged since 1997 and there are no signs of a rise. Overall, U.S. taxes are very low compared to other countries (DOE 2012e). Because the benchmark for assessment 0 is “no tax” and there is an existing tax, the assessment is 1.

#### *3.4.1.4 Policy package 52 Fiscal or other incentives which promote higher fuel use in transport (buy more cars, bigger cars or drive/fly more)*

For this barrier, no fiscal or other incentives for higher fuel use lead to a rating of 0. Strong incentives lead to a rating of -4 (Table 19).

- **China**

China was in 5th place of a fossil-fuel consumption subsidy ranking in 2010. When looking at oil subsidies only ($7.6 billion), China is in 9th place (IEA 2011e). With the price cap, China keeps prices low, while refineries have to pay the market price for crude oil (see section 3.3.1.5).

Again, there is a problem with undefined and unclear benchmarks (see section 2.1.3.2.1). Can the 9th place in the IEA oil subsidies ranking be considered as *strong incentives for higher fuel use*, which justify an assessment of -4 or is a different approach more useful?

Compared to the 2010 GDP, the Chinese oil subsidies account for 0.1%, the total subsidies for oil, natural gas, coal and electricity for 0.4% (IMF 2012c). Figure 23 shows the shares of all countries in the ranking; China has the lowest share of all countries. From that perspective, the subsidies are low. Considering that China had the second highest GDP in 2010 (IMF 2012c), the proportion of oil subsidies to GDP for countries which are not in the top 25 of the IEA ranking might be higher than China's.

Based on this information it was decided to evaluate this policy package in relation to the GDP. Because of the low share of 0.1% for oil subsidies per 2010 GDP, the assessment is -1.

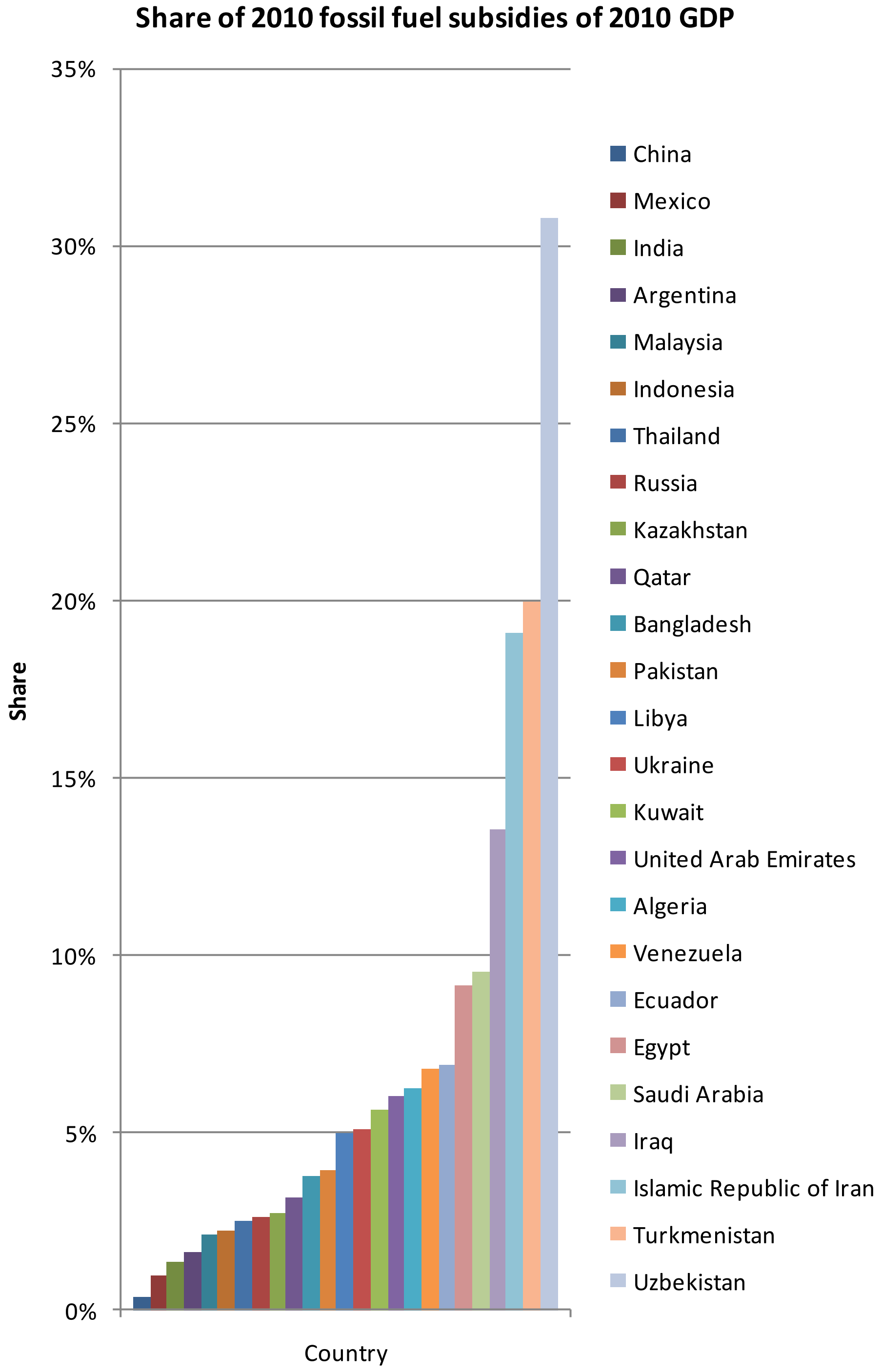

**Figure 23: Ranking of countries with fossil fuel subsidies by share of 2010 subsidies (IEA 2011e) of 2010 GDP (IMF 2012a).**

- **USA**

Fossil fuel subsidies together accounted for $2.3 billion in 2010 (EIA 2011a). The 2010 GDP was $13,088 billion (IMF 2012b), so the subsidies accounted for a share of 0.02%. Following the approach from China, this also results in an assessment of -1.

## 3.4.2 Energy efficiency

There are three policy packages in the energy efficiency segment. They share one MIF (see section 2.1.3.2.2). For all calculations, the take-back effect (sometimes referred to as rebound effect) was not taken into account. The take-back effect describes the phenomenon when increased energy efficiency reduces the price per unit (in this case vehicle kilometres) leading to more use (Blok 2007).

### *3.4.2.1 Policy package 53 Level of incentive to reduce new car emissions per kilometre (fuels only, not electricity)*

Fuel economy standards are in place in several countries. The targets force car manufacturers to reduce fuel consumption of vehicles (An, Earley 2011). For an assessment, the policies must lead to an emission reduction by 2020 compared to 2010 levels.

- **China**

The average emissions of 2009 models were 180 g $CO_2$/km. Detailed statistics with values for other years were not available. The fuel economy standard for 2020 is 116 g $CO_2$/km (An, Earley 2011). This demands an increase in efficiency of 3% per year.

China distinguishes between civil and private vehicles, whereas civil vehicles belong to the government (China statistical yearbook 2011). Together, the values result in the passenger vehicle stock. Between 1990 and 2010, the passenger vehicle stock in China increased by 23% on average per year. Except for three years (1996; 1998 and 2004) the change of vehicle stock was always higher than in the previous year (Figure 21). The minimum growth rate between 1990 and 2010 was 15%.

Now for the Chinese assessment, this is a problem, because the growth rate of the vehicle stock is larger than the increase in energy efficiency. This causes more emissions in 2020 than in 2010, resulting in an assessment of 0. This way, the whole policy is not counted, even though it causes an improvement.

As a solution for this problem, the benchmark and calculation method were changed. Instead of the old approach, the increase in energy efficiency caused by the policy was evaluated against autonomous energy efficiency improvement (AEEI). AEEI was calculated with available U.S. data. Between 1990 and 2010 the fuel economy standard remained unchanged, but the efficiency of the sold passenger vehicles improved with 1% per year (BTS 2012).

Using Equation 7 with 3% improvement per year in energy efficiency results in 8% less emissions compared to AEEI in 2020. This was modelled into the calculations individually.

- **USA**

The current target for 2012 is 30.1 mpg (204 g $CO_2$/km). The 2020 target equals 147 g $CO_2$/km (EPA 2010b). As in China, this demands an increase in efficiency of 3% per year.

On average, the vehicle stock increased by 1% per year in the USA. Since the growth of the vehicle stock is not larger than the improvement in energy efficiency, the approach from the methodology can be used. For the years 2011-2020, the average amount of VKM between 1990 and 2010 was used: 18,487 km (BTS 2012).

In 2007, 7.5 million vehicles were sold. During the financial crisis, sales numbers dropped to 5.4 million in 2009 and increased to 5.5 million in 2010 again. Because of the positive GDP projections (Figure 6) assumptions for vehicle sales were made (Table 36).

**Table 36: Assumptions for the calculations of policy package 53 for the USA.**

| Time period | Annual increase of passenger car sales |
|---|---|
| 2011-2013 | 500,000 |
| 2014-2015 | 250,000 |
| 2016-2020 | 200,000 |

With the assumptions, vehicle sales in 2020 will be 8.6 million per year. This is equivalent to the sales numbers of 1995. For 2009, calculated emissions were 461 Mt $CO_2$. The 2020 value is 368 Mt $CO_2$. This is for an emission reduction of 17% and leads to an assessment of 3.

Because the assessment is sensitive to the sales assumptions, this parameter will be assessed in the sensitivity analysis in how far sales numbers can affect the emission reduction.

#### *3.4.2.2 Policy package 54 Level of incentive to reduce new freight vehicles emissions per kilometre*

Fuel economy standards for heavy-duty vehicles exist in the USA and Japan (DieselNet 2012). For an assessment, incentives must exist that lead to less fuel consumption by heavy-duty vehicles by 2020 (see section 2.1.3.2.2).

- **China**

China has no policy that supports the reduction of $CO_2$ emissions by new freight vehicles. The China standard (see section 3.3.1.1) focuses on non-$CO_2$ emissions. Co-benefits of the China standard on $CO_2$ emissions were not found in literature. The assessment therefore is 0.

- **USA**

The benchmark of the policy package is based on the U.S. fuel economy standards for heavy-duty vehicles (see section 3.3.2.1). The assessment therefore is 4.

#### 3.4.2.3 Policy package 55 Level of energy and/or $CO_2$ taxes for transport fuels

See section 3.4.1.3 above. As mentioned before, this does not result in a double counting of the impact (see section 2.1.3.2.2).

### 3.4.3 Renewables

There are seven policy packages in the renewables section. Six of the seven policy packages are new (see section 2.2.2). As mentioned before, the CAT regards biofuels as carbon neutral.

The target of the USA is an absolute value and has to be converted for the calculations. (Elsayed et al. 2003) give the net calorific value of biodiesel with 37.27 MJ/kg and the density with 0.88 kg/L. This results in 32.8 MJ/L. The net calorific value of ethanol is 21.1 MJ/L (University of Washington 2005).

#### 3.4.3.1 Policy package 56 Bioethanol for road transport

- **China**

In 2009, bioethanol had a share of 2% (45 PJ) of the final motor gasoline consumption in the road transport sector (IEA 2011a). The target of 10 Mt bioethanol (see section 3.3.1.1) equals 288 PJ and accounts for a share of 6% of the final motor gasoline consumption in 2020, following the BAU.

The country wants to extend the E10 mandate from 9 provinces to the whole country by 2020 (Biofuels Digest 2011). To get an ethanol share of 10%, 470 PJ of ethanol is required. Since this policy is more recent, it is used for this thesis instead of the 10 Mt target.

With the net calorific value of ethanol from above, the 470 PJ equal 16.2 Mt. Between this value and the 2008 capacity, there is a gap of 14.3 Mt. Between 2000 and 2008 the capacity increased by only 1.74 Mt (Li, Chan-Halbrendt 2009). Yuanyuan (2012) indicates that a 5 Mt plant could be constructed in Mongolia, but this only closes the gap by 35%, so China needs to increase capacity or import biofuels. Producers of ethanol receive subsidies (see section 3.3.1.5), so there are incentives from the government.

The target of 10% results in an assessment of 1.

- **USA**

The final consumption of bioethanol in road transport in 2008 was 777 PJ (IEA 2011b). This equals 38 billion litres, exceeding the 2008 target of 34 billion litres of biofuels by 4 billion litres (see section 3.3.2.1).

By 2020, the AEO growth rate for E85 predicts a share of 42% for bioethanol in the BAU scenario with IEA data. In the AEO projections, E85 has a share of 1% by 2020, so this value is far too high (533 billion litres). Instead, the IEA growth rate for biofuels (4.2%

per year, Table 31) is used. This leads to a final consumption of 66 billion litres, which equal 1.4 EJ.

For biodiesel, there is only a target for 2012 in the legislation and no target for 2022. It is assumed that the 2012 target stays constant, since no other information is available. Reducing the 2022 target of 136 billion litres of biofuel by the 3.7 billion litres of biodiesel, leads to a gap of 52 billion litres (1.1 EJ) of bioethanol in 2020. Filling the gap will result in an increase of the share of bioethanol from 8% to 15%.

The production capacity for ethanol was 14.2 billion gallons (52.6 billion litres) in January 2011. The capacity is increasing, so the given financial incentives for biofuel production (see section 3.3.2.5) are sufficient for positive development (EIA 2011).

