

**TRANSPORT POLICIES RELATED TO CLIMATE CHANGE MITIGATION  
- THE CASE OF DENMARK**





The background of the entire page is a complex pattern of numerous thin, dark blue curved lines. These lines are arranged in a way that creates a sense of depth and movement, resembling a stylized, abstract landscape or a series of overlapping, curved planes. The lines are most densely packed in the lower half of the page and become more sparse towards the top.

**Transport policies related  
to climate change mitigation  
- the case of Denmark**

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**This report is prepared for  
the Swedish Government's  
Commission on fossil-free  
road transport**



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## 1. Introduction

This report presents the Danish national policies on reducing the emissions of greenhouse gasses and reducing Denmark's dependency on fossil fuels in the transport sector, as well as some of the results of the policies. Systematic focus on efficient transport and climate mitigation started in 2008 and 2009 with a change – not only in the wording and in the political visions – but also in the actual prioritisation of investments and policies to a very large extent. In March 2012 another milestone was set by the Government, to have Denmark based on 100% renewable energy in 2050. This entails large challenges for the transport sectors, which has not yet been systematically analysed from any Governmental body. In this report we list projects which have done so.

The first chapter describes policies and initiatives of international relevance within climate mitigation. The following chapters explain in further detail these policies and their effects as well as a number of additional policies and initiatives related to climate mitigation and transport. The private sector and local government has proven important in connection with an efficient transport sector. Hence selected local and regional projects and their results are introduced as well. To provide an overview of current trends, related scientific projects and other analyses on climate change mitigation and transport are given in the report. The references used in this report can also serve as a source of data and inspiration for the reader.

This report is prepared as one of many inputs to the analyses conducted in The Swedish Government's Commission on fossil-free road transport. The task of this Commission is to:

*“review alternative developments of fuels and vehicles for fossil-free road transport, to consider measures and policy options that would enable the Swedish road transport system to become climate neutral by 2050, and to propose intermediate emission reduction targets for years such as 2020, 2030 and 2040. “*

## **2. Summary of programs of international relevance**

This chapter provides selected examples of internationally relevant elements in the Danish transport sector that has had an actual effect on reducing fossil fuel dependency and hence reducing greenhouse gas emissions. In the following chapters these examples are elaborated and many other policies are presented.

### **2.1 Successful initiatives regarding public transportation, walking and biking**

Even though car ownership in Denmark is comparable with most European countries, public transportation covers a larger share of the passenger transport demand compared to other European countries (Eurostat, 2013). The share of biking in the cities is high in Denmark, mostly with the consequence of less car transport (European Platform on Mobility Management, 2013). However it is important to consider that international statistics on transport demands and especially on biking is hard to compare between countries.

Zoning laws and planning practise in Denmark has traditionally been reluctant to allow large shopping centres, which – in combination with a biking culture that was re-ignited during the oil-crisis – has meant that urban areas are predominantly mixtures between living, businesses and public institutions etc. This also means that it is physically possible to have another transport paradigm than one solely or mainly based on cars.

The higher share of biking seems to be related to the fact that biking infrastructure has been provided and that the urban structure has made it the most convenient way to travel – especially to work places. However, there seems to be no evidence to suggest that the car ownership has been reduced or that the amount of km travelled by cars annually is low due to the higher shares of bikes in towns and cities (Odyssee, 2013).

In Copenhagen 36% of trips are covered by bikes and in 2007 the municipality announced a goal of having 50% biking to work and education in 2015 (Copenhagen Municipality, 2007). Most other cities of Denmark also have very high bike shares in transportation, e.g. in Odense the share is 27%. The feeling of safety is mostly accomplished by the traffic separation and has been the predominant measure to increase biking. Many roads in Danish towns and cities, as well as roads between the cities, have separate biking paths additional to the pavement. 58% of cyclists feel safe while biking in Copenhagen - the goal is at least 80%. Currently so-called “cycling super highways” are being built and overall bike path infrastructure is being expanded in many Danish cities.

In Copenhagen another reason for the high share of biking is the good integration with public transportation that has been established. It is easy and now free to take the bike into the local train transport system – the S-trains. The S-trains connect Copenhagen to the surrounding municipalities and this initiative has increased the integration of public transport and biking significantly. The paths of the trains were laid out in 1947 in the so-called “Finger plan” with Copenhagen centre as the palm of the hand, the train-lines as the fingers with green corridors of parks, recreating and forests in between. In addition to the S-trains the city also has an underground driverless metro that covers the city centre and connects the city with the airport and the new city area of Ørestad. The Metro in Copenhagen is currently being expanded with the city circle line. The share of biking and public transport is high compared to other cities.