The number of vehicles that use E85 increased on average by 20% per year between 2005 and 2010. E85-AFVs represent the largest share of AFVs. In 2010 the share was 66%, while in 2005 it was 42%. Figure 24 shows the historical development (DOE 2012a). Increasing numbers of vehicles will also lead to increasing demand. There are requirements for governmental fleets to have a certain share of AFVs (see section 3.3.2.1). In 2012 there were 2,540 E85 fuelling stations in the country, compared to 58 in 2000 (DOE 2012c).

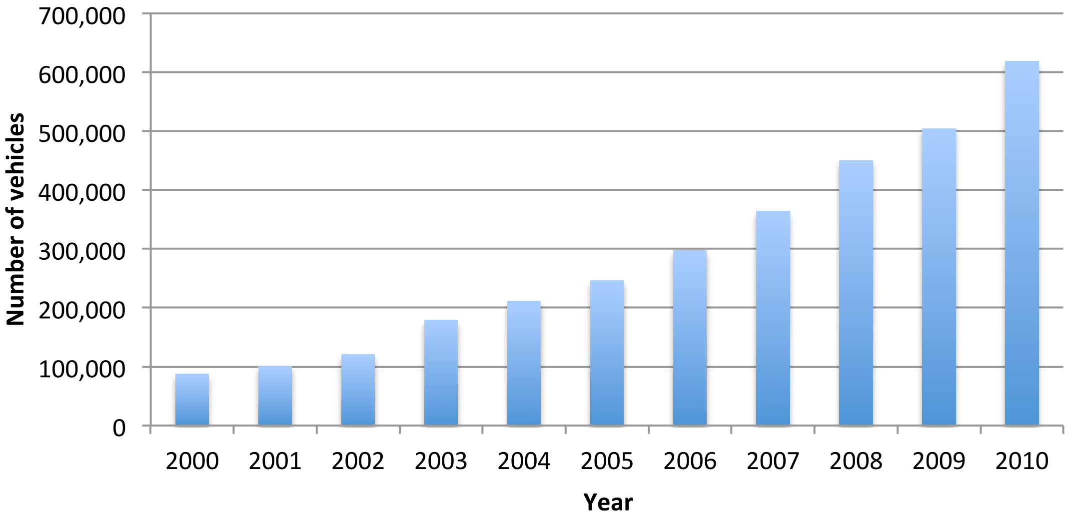

**Figure 24: E85 vehicle stock development in the USA between 2000 and 2010 (DOE 2012a).**

The data shows that there is a positive development of vehicles and infrastructure. The share of 15% leads to an assessment of 2.

### *3.4.3.2 Policy package 79 Biodiesel for road transport*

- **China**

In 2009, biodiesel had a share of 0.4% (6 PJ) of the final diesel consumption in the road transport sector (IEA 2011a). The target of 2 Mt biodiesel (see section 3.3.1.1) equals 74

PJ and accounts for a share of 2% of the final diesel consumption in 2020. This is because of the large growth rate of diesel. Due to this low share, the policy package receives an assessment of 0.

- **USA**

The target for 2012 is 3.7 billion litres of biodiesel (see section 3.3.2.1). Production capacity is currently 7.8 billion litres per year. Until July 2012, 2 billion litres were produced (EIA 2012c). Consumption data is not available for 2012, but the production is in line with the target.

However, following the same approach as for bioethanol, the 3.7 billion litres of biodiesel only represent a share of 3% of the final diesel consumption from road transport in 2012 and also in 2020. This leads to an assessment of 0.

#### *3.4.3.3 Policy package 74 Bio jet fuel*

There have only been tests with bio jet fuel until today (see section 3.3.1.3). China is the only country so far with a target for 2020, which is also the benchmark of this policy package (Yan 2012).

- **China**

The Civil Aviation Administration of China expects the consumption of jet fuel to increase to 40 million tonnes by 2020, so the biofuel target of 12 million tonnes represents a share of 30% (Yan 2012).

There is a difference between the projections of the Civil Aviation Administration and the BAU scenario. The BAU leads to a total jet fuel consumption of 18.3 million tonnes by 2020, when calculating with 43.7 MJ/kg for jet fuel (Blok 2007). By 2014, the planned capacity of bio jet fuel is 60,000 tonnes per year (Yan 2012), leaving a gap of 11.94 Mt to the numbers of the Civil Aviation Administration and 5.43 Mt to the IEA data. This gap needs to be closed through imports or increased capacity.

Achieving this target would give China a leading role worldwide in the use of bio jet fuel. The assessment is 4, since the benchmark is based on this target.

- **USA**

No policy and target for the use of bio jet fuel currently exists. The assessment is 0.

#### *3.4.3.4 Policy package 75 Biodiesel for railways*

Tests with biodiesel for railways have been successful in the past, so there is a potential for biodiesel use in rail transport (see section 2.2.2.4).

- **China**

There are no biodiesel policies and targets for locomotives in China. This corresponds to an assessment of 0.

- **USA**

The Energy Independence and Security Act of 2007 did not specify that the biodiesel target is intended for a certain mode of transport (110th United States Congress 19/12/2007).

However, there is a conflict with engine manufacturers, who “appear to be less willing to include use of higher blends” (UIC 2007, page 49) than B5 due to insurance and maintenance reasons. The high-speed trains of the FRA will run with diesel (CCAP 2006). However, the FRA has not announced that they plan to use biodiesel. There is one commuter train in New Mexico, run by a private company, that uses B20 (UIC 2007), but it is not known whether the new high speed trains will use engines from the same manufacturer.

This leads to an assessment of 0.

#### *3.4.3.5 Policy package 76 Biofuel for navigation*

Boat engine manufacturer Mercury Marine says that E10 is acceptable for fuel use in the marine industry with their engines, but E15 is not (Mercury Marine 2011).

- **China**

There are no policies and targets for the use of biofuel in ships. The assessment therefore is 0.

- **USA**

It is possible that E10, is bought at regular gas stations and used for boat engines, but it might be accounted for road transport because of the location of the purchase. Since there are no special alternative engines, equivalent to E85-AFVs, or other incentives, the assessment is 0.

#### *3.4.3.6 Policy package 78 Biodiesel for navigation*

No policies or plans for the use of biodiesel in ships were found for both countries. This corresponds to an assessment of 0 for both countries.

### 3.4.4 Low carbon

There are four policy packages in the low carbon segment, each of which has its own MIF. Two of the policy packages are in section 2.1.3.2.4. The other two are new (see section 2.2.2).

The USA has policies for AFVs (sections 3.3.2.1 and 3.3.2.5), including EVs, FCVs, NGVs and LPG vehicles. Data for AFVs was available until 2010 (DOE 2012a), hybrid sales until 2012 (BTS 2012).

In this segment policies exist which do not receive attention in the CAT model. There is no policy package for hydrogen, which is also not listed as an energy carrier in the IEA balances (IEA 2011a).

There were only 421 FCVs in use in the USA in 2010 (DOE 2012a), while 230,444,440 light-duty vehicles were registered in the same year (BTS 2012). The number of gas stations that sell hydrogen currently is 54, of which 23 are in California (DOE 2012c).

Because of this small share it was decided to ignore hydrogen in the analysis.

#### *3.4.4.1 Policy package 58 Support for fuel switch from motor gasoline and diesel to natural gas*

Originally this policy package covered low carbon technologies, including CNG, LNG and LPG. With the introduction of LPG as an energy carrier, the focus is on natural gas (Table 24).

- **China**

Figure 21 (page 78) shows the passenger vehicle development in China between 1990 and 2010. The number of vehicles increased from 2 to 111 million, of which 91% are small cars (China statistical yearbook 2011). The average annual growth rate is 23%. The minimum growth rate in the whole period is 15%. Using the approach from policy package 53 (page 83), leads to 439 million vehicles by 2020.

In 2012, there were 1.1 million NGVs (NGV Global 2012) representing a share of 0.8% of all passenger vehicles. Just between April 2011 and May 2012 the number of NGVs increased by 378,000 (NGV Global 2012). That is a growth rate of 52%.

Assuming the retrofitting programmes (see section 3.3.1.1) expand to private vehicles, the target of 3 million vehicles can be achieved with an annual growth rate of 14% for NGVs. However, the 3 million vehicles will represent a share of 0.7% in 2020, leading to an assessment of 0.

- **USA**

The USA has fuel tax exemptions for natural gas (see section 3.3.2.5). Certain fleets are required to acquire AFVs, which include NGVs, and NGVs also have some privileges for certain highway lanes (see section 3.3.2.1).

Between 1992 and 2009, the total number of NGVs increased from 23,281 to 117,446 (DOE 2012a). Figure 25 shows the development. There are more CNG than LNG vehicles on the road.

Until 2002, the stock of CNG powered vehicles increased by 18% per year on average. Until 2009, the number of vehicles decreased by 6,569 cars. The average decrease per year was 1%.

The LNG vehicle stock had large growth rates in the past (30% per year on average), but is small. In 1992, there were 90 registered vehicles. Until 2009, the stock increased to 3,176 vehicles.

The number of gas stations, selling LNG and CNG increases. In 2012, there were 1,085 selling CNG and 147 selling LNG. Between 1990 and 2012, 1,027 gas stations for NG products opened or existing gas stations added new filling pumps (DOE 2012c).

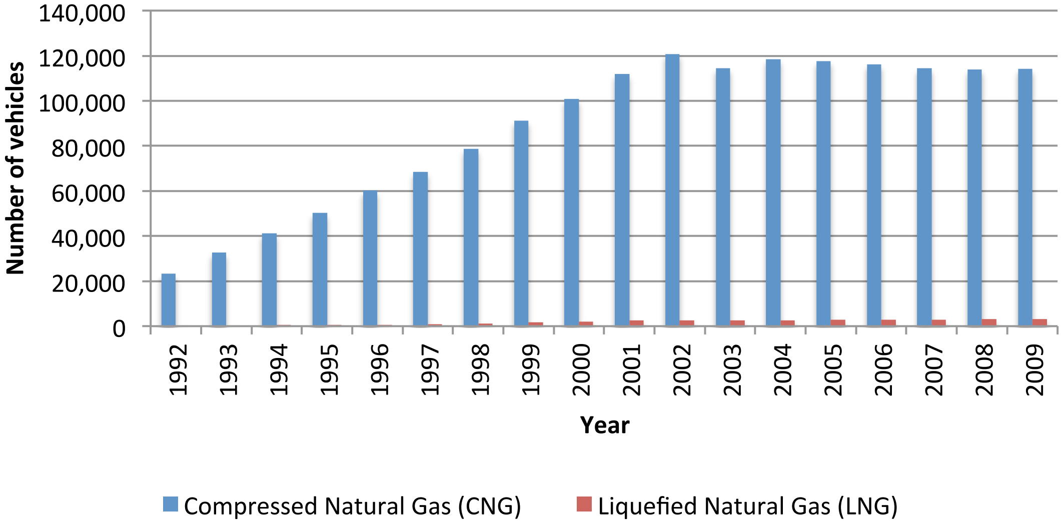

**Figure 25: NGV vehicle stock in the USA between 1992 and 2009 (DOE 2012a).**

The vehicle acquisition and fuel use requirements from the Energy Policy Act of 1992 does not have a big impact on NGV sales (DOE 2011a). The DOE states that gas station and NGV availability are limiting factors for the development (DOE 2012f).

**Table 37: AFV acquisitions by regulated fleets (by fuel type) (DOE 2011a).**

| Model Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|
| Hydrogen | 3 | 7 | 2 | 1 | 0 | 3 |
| CNG | 682 | 563 | 713 | 354 | 247 | 382 |
| E85 | 9,294 | 12,100 | 14,194 | 20,611 | 10,424 | 9,569 |
| LNG | 1 | 0 | 4 | 5 | 0 | 0 |
| Propane | 150 | 17 | 7 | 10 | 19 | 5 |
| Methanol (M85) | 0 | 0 | 0 | 0 | 0 | 149 |
| Electric | 92 | 151 | 220 | 175 | 104 | 268 |
| Total | 10,222 | 12,838 | 15,140 | 21,156 | 10,794 | 10,376 |

With the given incentives, laws and regulations, the development in the last years was negative. The 2010 share was below 0.1%. Continuing with the negative trend will lead to a smaller share. This results in an assessment of 0.

#### *3.4.4.2 Policy package 80 Support for fuel switch from motor gasoline and diesel to LPG*

- **China**

LPG was introduced in 1999 and distributed to some model areas, where vehicles, mainly taxis, were retrofitted (see section 3.3.1.1). Until 2004, the number of LPG vehicles increased to 114,000. This represented a share of 0.4% of the vehicle stock of 28 million vehicles (China statistical yearbook 2011). In 2006, “the government removed the regulation for the new taxis to be quipped with either dedicated or bi-fuel LPG system” (Leung 2011, page 3722), following a drop of vehicle stock to less than 80,000 vehicles (Leung 2011).

Leung (2011) points out that the price advantage of LPG over motor gasoline is not high enough to increase the vehicle stock (see section 3.3.1.5). There is also a lack of fuelling stations for LPG, which does not give incentives to consumers to convert vehicles or buy LPG cars.

Continuing with the negative growth of LPG vehicles, because there is a lack of policy support for this technology leads to a smaller share than the 0.4% in 2004, resulting in an assessment of 0.

- **USA**

LPG has the same support as natural gas, as it falls under the term *alternative fuels* (see sections 3.3.2.1 & 3.3.2.5).

Figure 26 shows the development of LPG vehicles in the USA between 1995 and 2009. Data for earlier years was not available. Between 1995 and 2003, the number of LPG vehicles increased by 1% per year on average, reaching 190,369 vehicles in 2003. From then on, the vehicle stock decreased on average by 4% to 147,030 vehicles in 2009. Table 37 also shows that the acquisition of LPG vehicles by regulated fleets is decreasing.

While the number of vehicles is decreasing, the number of gas stations that sell LPG has increased. In 2012, there were 2,675 gas stations selling LPG, of which with 481 the most were in Texas (DOE 2012c). The DOE lists the same disadvantages as for natural gas, but emphasizes that 90% of the consumed LPG comes from the United States. LPG is also cheaper than motor gasoline and diesel (DOE 2012g).

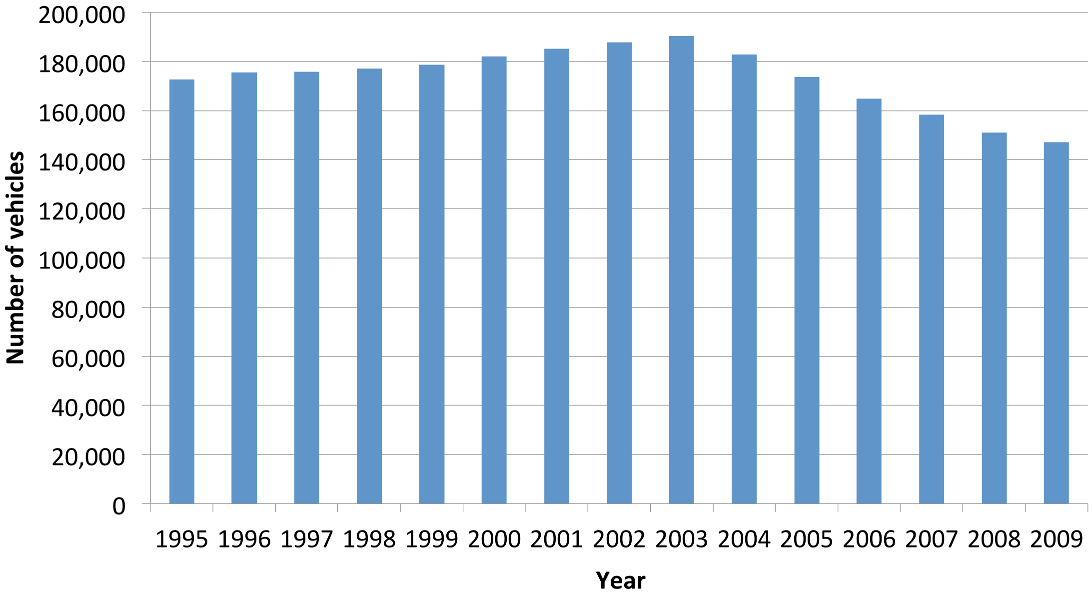

**Figure 26: LPG vehicle stock in the USA between 1995 and 2009 (DOE 2012a).**

The negative development since 2003 shows that the given incentives, laws and regulations are not effective enough to lead to a larger share of LPG vehicles by 2020. Also the increasing infrastructure does not increase sales. The 2010 share was below 0.1% and with the negative development it will be even smaller by 2020. This leads to an assessment of 0.

#### *3.4.4.3 Policy package 59 Incentives for electric mobility*

Electric mobility has the opportunity to be $CO_2$ free, when the electricity comes from renewable sources. When it comes from fossil sources, it might cause more emissions than combustion of motor gasoline or diesel. Section 3.7 includes an assessment of the shifted $CO_2$. Ireland has the most ambitious target to have a share of 10% of EVs by 2020 (Table 25).

- **China**

The target of 5 million electric vehicles on the road by 2020 and 500,000 by 2015 receives (see section 3.3.1.1) support from the government through subsidies for producers and manufacturers (see section 3.3.1.5) and also accelerated establishment of charging stations (China Climate Change Info-Net 2012b).

In the first quarter of 2012, car sales of EVs were small with 1,830. Pike Research expects that by 2017 there will be only around 152,000 EVs on the road, as the Chinese people who could afford an EV tend to buy other luxury cars (Motavalli 2012). Sales for 2011 barely exceeded 8,000 vehicles. They were mainly to government fleets (Electric cars in China 2012).

The target of 5 million vehicles would represent a share of 1.1% of the fleet with the approach from policy package 58, but with the given numbers it seems more realistic that there will be less EVs than NGVs in 2020 and the share will be below 0.5%, which would equal 2 million EVs and an assessment of 0.

- **USA**

By 2015, the USA has the target of one million EVs on the road. Buyers receive tax incentives and in some areas road privileges (see sections 3.3.2.1 & 3.3.2.5)

Data for electric vehicles in use is available until 2010 and is in Figure 27 (DOE 2012a). Sales numbers for plug-in hybrids are available at http://www.hybridcars.com. Between 2010 and today, 35,686 plug-in hybrids were sold in the United States, of which the majority were the Chevrolet Volt (16,814 units) and Nissan LEAF (12,841 units). Until June 2012, almost as many vehicles as in the year 2011 were already sold (Hybrid Cars 2011, Hybrid Cars 2012a, Hybrid Cars 2012b).

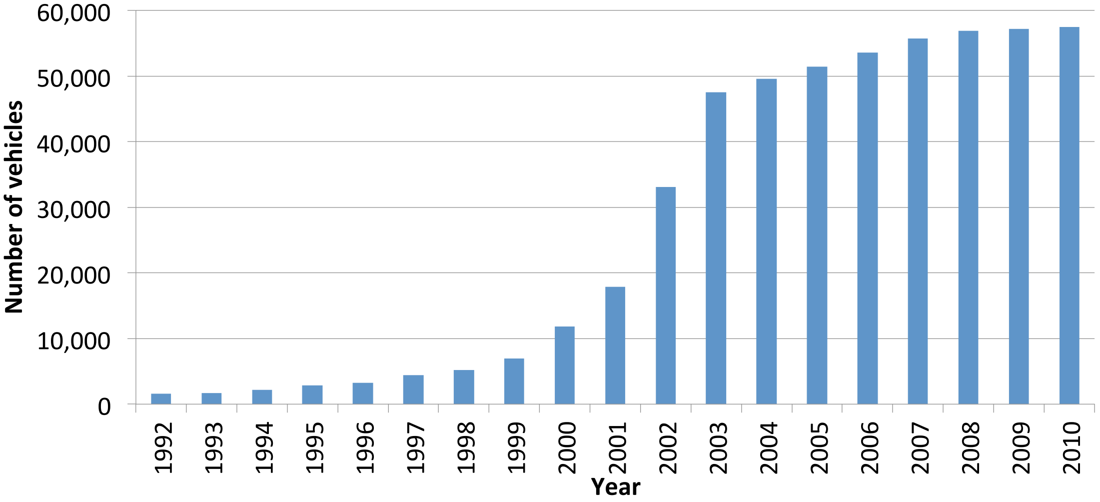

**Figure 27: EV development in the USA between 1992 and 2010, excluding PHEVs (DOE 2012a).**

In 1995, there were only eight fuel stations for electric vehicles. Development started accelerating after 2010 when it increased from 606 stations to 5,654 today (Figure 28), of which 20% are in California. The numbers exclude private garages (DOE 2012c). Government fleets use more NGVs than EVs but compared to E85 vehicles the numbers are small (see Table 37).

With the recent EV development (Figure 27), it is very unrealistic that the 2015 target will be met. Sales are not big enough to fill the gap of over 400,000 vehicles (Figure 27). The total share of EVs (0.4% in 2010) will also decrease, as the total vehicle stock will increase by more than 400,000 vehicles with the assumptions from policy package 53. This leads to an assessment of 0.

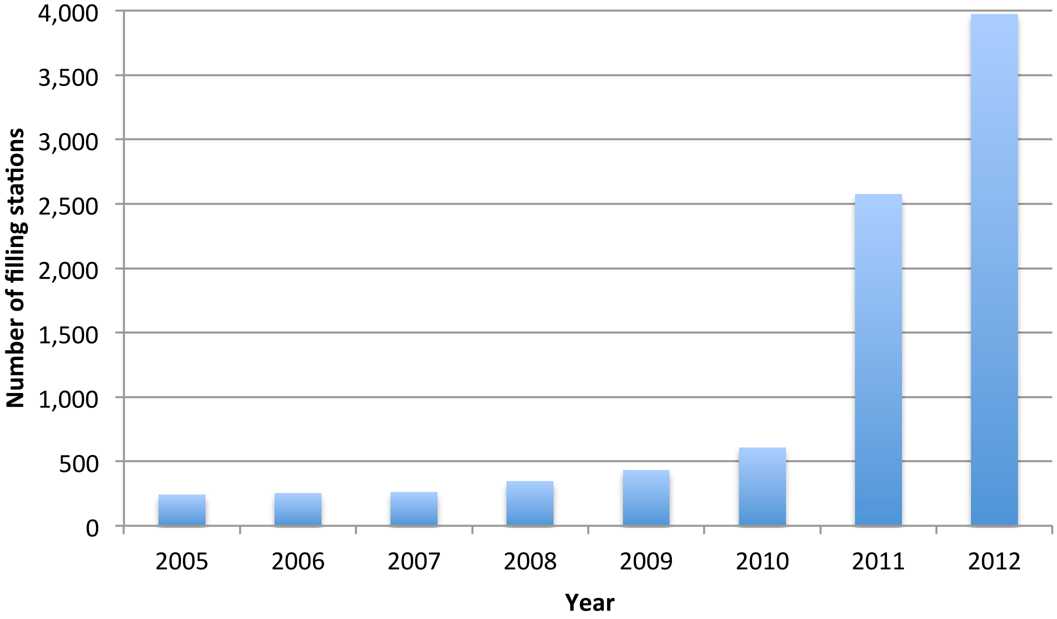

**Figure 28: Development of filling stations for EVs in the USA between 2005 and 2012 (excluding home stations) (DOE 2012c).**

### *3.4.4.4 Policy package 77 Electrification of railways*

According to the IEA balances, the following countries had an electricity share of 100% in the rail sector in 2009 (IEA 2011a, IEA 2011b): Algeria, Argentina, Cuba, Morocco, Nepal, Philippines, Singapore, Slovak Republic and Venezuela.

However, this share is not achievable for all countries, especially those with a large railway infrastructure. But still, progress can be made and some countries even have policies for electrification (see section 2.2.2.4).

- **China**

As noted in section 1.2.1.1, the amount of electrified railways in China increased from 14,864 km (25%) in 2000 to 32,717 km (49%) in 2010, while the total length of railways increased from 58,656 to 66,239 km. This represents an annual increase of 2.4% of electrified railways (China statistical yearbook 2011).

China is targeting an increase in railway length to 120,000 km by 2020 and to further develop the high-speed railways (see section 3.3.1.2). Assuming, the target will be met, this represents an average annual increase of 6% of the railway length. The newest Chinese high-speed train is the CRH380AL and uses electricity for operation (China Daily 2010).

With an annual increase of 2.4% of electrified railways, by 2020 the length will be 41,474 km and represent 35% of the total railway length. Compared to 2010, the share will decrease by 14%.

Considering the growth of the past, the targets and the 2.4% growth of electrified railways are considered achievable and lead to an assessment of 4.

- **USA**

There are no statistics about electrified railway tracks in the USA. However, as there is information that the new high-speed trains will use diesel technology (CCAP 2006), it is not likely that existing tracks will be electrified. In a report about the Next Generation High-Speed Rail Technology Program, the FRA includes the following element: "High-Speed Non-Electric Locomotive - Demonstration of a locomotive to achieve the speed and acceleration capability of electric trains without the expensive infrastructure of railroad electrification" (FRA 2012b, paragraph 5).

This leads to an assessment of 0.

### 3.4.5 Overview of all assessments

Only few policies were introduced in China after the announcement of the 12th Five-Year Plan. These include the fuel standard for new car emissions and the bio jet fuel target. In the USA, only the fuel economy standards for passenger and heavy-duty vehicles were announced after mid-2011.

Policy packages with policies from before mid-2011 have the values of their assessments in brackets (Table 38). The values play a role for the additional reduction potential. Because the calculations for the biofuel targets lead to a different result than the BAU for both countries, the assessments are also included in the policy analysis.

**Table 38: Overview of all assessments.**

| # | Policy package | Assessment China | Assessment USA |
|---|---|---|---|
| **Changing activity segment** | | | |
| 49 | Strategies to avoid traffic and to move to non-motorised transport | (0) | (0) |
| 50 | Strategies for modal shift to low carbon modes of transport | (4) | (3) |
| 51 | Level of energy and/or $CO_2$ taxes for transport fuels | (0) | (1) |
| 52 | Fiscal or other incentives which promote higher fuel use in transport | (-1) | (-1) |
| **Energy efficiency segment** | | | |
| 53 | Level of incentive to reduce new car emissions per kilometre | * | 3 |
| 54 | Level of incentive to reduce new freight vehicles emissions per kilometre | (0) | 4 |
| 55 | Level of energy and/or $CO_2$ taxes for transport fuels | (0) | (1) |

| | | | |
|---|---|---|---|
| **Renewables segment** | | | |
| 56 | Bioethanol for road transport | 1 | 2 |
| 79 | Biodiesel for road transport | (0) | (0) |
| 74 | Bio jet fuel | 4 | (0) |
| 75 | Biodiesel for railways | (0) | (0) |
| 76 | Biofuel for navigation | (0) | (0) |
| 78 | Biodiesel for navigation | (0) | (0) |
| **Low carbon segment** | | | |
| 58 | Support for fuel switch from motor gasoline and diesel to natural gas | (0) | (0) |
| 80 | Support for fuel switch from motor gasoline and diesel to LPG | (0) | (0) |
| 59 | Incentives for electric mobility | (0) | (0) |
| 77 | Electrification of railways | (4) | (0) |

* 8% reduction in 2020 over BAU; modelled individually

### 3.4.6 Transport policy impact on $CO_2$ emissions

The next paragraphs present the policy impact the model calculated with the assessments without brackets from Table 38. The graphs only include the energy carriers, of which the emissions are reduced.

#### *3.4.6.1 China*

The policies for fuel economy and renewable fuels in road transport and aviation lead to an emission reduction of 68 Mt $CO_2$ in 2020 (Figure 29). This is a reduction of 9% below the BAU scenario.

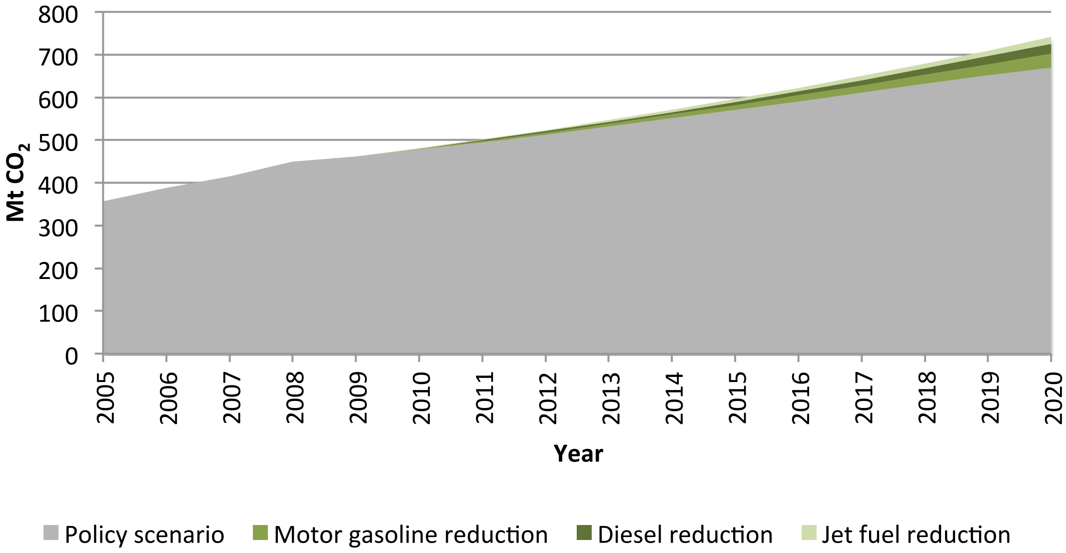

**Figure 29: Policy impact on $CO_2$ emissions - China.**

The motor gasoline emission reduction is 30 Mt $CO_2$ and is caused by an increasing share of biogasoline and the fuel economy standard. The diesel emission reduction is 21 Mt $CO_2$, caused by the fuel economy standard. The jet fuel reduction due to use of bio jet fuel is 17 Mt $CO_2$.

The reduction target of China under the Copenhagen Accord is 40-45% below 2005 levels per unit of GDP (see section 1.1 and Figure 4). Using the 2020 emissions of the BAU results in a reduction of 47% below 2005 levels per unit of GDP. The policy scenario emissions result in 52% below 2005 levels.

Christian Ellermann from Ecofys China said in a phone interview that Chinese targets are usually set low so they can be exceeded (Christian Ellermann 5/04/2012).

### *3.4.6.2 USA*

The policies lead to an emission reduction of 268 Mt $CO_2$ in 2020 (Figure 30). This is a reduction of 16% below the BAU scenario.

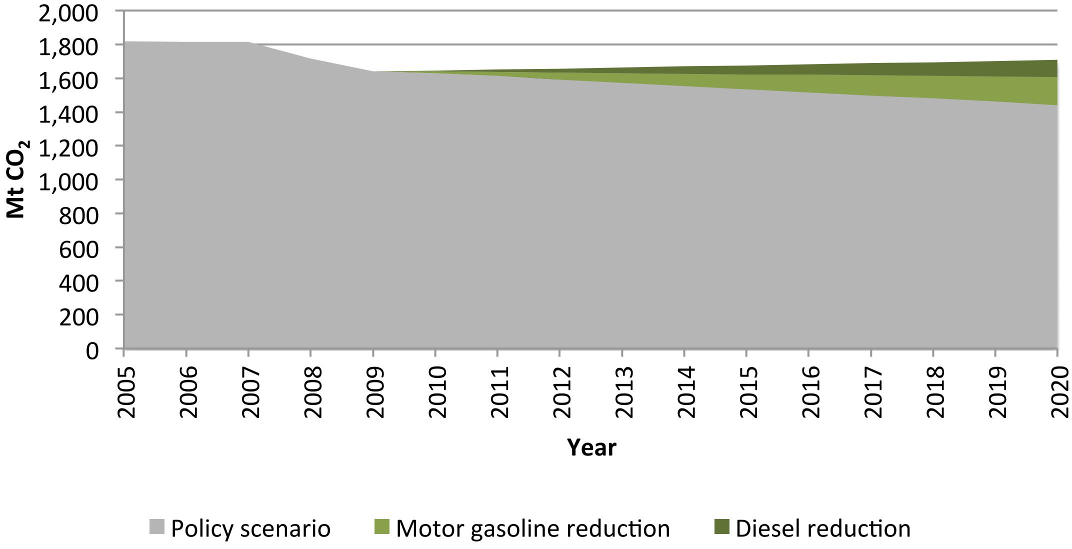

**Figure 30: Policy impact on $CO_2$ emissions - USA.**

The diesel emission reduction is 101 Mt $CO_2$. This is 23% compared to the BAU. The motor gasoline emission reduction is 167 Mt $CO_2$, 15% compared to the BAU.

The decrease in fuel consumption of passenger and heavy-duty vehicles accounts for 82% of the reduction and the increase in biofuels for 17%.

The $CO_2$ emission reduction below 2005 levels is 21%. This creates a little buffer for other sectors, as the pledge is to reduce emissions by 17% below 2005 levels by 2020 (see section 1.1).

## 3.5 Comparison of strategies

Both countries have similarities in their strategies. Rail transport and biofuels play a big role, as well as AFVs. The following paragraphs compare the policies per segment.

### 3.5.1 Changing activity segment

Both countries have actions to avoid traffic and promote non-motorised transport but apply most of them only at a local level and not countrywide. China often tests policies locally before applying them countrywide however (Earley et al. 2011).

China avoids traffic by limiting the issue of license plates in four cities (see section 3.3.1.1). In future construction of highway and transport infrastructure, China can learn from other countries' planning mistakes and avoid traffic jams. In combination, an effective public transport system and the expansion of existing policies have potential to reduce traffic and vehicle stock growth.

The USA has special lanes for certain vehicles, but these only exist on several highways (Figure 20). Expanding this policy to more metropolitan areas can boost sales of AFVs and reduce trips of vehicles with only one passenger.

The promotion of non-motorised transport needs more attention in both countries. Requiring at least one coordinator per state and project funding through the CMAQ Program in the USA is a good start (see section 3.3.2.1). China does not have any policies promoting non-motorised transport. However, the promotion of non-motorised transport is difficult for China because increasing welfare increases the demand for own motorised vehicles (Yanli et al. 2012).

Large investments in rail transportation and an increase of capacities are on the agenda for both countries (see sections 3.3.1.2 and 3.3.2.2). That is a step in the right direction, but the USA needs to choose electric instead of diesel locomotives for their high-speed railways, which use clean electricity. Political issues that block development also need to be overcome (Laing 2011).

Taxes and prices for fuels are a lot lower than in other countries and both countries also subsidize fossil fuel use (see sections 3.3.1.5 and 3.3.2.5). This needs to change, as it sends a signal in the wrong direction.

### 3.5.2 Energy efficiency segment

A standard for passenger vehicle fuel economy exists in both countries. China has a more stringent target with 116 g $CO_2$/km by 2020. The proposed U.S. target for 2020 is 147 g $CO_2$/km. The target for 2025 is just a little lower than China's 2020 target with 112 g $CO_2$/km. Both countries could adopt the EU target of 95 g $CO_2$/km.

The USA has a standard for heavy-duty vehicle $CO_2$ emissions that will lead to an average reduction of 15%, while China only adopted the Euro standard which focuses on other emissions than $CO_2$ (see sections 3.3.1.1 and 3.3.2.1). By adopting the U.S. fuel economy standards, China can reduce $CO_2$ emissions from heavy-duty transport.

### 3.5.3 Renewables segment

A quota target exists in both countries. While in the USA, the quota would lead to a share of 15% in the road transport sector; the numbers in China do not match with the E10 target planned countrywide by 2020 but the latter target is younger, so the quota target might be out-dated. Information about a replacement of the quota target was not found. In the USA the quota is not limited to road transportation only, but no signs were found for the use of biofuels in other modes of transport than road transport (see sections 3.3.1.1 and 3.3.2.1).

China is the only country with a target for bio jet fuel (see section 3.3.1.3).

Renewable fuels have a large reduction potential as the CAT regards them as $CO_2$ neutral (Höhne et al. 2011a). Engine manufacturers must design their engines that the use of high renewable fuel contents does not cause malfunction and warranty problems. At the moment this is not always the case (see sections 3.4.3.4 and 3.4.3.5).

### 3.5.4 Low carbon segment

The CAT has three policy packages for road transport and low carbon energy carriers. One is for electricity, one for natural gas vehicles and one for. Both countries focus more on EVs than on the other technologies (see sections 3.3.1.1 and 3.3.2.1).

China uses natural gas as fuel for public transport vehicles and taxis in some cities. In the USA, infrastructure development grows at a slower pace than for electric vehicles.

For EVs both countries provide incentives via subsidies. Infrastructure for electric vehicles in the USA is growing at a fast pace. Vehicle sales are not. Excluding private homes, between 2010 and 2012, 3,365 new loading stations were built, compared to 460 other alternative fuel station pumps. For China, such information was not available.

In regards to railway electrification, China does a lot more than the USA, which focuses on diesel trains for their high-speed railways. 49% of China’s tracks were electrified by 2010 (see sections 3.3.1.2 and 3.3.2.2).

## 3.6 Policy gaps

Both countries have some gaps in common with each other but also have country specific policy gaps (see Table 38). To fill gaps in the low carbon segment, the focus is on EVs, because with electricity from renewable sources, this technology emits less $CO_2$ than NGVs and LPG vehicles and both countries have targets for this technology. By only focusing on one technology instead of three, it is assumed that there will be better success. Also, most buildings already have access to electricity, which enables the charging of batteries at home without depending on gas stations. Section 3.7 quantifies the emissions of EVs if the electricity comes from fossil fuels.

### 3.6.1 Country specific gaps: China

China has one country specific gap; the others are shared with the USA. There is no standard for heavy-duty vehicle $CO_2$ emissions. The fuel economy standards from the United States, which are the most ambitious worldwide, can be adopted. A programme that gives a refund for trading in an old and inefficient heavy-duty vehicle for a new one can accelerate the impact.

### 3.6.2 Country specific gaps: USA

The USA has two country specific gaps: biofuel for aviation and electrification of railways.

- **Biofuel for aviation**

USA can adopt China's target. China is the only country with a target at the moment.

- **Electrification of railways**

Diesel will most likely be the fuel for the high-speed trains (CCAP 2006). In Japan, the Shinkansen high-speed train uses electricity (Smith 2003), as well as the French TGV (Railway Technology 2012b) and the German ICE (Railway Technology 2012a). A larger share of tracks for electric locomotives will reduce emissions, if electricity comes from clean sources.

### 3.6.3 Shared gaps

The countries have six gaps in common, which are presented in the following paragraphs.

- **Strategies to avoid traffic and to move to non-motorised transport**

Existing actions, limited to certain cities or areas, should be applied countrywide. Non-motorised transport must be promoted more heavily.

- **Fuel taxation**

Higher gasoline prices can also affect rail and navigation, leading to replacement of old and inefficient engines. Both countries had fuel prices in 2009 that could increase by 100% and would still be cheaper than gasoline and diesel in other countries (Ebert et al. 2009).

With the excise tax rate being very low in the U.S. (see section 3.3.2.5, page 76), doubling will not affect the fuel price as much as changes in crude oil prices.

China must remove the cap on the fuel price and install a fuel tax.

- **Fiscal incentives for higher fuel use**

As a share of the 2010 GDP, the 2010 subsidies for fossil fuels outside the electricity supply sector of both countries are low. Still, there is room for improvement and subsidies can be cut.

- **More incentives for electric vehicles**

The London Congestion Charging makes exemptions for greener vehicles that emit less than 100 g $CO_2$/km and meet the Euro 5 standard. Electric and plug-in hybrid vehicles also receive a 100% discount (TfL 2012). This incentive is to combine with other incentives in order to avoid traffic. This is already done in some states in the US, giving access to carpool lanes (Plug In America 2012), but there must be incentives in more regions.

There are at least 14 OECD countries with a feebate system installed. A feebate adds a fee on a high-emission vehicle and gives a rebate to a low-emission vehicle. For instance, since 2007, with the bonus-malus programme in France, vehicles with emissions of less than 130 g $CO_2$/km receive a reduction of up to 5,000€ and vehicles with emissions of more than 160 g $CO_2$/km receive an extra fee of up to 2,600€. In 2008, the average emissions of sold vehicles dropped by 7 g $CO_2$/km (Greene 2011).

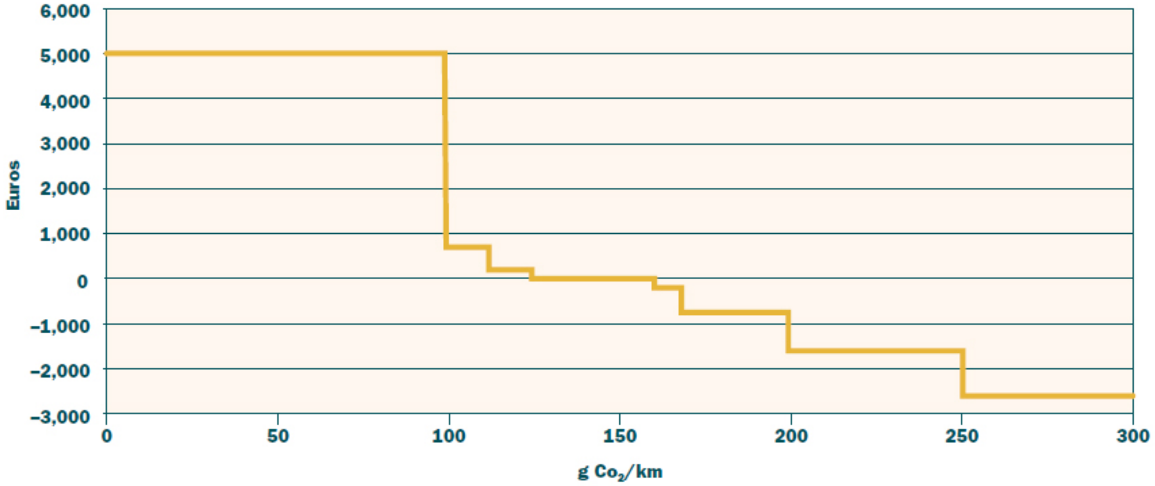

**Figure 31: Fees and rebates of the French bonus-malus programme (Greene 2011).**

- **Biofuel for road, rail and navigation**

With the current target, ethanol will have a share of 5% in China's road transport. There is more potential, also for other modes of transport and biodiesel. The same applies for the USA, except for ethanol, which will have a share of 15% with the current target.

This will require additional capacity for production or imports.

- **More stringent fuel economy standards**

The European Union has a target of 95 g $CO_2$/km. If manufacturers can produce passenger vehicles that meet this requirement until 2020 for the European market, they can also do so for the Chinese and U.S. market.

Increasing the fines for manufacturers for not meeting the standard is an incentive to support the more stringent target.

## 3.7 Reduction potential according to best practice policies

Several gaps exist, as the previous section outlines. For the $CO_2$ reduction potential according to best practice the assessments were set to the difference of the current and maximum assessment.

### 3.7.1 China

The $CO_2$ reduction potential of the domestic transport sector in China according to best practice policies is 420 Mt $CO_2$ (Figure 32). It reduces emissions to 337 Mt $CO_2$, which is close to 2004 levels (334 Mt $CO_2$). Replacing the Chinese target of 116 g $CO_2$/km with the European target of 95 g $CO_2$/km results in a reduction of 11% instead of 8% in 2020.

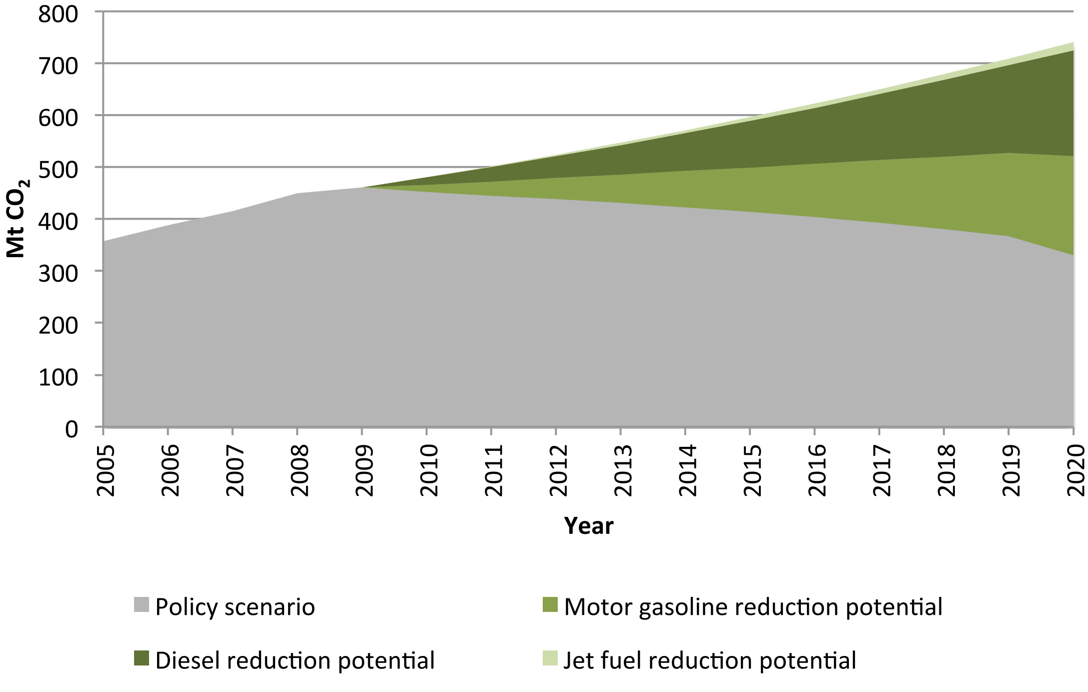

**Figure 32: $CO_2$ emission reduction potential - China.**

With 208 Mt $CO_2$, diesel has the largest reduction potential by 2020, followed by motor gasoline with 195 Mt $CO_2$ and jet fuel with 17 Mt $CO_2$.

The policy package for electric mobility replaces 1 EJ of each diesel and motor gasoline with 0.6 EJ of electricity. Electrification of railways is already included in the BAU.

**Emissions shifted to the electricity supply sector**

Using IEA data (IEA 2011a), the average efficiency of Chinese coal fired power plants in 2009 was calculated. The results indicate an average efficiency of 35% and for natural gas fired power plants of 39%. Best practice corresponds to 60% efficiency for natural gas fired power plants and 47% for coal fired power plants (Graus 2010).

The numbers in Table 41 show that the switch to EVs can generate more $CO_2$ emissions than combustion of diesel and motor gasoline, when a coal fired power plant with low efficiency generates the electricity. All other power plants generate fewer emissions than fuel combustion in cars. In the ideal case, consumed electricity comes from renewable sources and is clean.

**Table 39: $CO_2$ shifted to the electricity supply sector in China.**

| [Mt $CO_2$] | Coal 2009 efficiency 35% | Coal best practice efficiency 47% | Natural gas 2009 efficiency 39% | Natural gas best practice efficiency 60% |
|---|---:|---:|---:|---:|
| **EV** | +27 | -17 | -53 | -85 |

Table 40 shows the reduction potential per segment and energy carrier. The LC segment of road transport has the largest reduction potential with 144 Mt $CO_2$, note that this value does not account for the emissions from the electricity supply sector.

**Table 40: Reduction potential per segment and energy carrier in 2020 - China.**

| Segment | Energy carrier | Reduction [Mt $CO_2$] |
|---|---|---:|
| ***Aviation*** | | |
| Renewables | Jet fuel | 17 |
| ***Navigation*** | | |
| Renewables | Diesel | 10 |
| | Motor gasoline | 0 |
| ***Rail*** | | |
| Renewables | Diesel | 6 |
| Low carbon | Diesel | 0 |
| ***Road*** | | |
| Changing activity | Diesel | 50 |
| | Motor gasoline | 51 |
| Energy efficiency | Diesel | 26 |
| | Motor gasoline | 27 |
| Renewables | Diesel | 43 |
| | Motor gasoline | 46 |
| Low carbon | Diesel | 72 |
| | Motor gasoline | 72 |

### 3.7.2 USA

The $CO_2$ reduction potential of the domestic transport sector in the USA according to best practice is 949 Mt $CO_2$ (Figure 33). It reduces emissions to 759 Mt $CO_2$. This is below 1990 levels.

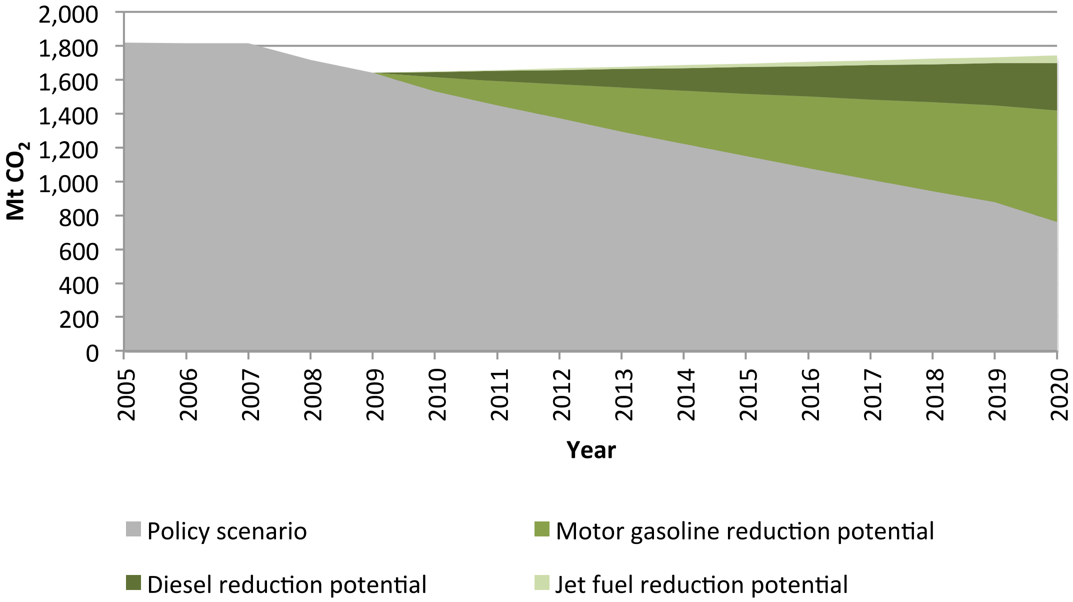

**Figure 33: $CO_2$ emission reduction potential - USA.**

Motor gasoline is the energy carrier with the largest reduction potential. By 2020 it is 623 Mt $CO_2$, followed by diesel with 282 Mt $CO_2$ and jet fuel with 44 Mt $CO_2$.

The policy package for electric mobility replaces 1.2 EJ of diesel and 4.4 EJ of motor gasoline with 1.8 EJ of electricity. Electrification of railways increases the electricity consumption by 9 PJ to 41 PJ.

**Emissions shifted to the electricity supply sector**

Analogous to China, the average efficiency of power plants was calculated with IEA data (IEA 2011b). Average efficiency was 37% for coal fired power plants and 53% for natural gas fired power plants.

The numbers in Table 41 show that the switch to EVs can generate more $CO_2$ emissions than combustion of diesel and motor gasoline when a coal fired power plant with low efficiency generates the electricity. For trains it was calculated that the natural gas fired power plant with best practice efficiency generates less $CO_2$ emissions.

**Table 41: $CO_2$ shifted to the electricity supply sector in the USA.**

| [Mt $CO_2$] | Coal 2009 efficiency 37% | Coal best practice efficiency 47% | Natural gas 2009 efficiency 53% | Natural gas best practice efficiency 60% |
|---|---:|---:|---:|---:|
| **EV** | +57 | -39 | -209 | -231 |
| **Rail** | +1,483 | +978 | +73 | -43 |

Table 42 shows the reduction potential per segment and energy carrier. The LC segment of road transport has the largest reduction potential with 402 Mt $CO_2$. This excludes the shifted $CO_2$ emissions to the electricity supply sector, which are zero, when the electricity comes from clean sources.

**Table 42: Reduction potential per segment and energy carrier in 2020 - USA.**

| Segment | Energy carrier | Reduction [Mt $CO_2$] |
|---|---|---:|
| ***Aviation*** | | |
| Renewables | Jet fuel | 44 |
| ***Navigation*** | | |
| Renewables | Diesel | 0 |
| | Motor gasoline | 2 |
| ***Rail*** | | |
| Renewables | Diesel | 6 |
| Low carbon | Diesel | 7 |
| ***Road*** | | |
| Changing activity | Diesel | 72 |
| | Motor gasoline | 191 |
| Energy efficiency | Diesel | 57 |
| | Motor gasoline | 16 |
| Renewables | Diesel | 50 |
| | Motor gasoline | 102 |
| Low carbon | Diesel | 91 |
| | Motor gasoline | 311 |

## 3.8 Sensitivity analysis

As mentioned in the methodology, the rationale of the weightings of some policy packages (see section 2.1.3.2) is undocumented. The sensitivity analysis aims to quantify the impact of changes of the weightings.

Further, assumptions for the calculations of policy packages 50 and 53 for the USA were made, which can influence the assessment. Impacts of the changes of the assumptions are also assessed.

### 3.8.1 Weighting factors

Two MIFs have policy packages with a weighting: the MIF from the CA segment and the MIF from the EE segment. For the policy analysis, the weightings only influence the analysis of the USA. For the reduction potential, the weightings influence both the policy and reduction potential analysis. The assessments of both analyses and the weightings are in Table 43.

**Table 43: Assessments and weighting of factors used by the sensitivity analysis.**

| Policy package | Assessment China | Assessment USA | Weighting |
|---:|---:|---:|---:|
| #49 | (0) | (0) | 40% |
| #50 | (4) | (4) | 30% |
| #51 | (0) | (1) | 30% |
| #52 | (-1) | (-1) | -30% |
| #53 | * | 3 | 60% |
| #54 | 0 | 4 | 20% |
| #55 | (0) | (1) | 20% |

* 8% reduction in 2020 over BAU; modelled individually

#### *3.8.1.1 China*

The variations of the weightings of policy packages 49-52 and the impact are in Table 44.

**Table 44: Variations of the weightings of policy packages 49-52 and the impact - China.**

| Weighting #49 | Weighting #50 | Weighting #51 | Weighting #52 | Change |
|---:|---:|---:|---:|---:|
| 10% | 60% | 30% | -30% | -17 Mt $CO_2$ (-4%) |
| 20% | 50% | 30% | -30% | -11 Mt $CO_2$ (-3%) |
| 30% | 40% | 30% | -30% | -6 Mt $CO_2$ (-1%) |
| 35% | 35% | 30% | -30% | -3 Mt $CO_2$ (-1%) |
| 50% | 25% | 25% | -25% | 3 Mt $CO_2$ (1%) |
| 50% | 20% | 30% | -30% | 5 Mt $CO_2$ (1%) |
| 60% | 20% | 20% | -20% | 5 Mt $CO_2$ (1%) |
| 90% | 5% | 5% | -5% | 13 Mt $CO_2$ (3%) |

Varying the weighting of policy packages 49-52 with the values from Table 44 changes the reduction potential by less than ±5%.

For policy packages 53-55, the weighting factors can be adjusted to represent the share of energy consumption of passenger and heavy-duty vehicles. However, for China there are no detailed numbers available. Using the values from table 5.1 of the 2007 IPCC report, buses, medium- and heavy-duty trucks account for 40% of the energy consumption, leaving 60% for light-duty vehicles (Kahn Ribeiro et al. 2007).

Leaving the 20% for policy package 55 and splitting the remaining 80% by the 60% and 40% leads to a weighting of 32% for heavy-duty vehicles and 48% for passenger vehicles. This increases the emission reduction of the reduction potential by 0.1%.

Changing the weighting of policy package 55 to 10% and splitting the remaining 90% by the 60% and 40% leads to a weighting of 36% for heavy duty vehicles and 54% for passenger vehicles. This increases the emission reduction of the reduction potential by 0.1%.

Setting the weighting of the fuel tax policy package (55) to 0% and changing the weightings of policy packages 53 and 54 to 60% and 40% does not change the reduction potential.

Varying the weighting of policy packages 53-55 with the values from the paragraphs above changes the reduction potential by less than 1%.

#### *3.8.1.2 USA*

For the weightings of policy packages 49-52 the same as for China applies, except that a change of policy package 49's weighting will have a greater impact due to the assessment. The variations of the weightings and the impact are shown in Table 45.

**Table 45: Variations of the weightings of policy packages 49-52 and the impact - USA.**

| Weighting #49 | Weighting #50 | Weighting #51 | Weighting #52 | Change |
|---:|---:|---:|---:|---:|
| 10% | 60% | 30% | -30% | -7.9 Mt $CO_2$ (-0.9%) |
| 20% | 50% | 30% | -30% | -5.3 Mt $CO_2$ (-0.6%) |
| 30% | 40% | 30% | -30% | -2.6 Mt $CO_2$ (-0.3%) |
| 35% | 35% | 30% | -30% | -1.3 Mt $CO_2$ (-0.1%) |
| 50% | 25% | 25% | -25% | 1.6 Mt $CO_2$ (0.2%) |
| 50% | 20% | 30% | -30% | 2.6 Mt $CO_2$ (0.3%) |
| 60% | 20% | 20% | -20% | 3.3 Mt $CO_2$ (0.4%) |
| 90% | 5% | 5% | -5% | 8.2 Mt $CO_2$ (0.9%) |

Varying the weighting of policy packages 49-52 with the values from Table 45 changes the reduction potential by less than ±1%.

For the United States, the BTS provides fuel consumption data by mode for 2010 (BTS 2012). With the data it was calculated that heavy-duty vehicles consume 28% and passenger vehicles 72% of the fuel from road transport.

Leaving the 20% for policy package 55 and splitting the remaining 80% by the 72% and 28% leads to a weighting of 22% for heavy-duty vehicles and 58% for passenger vehicles. This increases the emission reduction of the policy analysis by 0.4% from 268 to 269 Mt $CO_2$. The reduction potential does not change.

Changing the weighting of policy package 55 to 10% and splitting the remaining 90% by the 72% and 28% leads to a weighting of 25% for heavy duty vehicles and 65% for passenger vehicles. This increases the emission reduction of the policy analysis by 8% to 290 Mt $CO_2$. The reduction potential increases by 0.3% from 920 to 923 Mt $CO_2$.

Setting the weighting of the fuel tax policy package (55) to 0% and changing the weightings of policy packages 53 and 54 to 72% and 28% increases the reduction from 268 to 306 Mt $CO_2$. This is an increase of 14%. The additional reduction potential increases by 0.6% from 920 to 926 Mt $CO_2$.

Varying the weighting of policy packages 53-55 with the values from the paragraphs above changes the policy reduction by up to 14% and the reduction potential by less than 1%.

### 3.8.2 Assumptions for policy packages 50 and 53

Assumptions for the calculations for policy packages 50 and 53 for the USA are in Table 35 and Table 36.

The assessment for policy package 50 depends on the increase of the capacity of public transport. Increasing the assumptions of passenger capacities by the same factor does not change the increase (in per cent) of the capacity, so in the sensitivity analysis the different modes of transport are treated individually. The increase used in the policy analysis is 16%

**Table 46: Variations of assumptions for policy package 50.**

| Change | Capacity increase change | Assessment |
|---|---:|---:|
| Bus capacity -20% | +0.7% | 3 |
| Bus capacity -10% | +0.3% | 3 |
| Bus capacity +10% | -0.3% | 3 |
| Bus capacity +20% | -0.5% | 3 |
| Train capacity -20% | -0.1% | 3 |
| Train capacity -10% | 0% | 3 |
| Train capacity +10% | 0% | 3 |
| Train capacity +20% | 0.1% | 3 |
| Demand response + other capacity -20% | -0.5 | 3 |
| Demand response + other capacity -10% | -0.3 | 3 |
| Demand response + other capacity +10% | 0.3% | 3 |
| Demand response + other capacity +20% | 0.5% | 3 |

Table 46 shows that variations of the seat capacities of different modes of transport of ±20% do not lead to a different assessment for policy package 50.

For policy package 53 the assessment depends on the assumptions on annual increase of passenger car sales. The decrease of emissions used in the calculations is 17% over 2010 levels by 2020.

Table 47: Variation of assumptions for policy package 53.

| Change | Reduction change | Assessment |
|---|---:|---:|
| Assumptions -20% | 3% | 4 |
| Assumptions -10% | 2% | 4 |
| Assumptions +10% | -1% | 3 |
| Assumptions +20% | -2% | 3 |

Decreasing the amount of sales results in higher reductions and an assessment of 4. This would increase the policy impact from 268 to 301 Mt $CO_2$. This is an increase of 12%.

### 3.8.3 Take-back effect

As mentioned, the take-back effect was not taken into account for the assessments of the fuel economy standards. The amount of vkm remained constant through 2020 (see section 3.4.2).

Increasing the vkm of the years 2014-2017 by 5% and 2018-2020 by 10% results in 3% less reduction (14%) for the USA. This does not change the assessment. For the individual calculation for China, the increase of vkm decreases the reduction of the fuel economy standard from 8% to 6%. This corresponds to 10 Mt less $CO_2$ reduction from diesel and motor gasoline.

# 4 Discussion

In this study, the policy impact on $CO_2$ emissions from the domestic transport sector of the USA and China was assessed with the help of the CAT model. The USA and China were the countries with the largest $CO_2$ emissions from the domestic transport sector worldwide in 2009 (Figure 1). Furthermore, the policy strategies of the two countries were compared and policy gaps to best practice policies were identified. The $CO_2$ reduction potential of best practice policies was calculated with the model. This section discusses limitations of the model and input for the analysis.

## 4.1 Methodology

During the analysis of Chinese policies, questions arose on whether the CAT is suitable for the analysis of an emerging economy country. The CAT claims that it can be used for every country (Höhne et al. 2011a). Table 48 shows the growth rates of the IEA CPS for China from the 2010 and 2011 WEO. The 2011 growth rates are larger, except for biofuels (IEA 2010, IEA 2011e).

**Table 48: Annual growth rates of the CPS for China from the 2011 and 2010 WEO (IEA 2010, IEA 2011e).**

| | **2010 WEO** | **2011 WEO** | **Δ2011-2010** |
|---|---:|---:|---:|
| **Oil** | 4.5% | 4.6% | 0.1% |
| **Electricity** | 6.5% | 7.1% | 0.6% |
| **Biofuels** | 9.6% | 9.2% | -0.4% |
| **Other fuels** | -0.5% | 0.3% | 0.8% |

The 2011 WEO includes the targets of the 12th Five-Year-Plan (IEA 2011e). By using the 2010 growth rates, the targets of the 12th Five-Year-Plan would have had to be included in the policy analysis and led to assessments, which would have resulted in emission reductions. However, Table 48 shows that the final energy demand increases with the new policies, because the domestic transport sector is growing. The increase of public transport capacity does not necessarily lead to a modal shift from road to rail, but enables more Chinese people to travel in general.

The CAT assumes that policies lead to reductions. In China they currently lead to growth (WEO 2010 vs. WEO 2011). Due to the larger growth rate of the vehicle stock than energy efficiency improvement, the calculations of the CAT had to be modified for policy package 53. Therefore the CAT is limited for emerging economy countries. For developed countries with a saturated market, such as the USA, the CAT model is suitable.

## 4.2 Results

### 4.2.1 Comparison to other studies

Table 7 and Table 8 show projections and mitigation potentials of other studies for China and the USA. These differ from the BAU used in this thesis. Using the growth rate from the 2011 WEO (IEA 2011e) led to a smaller BAU than projected by the IEA. The difference for the USA and China is 3.2 EJ each and due to the fact that the growth rate is an average value over a period of 26 years.

Why is a comparison with other studies difficult? Most studies underlie a different reference case. The 12th Five-Year-Plan of China is from 2011 (Delegation of the European Union in China 2011). Only one study from Yanli is from 2012 and only focuses on road transport. Due to the separation of the modes of transport, this is comparable. Yanli estimated that in 2020, road transport would consume 179 million tonnes of oil. This is equivalent to 7.5 EJ. The CAT calculates that in 2020, road transport will consume 8.4 EJ of final energy. Yanli uses the estimation that automobiles will use 53% less energy by 2020 than in 2004. This is more than used in the CAT calculations (39%). He does not include the increase of vehicle stock in his calculations, but passenger and freight turnover and converts this into fuel consumption. This approach differs from the one used in this thesis. Both differences can be the reason for the difference in energy demand.

The same applies for the USA. Most studies use a reference case from 2009 or earlier. The growth rates between the annual AEO reference cases differ, as Table 9 and Table 32 show for 2010 and 2011 as example. Also, other studies did scenario analyses (Andress et al. 2011, Ross Morrow et al. 2010), which differ from the approach in this thesis. Andress et al. have scenarios for different technologies where they assume that these will be successful in the future rather than analysing current and planned policies. Ross Morrow et al. have a different approach, as they do not use best practice policies in their scenarios but own assumptions.

### 4.2.2 Data input

Data from the 2011 IEA balances (IEA 2011a, IEA 2011b) was used for this thesis. In general, these are very detailed, but a few discrepancies were observed.

- There is no final electricity consumption of road transport in the balances although EVs have been used for several years in both countries (see Table 34 and Table 37). It is possible that part of the electricity consumption is accounted in the residential sector, when people charge their vehicles at home over night.
- Hydrogen has been used in the USA for several years (Table 37), although only by a rather small fraction of the vehicles. It is not listed as an energy carrier in the balances.

- Besides fuel oil, domestic navigation consumes only motor gasoline in the USA and only diesel in China. This seems odd but was not further investigated, because the numbers only account for a small share of the total final energy consumption.

These discrepancies only have a minor impact on emissions, because of low shares of the total final consumption, so it is considered acceptable for this thesis.

### 4.2.3 Chinese sources

Availability of official Chinese websites in English was a barrier. Only few official Chinese websites have an English version with limited content. Most policies in the inventory come from scientific literature or English versions of Chinese newspapers. Sometimes scientific literature referred to Chinese websites, which could be translated with Google. However, it is possible that recent policies were overlooked due to lack of English references.

### 4.2.4 Emission factors

Country specific emission factors for the USA were available through the EPA and increased the $CO_2$ emissions, compared to the IPCC emission factors (Figure 14). For China, the IPCC emission factors (Table 49) were used to calculate the $CO_2$ emissions. Country specific emission factors will likely produce other results, but are not available at the time of writing this thesis.

### 4.2.5 Sensitivity analysis

Depending on the variation of the weighting factors and assumptions, the emission reduction results can be up to 14% higher for the USA. This value is considered barely acceptable. The impact of variations on the reduction potential is smaller than ±5%. This is considered an acceptable value.

A change in politics has not been subject for the sensitivity analysis, but in the USA, the political direction can change with every presidential election. In China, a change in politics will most likely not happen in the near future. For instance, Republicans in the USA cut most of the funding for the development of the railways in 2011 (Laing 2011). In 1996, they even challenged the evidence of man-made climate change (Macilwain 1996). A change in politics will have negative impacts on the emission reductions through policies. This could be a subject for a future analysis.

### 4.2.6 Biofuel vs. food issue

Biofuel accounts for 16% (152 Mt $CO_2$) of the reduction potential of the USA and 21% (89 Mt $CO_2$) of China's. It has recently been in the news due to the weather conditions this summer, which destroyed part of the U.S. corn crop. As there is a quota on how much corn has to be converted to biofuel in the Renewable Fuel Standard, food prices are most likely to rise (BBC 2012). Because of the food issue, the German federal minister for economic cooperation and development, Dirk Niebel, asked for the end of E10 in August (BMZ 2012).

Since this year is already causing problems, what will the situation in 2020 be like? Second generation biofuels that do not use food crops as input source are needed to overcome the food issue. Sims et al. point out that second generation biofuels still have some technical and environmental barriers to overcome and need policy support (Sims et al. 2010).

If second generation biofuels cannot be developed due to the barriers, biofuel targets should be suspended and the more attention should be given to EVs with electricity from renewable sources.

# 5 Conclusion

This thesis aimed to assess whether the transport policies in China and the USA lead to a $CO_2$ emission reduction that is in line with the pledge under the Copenhagen Accord and how the policy strategies of the two countries differ. This thesis used the CAT model to evaluate policies against best practices. This thesis also identified policy gaps and the $CO_2$ reduction potential until 2020.

The BAU scenarios show that emissions in China will double between 2005 and 2020 with current policies. China has a reduction target based on the $CO_2$ emissions per unit of GDP. With a conservative assumption for GDP development, the upper end of the target range of the pledge (45%) is exceeded by 2% without further policy action. The policy impact exceeds the pledge by 7%, the reduction potential by 31% (Figure 34).

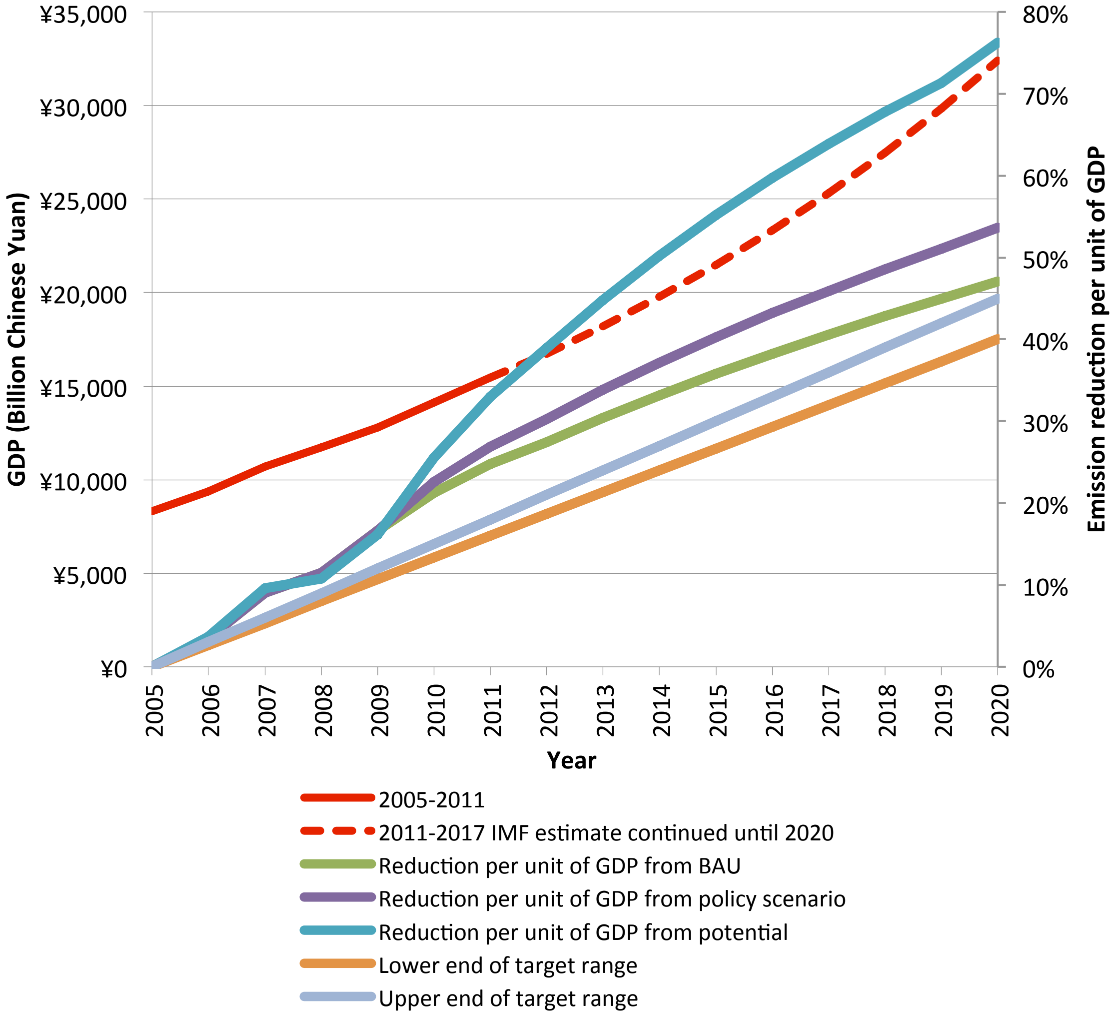

**Figure 34: Emission reduction per unit of GDP in China from 2005-2020. GDP data from IMF (IMF 2012c).**

Meanwhile in the USA, emissions will decrease by 6% in the same timeframe because of the impact of the financial crisis after 2007. By 2020, the USA will only emit two times more $CO_2$ emissions than China. In 2005, the USA emitted five times more CO2 than China in the domestic transport sector.

Announced policies that are not included in the BAU scenario will lead to an emission reduction of 21% below 2005 levels in the USA by 2020 in the domestic transport sector. The reduction potential is 58% below the 2005 levels (Figure 35). To fulfil the pledge under the Copenhagen Accord, this gives the other sectors a little buffer.

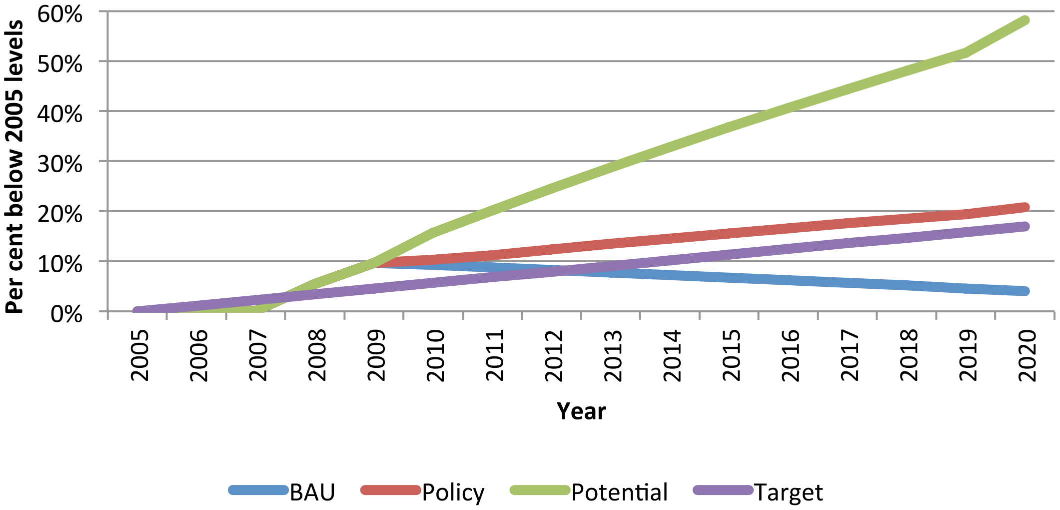

**Figure 35: Reduction of $CO_2$ emissions from the domestic transport sector below 2005 levels - USA.**

In their policy strategies, both countries focus on fuel economy standards, public transport, biofuels and have ambitious targets for EVs. The USA even has fuel economy standards for heavy-duty vehicles, while China has also a biofuel target for aviation. In regard of railways, the USA plans to use diesel locomotives. In China, electrification of railways tracks increases with the expansion of the network.

Both countries have policy gaps in their strategies. Promotion of non-motorised transport has not received enough attention. Fuel taxes do not exist in China and are low in the USA. Both countries have subsidies for fossil fuel use and need more incentives for a bigger market penetration of EVs. Fuel economy standards for passenger vehicles can be increased to the European level of 95 g $CO_2$/km.

China needs a fuel economy standard for heavy-duty vehicles. The USA can set a target for biofuels in aviation and must use more electric locomotives with clean electricity rather than diesel powered.

By 2020, China has a reduction potential of 420 Mt $CO_2$ through the policy gaps against best practice. The USA has a reduction potential of 949 Mt $CO_2$. The potential was calculated with the focus on EVs in the road transport sector. LPG and NGVs were not regarded because both countries focus on EVs and that technology has the potential to emit no emissions, when the electricity comes from renewable sources.

The more detailed data input by mode of transport increased the accuracy of the calculations of the CAT model. Based on the uncertainty in the policy analysis, further work on the weightings is recommended.

The CAT assumes that all policy packages marked as incentives lead to emission reductions. However, calculations showed that there are problems with some policy packages and emerging economy countries, such as China. Growth of public transportation does not necessarily lead to a modal shift and fewer reductions. Also the calculation for policy package 53 had to be modified for China to have an impact. Following the methodology, the assessment would have been 0 and the policy would have been disregarded in the results. Future work could focus on this issue, also for the other sectors of the model.

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# 7 Annex

**Table 49: Emission factors from the IPCC (IPCC 1995).**

| Energy carrier | Emission factor [kg $CO_2/GJ_{LHV}$] |
|---|---:|
| Bituminous coal | 95 |
| Brown coal (Lignite) | 101 |
| Diesel | 74 |
| Jet fuel | 74 |
| LPG | 63 |
| Motor gasoline | 69 |
| Natural gas | 56 |
| Fuel oil | 77 |

**Table 50: Definition of energy carriers used by the CAT model (IEA 2011c, pages 23-34).**

| Energy carrier | Definition |
|---|---|
| Coal and coal products | Includes all entries below until "Oil products" |
| Anthracite | Anthracite is a high rank coal used for industrial and residential applications. It is generally less than 10% volatile matter and a high carbon content (about 90% fixed carbon). Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ash-free but moist basis. |
| Coking coal | Coking coal refers to coal with a quality that allows the production of a coke suitable to support a blast furnace charge. Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ash-free but moist basis. |
| Other bituminous coal | Other bituminous coal is used for steam raising and space heating purposes and includes all bituminous coal that is not included under coking coal. It is usually more than 10% volatile matter and a relatively high carbon content (less than 90% fixed carbon). Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ashfree but moist basis. |
| Sub-bituminous coal | Non-agglomerating coals with a gross calorific value between 17 435 kJ/kg (4 165 kcal/kg) and 23 865 kJ/kg (5 700 kcal/kg) containing more than 31% volatile matter on a dry mineral matter free basis. |
| Lignite | Lignite is a non-agglomerating coal with a gross calorific value of less than 17 435 kJ/kg (4 165 kcal/kg), and greater than 31% volatile matter on a dry mineral matter free basis. Oil shale and tar sands produced and combusted directly are included in this category. Oil shale and tar sands used as inputs for other transformation processes are also included here (this includes the portion consumed in the transformation process). Shale oil and other products derived from liquefaction are included in *from other sources* under crude oil (*other hydrocarbons*). |

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| Patent fuel | Patent fuel is a composition fuel manufactured from hard coal fines with the addition of a binding agent. The amount of patent fuel produced is, therefore, slightly higher than the actual amount of coal consumed in the transformation process. Consumption of patent fuels during the patent fuel manufacturing process is included under *other energy industries*. |
| Coke oven coke | Coke oven coke is the solid product obtained from the carbonization of coal, principally coking coal, at high temperature. It is low in moisture content and volatile matter. Coke oven coke is used mainly in the iron and steel industry, acting as energy source and chemical agent. Also included are semi-coke (a solid product obtained from the carbonisation of coal at a low temperature), lignite coke (a semi-coke made from lignite), coke breeze and foundry coke. The heading *other energy industries* includes the consumption at the coking plants themselves. Consumption in the *iron and steel industry* does not include coke converted into blast furnace gas. To obtain the total consumption of coke oven coke in the iron and steel industry, the quantities converted into blast furnace gas have to be added (these are included in *blast furnaces*). |
| Gas coke | Gas coke is a by-product of hard coal used for the production of town gas in gas works. Gas coke is used for heating purposes. *Other energy industries* includes the consumption of gas coke at gas works. |
| Coal tar | Coal tar is a result of the destructive distillation of bituminous coal. Coal tar is the liquid by-product of the distillation of coal to make coke in the coke oven process. Coal tar can be further distilled into different organic products (e.g. benzene, toluene, naphthalene), which normally would be reported as a feedstock to the petrochemical industry. |
| BKB/peat briquettes | BKB are composition fuels manufactured from lignite, produced by briquetting under high pressure. These figures include peat briquettes, dried lignite fines and dust. The heading *other energy industries* includes consumption by briquetting plants. |
| Gas works gas | Gas works gas covers all types of gas produced in public utility or private plants, whose main purpose is the manufacture, transport and distribution of gas. It includes gas produced by carbonisation (including gas produced by coke ovens and transferred to gas works), by total gasification (with or without enrichment with oil products) and by reforming and simple mixing of gases and/or air. |
| Coke oven gas | Coke oven gas is obtained as a by-product of the manufacture of coke oven coke for the production of iron and steel. |

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| Blast furnace gas | Blast furnace gas is produced during the combustion of coke in blast furnaces in the iron and steel industry. It is recovered and used as a fuel, partly within the plant and partly in other steel industry processes or in power stations equipped to burn it. |
| Other recovered gases | Oxygen steel furnace gas is obtained as a by-product of the production of steel in an oxygen furnace and is recovered on leaving the furnace. Oxygen steel furnace gas is also known as converter gas, LD gas or BOS gas. This category may also cover other recovered gases. |
| Oil products | Includes all entries below until "Natural gas" |
| Refinery gas | Refinery gas is defined as non-condensable gas obtained during distillation of crude oil or treatment of oil products (e.g. cracking) in refineries. It consists mainly of hydrogen, methane, ethane and olefins. It also includes gases which are returned from the petrochemical industry. Refinery gas production refers to gross production. Own consumption is shown separately under oil refineries in energy industry own use. |
| Ethane | Ethane is a naturally gaseous straight-chain hydrocarbon ($C_2H_6$). It is a colourless paraffinic gas which is extracted from natural gas and refinery gas streams. |
| Liquefied petroleum gases (LPG) | Liquefied petroleum gases are the light hydrocarbon fraction of the paraffin series, derived from refinery processes, crude oil stabilization plants and natural gas processing plants, comprising propane ($C_3H_8$) and butane ($C_4H_{10}$) or a combination of the two. They could also include propylene, butylene, isobutene and isobutylene. LPG are normally liquefied under pressure for transportation and storage. |
| Motor gasoline | Motor gasoline is light hydrocarbon oil for use in internal combustion engines such as motor vehicles, excluding aircraft. Motor gasoline is distilled between 35°C and 215°C and is used as a fuel for land based spark ignition engines. Motor gasoline may include additives, oxygenates and octane enhancers, including lead compounds such as TEL (tetraethyl lead) and TML (tetramethyl lead). Motor gasoline does not include the liquid biofuel or ethanol blended with gasoline - see liquid biofuels. This differs from the presentation of motor gasoline in the Oil Information publication. |
| Aviation gasoline | Aviation gasoline is motor spirit prepared especially for aviation piston engines, with an octane number suited to the engine, a freezing point of -60°C, and a distillation range usually within the limits of 30°C and 180°C. |
| Gasoline type jet fuel | Gasoline type jet fuel includes all light hydrocarbon oils for use in aviation turbine power units, which distil between 100°C and |

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| | 250°C. This fuel is obtained by blending kerosenes and gasoline or naphthas in such a way that the aromatic content does not exceed 25% in volume, and the vapour pressure is between 13.7 kPa and 20.6 kPa. Additives can be included to improve fuel stability and combustibility. |
| Kerosene type jet fuel | Kerosene type jet fuel is a medium distillate used for aviation turbine power units. It has the same distillation characteristics and flash point as kerosene (between 150°C and 300°C but not generally above 250°C). In addition, it has particular specifications (such as freezing point) which are established by the International Air Transport Association (IATA). It includes kerosene blending components. |
| Other Kerosene | Kerosene (other than kerosene used for aircraft transport which is included with aviation fuels) comprises refined petroleum distillate intermediate in volatility between gasoline and gas/diesel oil. It is a medium oil distilling between 150°C and 300°C. |
| Gas/diesel oil | Gas/diesel oil includes heavy gas oils. Gas oils are obtained from the lowest fraction from atmospheric distillation of crude oil, while heavy gas oils are obtained by vacuum redistillation of the residual from atmospheric distillation. Gas/diesel oil distils between 180°C and 380°C. Several grades are available depending on uses: diesel oil for diesel compression ignition (cars, trucks, marine, etc.), light heating oil for industrial and commercial uses, and other gas oil including heavy gas oils which distil between 380°C and 540°C and which are used as petrochemical feedstocks. Gas/diesel oil does not include the liquid biofuels blended with gas/diesel oil – see liquid biofuels. This differs from the presentation of gas/diesel oil in the Oil Information publication. |
| Fuel oil | Fuel oil defines oils that make up the distillation residue. It comprises all residual fuel oils, including those obtained by blending. Its kinematic viscosity is above 10 cSt at 80°C. The flash point is always above 50°C and the density is always higher than 0.90 kg/l. |
| Naphtha | Naphtha is a feedstock destined either for the petrochemical industry (e.g. ethylene manufacture or aromatics production) or for gasoline production by reforming or isomerisation within the refinery. Naphtha comprises material that distils between 30°C and 210°C. Naphtha imported for blending is shown as an import of naphtha, and then shown in the transfers row as a negative entry for naphtha and a positive entry for the corresponding finished product (e.g. gasoline). |

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| White spirit & SBP | White spirit and SBP are refined distillate intermediates with a distillation in the naphtha/kerosene range. White Spirit has a flash point above 30oC and a distillation range of 135°C to 200°C. Industrial Spirit (SBP) comprises light oils distilling between 30°C and 200°C, with a temperature difference between 5% volume and 90% volume distillation points, including losses, of not more than 60oC. In other words, SBP is a light oil of narrower cut than motor spirit. There are seven or eight grades of industrial spirit, depending on the position of the cut in the distillation range defined above. |
| Lubricants | Lubricants are hydrocarbons produced from distillate or residue; they are mainly used to reduce friction between bearing surfaces. This category includes all finished grades of lubricating oil, from spindle oil to cylinder oil, and those used in greases, including motor oils and all grades of lubricating oil base stocks. |
| Bitumen | Bitumen is a solid, semi-solid or viscous hydrocarbon with a colloidal structure that is brown to black in colour. It is obtained by vacuum distillation of oil residues from atmospheric distillation of crude oil. Bitumen is often referred to as asphalt and is primarily used for surfacing of roads and for roofing material. This category includes fluidised and cut back bitumen. |
| Paraffin waxes | Paraffin waxes are saturated aliphatic hydrocarbons. These waxes are residues extracted when dewaxing lubricant oils, and they have a crystalline structure which is more or less fine according to the grade. Their main characteristics are that they are colourless, odourless and translucent, with a melting point above 45°C. |
| Petroleum coke | Petroleum coke is defined as a black solid residue, obtained mainly by cracking and carbonising of petroleum derived feedstocks, vacuum bottoms, tar and pitches in processes such as delayed coking or fluid coking. It consists mainly of carbon (90 to 95%) and has a low ash content. It is used as a feedstock in coke ovens for the steel industry, for heating purposes, for electrode manufacture and for production of chemicals. The two most important qualities are "green coke" and "calcinated coke". This category also includes "catalyst coke" deposited on the catalyst during refining processes: this coke is not recoverable and is usually burned as refinery fuel. |
| Non-specified oil products | Other oil products not classified above (e.g. tar, sulphur and grease) are included here. This category also includes aromatics (e.g. BTX or benzene, toluene and xylene) and olefins (e.g. propylene) produced within refineries. |
| Natural gas | Natural gas comprises gases, occurring in underground deposits, |

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| | whether liquefied or gaseous, consisting mainly of methane. It includes both "non-associated" gas originating from fields producing only hydrocarbons in gaseous form, and "associated" gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas) or from coal seams (coal seam gas). Production represents dry marketable production within national boundaries, including offshore production and is measured after purification and extraction of NGL and sulphur. It includes gas consumed by gas processing plants and gas transported by pipeline. Quantities of gas that are re-injected, vented or flared are excluded. |
| Biofuels and waste | Includes all entries below until “Electricity” |
| Industrial waste | Industrial waste of non-renewable origin consists of solid and liquid products (e.g. tyres) combusted directly, usually in specialized plants, to produce heat and/or power. Renewable industrial waste is not included here, but with solid biofuels, biogases or liquid biofuels. |
| Municipal waste (renewable) | Municipal waste consists of products that are combusted directly to produce heat and/or power and comprises wastes produced by households, industry, hospitals and the tertiary sector that are collected by local authorities for incineration at specific installations. Municipal waste is split into renewable and non-renewable. |
| Municipal waste (non-renewable) | Municipal waste consists of products that are combusted directly to produce heat and/or power and comprises wastes produced by households, industry, hospitals and the tertiary sector that are collected by local authorities for incineration at specific installations. Municipal waste is split into renewable and non-renewable. |
| Primary solid biofuels | Primary solid biofuels is defined as any plant matter used directly as fuel or converted into other forms before combustion. This covers a multitude of woody materials generated by industrial process or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, sulphite lyes also known as black liquor, animal materials/wastes and other solid biofuels). |
| Biogases | Biogases are gases arising from the anaerobic fermentation of biomass and the gasification of solid biomass (including biomass in wastes). The biogases from anaerobic fermentation are composed principally of methane and carbon dioxide and comprise landfill gas, sewage sludge gas and other biogases from anaerobic fermentation. Biogases can also be produced from thermal processes (by gasification or pyrolysis) of biomass and |

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| | are mixtures containing hydrogen and carbon monoxide (usually known as syngas) along with other components. These gases may be further processed to modify their composition and can be further processed to produce substitute natural gas. Biogases are used mainly as a fuel but can be used as a chemical feedstock. |
| Biogasoline | Biogasoline includes bioethanol (ethanol produced from biomass and/or the biodegradable fraction of waste), biomethanol (methanol produced from biomass and/or the biodegradable fraction of waste), bioETBE (ethyl-tertio-butyl-ether produced on the basis of bioethanol; the percentage by volume of bioETBE that is calculated as biofuel is 47%) and bioMTBE (methyl-tertio-butyl-ether produced on the basis of biomethanol: the percentage by volume of bioMTBE that is calculated as biofuel is 36%). Biogasoline includes the amounts that are blended into the gasoline - it does not include the total volume of gasoline into which the biogasoline is blended. |
| Biodiesels | Biodiesels includes biodiesel (a methyl-ester produced from vegetable or animal oil, of diesel quality), biodimethylether (dimethylether produced from biomass), Fischer Tropsch (Fischer Tropsch produced from biomass), cold pressed bio-oil (oil produced from oil seed through mechanical processing only) and all other liquid biofuels which are added to, blended with or used straight as transport diesel. Biodiesels includes the amounts that are blended into the diesel – it does not include the total volume of diesel into which the biodiesel is blended. |
| Other liquid biofuels | Other liquid biofuels includes liquid biofuels not reported in either biogasoline or biodiesels. |
| Non-specified primary biofuels and waste | This item is used when the detailed breakdown for primary biofuels and waste is not available. |
| Charcoal | Charcoal includes charcoal produced from solid biomass. |
| Electricity | Gross electricity production is measured at the terminals of all alternator sets in a station; it therefore includes the energy taken by station auxiliaries and losses in transformers that are considered integral parts of the station. The difference between gross and net production is generally estimated as 7% for conventional thermal stations, 1% for hydro stations, and 6% for nuclear, geothermal and solar stations. Production in hydro stations includes production from pumped storage plants. |

**Table 51: Data for the calculations for policy package 53 for the USA (BTS 2012).**

| | Average emissions of new cars [g $CO_2$/km] | Sales of passenger vehicles | Vehicle kilometres [*1,000,000] |
|---|---|---|---|
| **1990** | 221 | 9,303,215 | 3,172,539 |
| **1991** | 218 | 8,184,979 | 3,212,126 |
| **1992** | 222 | 8,213,113 | 3,325,491 |
| **1993** | 218 | 8,517,859 | 3,392,734 |
| **1994** | 218 | 8,990,517 | 3,473,157 |
| **1995** | 216 | 8,620,159 | 3,565,317 |
| **1996** | 217 | 8,478,545 | 3,658,230 |
| **1997** | 215 | 8,217,480 | 3,765,272 |
| **1998** | 215 | 8,084,989 | 3,868,563 |
| **1999** | 218 | 8,637,708 | 3,952,195 |
| **2000** | 217 | 8,777,723 | 4,037,354 |
| **2001** | 215 | 8,352,000 | 4,111,968 |
| **2002** | 213 | 8,042,255 | 4,199,213 |
| **2003** | 209 | 7,555,551 | 4,249,580 |
| **2004** | 209 | 7,482,555 | 4,363,286 |
| **2005** | 204 | 7,659,983 | 4,399,155 |
| **2006** | 205 | 7,761,592 | 4,436,840 |
| **2007** | 198 | 7,562,334 | 4,305,655 |
| **2008** | 196 | 6,769,107 | 4,208,341 |
| **2009** | 188 | 5,400,890 | 4,213,196 |
| **2010** | 182 | 5,635,433 | Not available |