In general very large investments of approx. 140 Billion DKK are being made currently and in the coming years to expand transport infrastructure in Denmark – 80% of which is prioritised to public transport. The results remain to be seen, but there is a clear shift in the focus to investing more strategically in this sectors as appose to the road sector expansion.

## 2.2 The Danish Car taxation structure and the effects on vehicle efficiency

Car taxation has resulted in a rather efficient personal car fleet (Odyssee, 2013). In Denmark the car taxation is threefold. The taxation consist of an annual weight fee, progressive car registration taxation and fuel taxes. It is often stated that the Danish tax adds 180% more on the car price. This is only partly true however as described below.

*Progressive taxation on car registration* was introduced in 1924 to help the balance of trade since no Danish car manufacturer existed at that time. In 2012 the level for private cars is 105% on the price below 79,000 DKK and 180 % on the part of the price above with an adjustment for mileage described below. The tax rates have been constant since 1977, but the amount above which the high tax must be paid is adjusted yearly. The tax rate is higher for motorcycles but lower for cargo trucks, taxis, ambulances, limousines and busses. (Ministry of Taxation, 2013)

In 2007 an addition to the legislation *Progressive taxation on car registration* was enforced. The total registration fee is reduced by 4,000 DKK per km the car can travel pr. liter above 16 km/l for petrol and above 17 km/l for diesel cars. In addition, cars with efficiencies lower than 16km/l for petrol cars and 18 km/l for diesel cars are charged an extra 1,000 DKK per km/l. this applies both for personal cars as well as for company cars. (Ministry of Taxation, 2013)

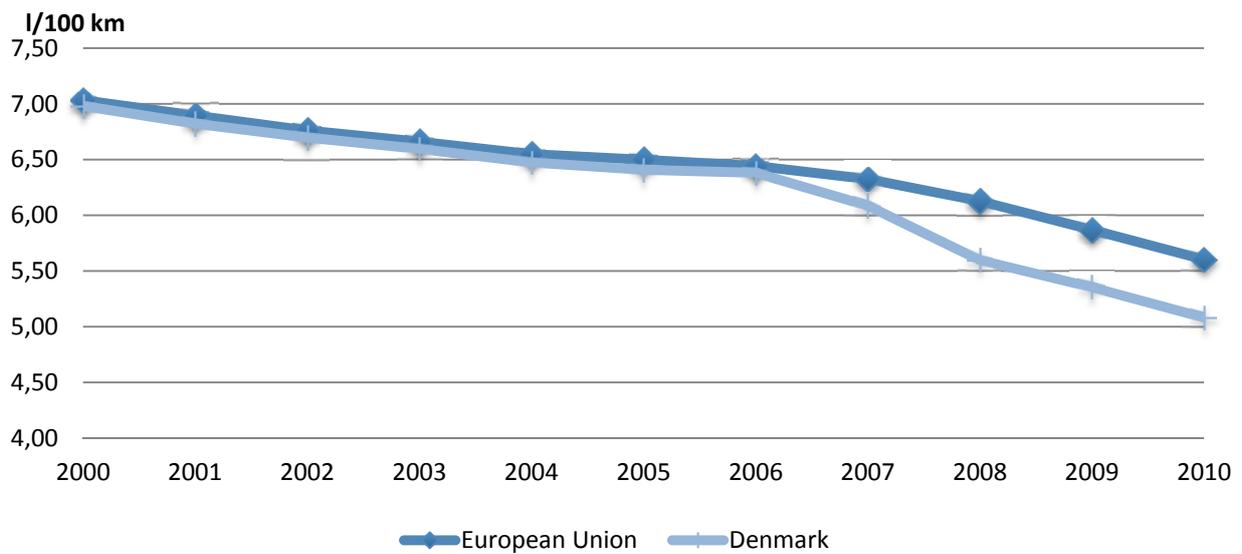
In 1997, the annual weight fee for private cars was changed into a fee dependent on the fuel efficiency called a *green owners fee*, which is the second part of the Danish cars taxation scheme. The law applies to vehicles registered in 1997 or later. In 2009, the same rule was applied to cargo vans registered in 2009 or later. Vehicles are separated into 25 categories and priced accordingly. Private petrol and diesel vehicles are charged as follows: Petrol cars with an efficiency of 20 km/l or more pay 580 DKK/year in 2013. Petrol cars with efficiencies less than 4.5 km/l pay 20,160 DKK/year. Diesel cars with efficiencies higher than 32.1 km/l pay 240 DKK/year. Diesel cars with efficiencies lower than 5.1 km/l pay 30,180DKK/year. Petrol and diesel cars in between the stated intervals pay a proportionate fee calculated by linear interpolation. Since 2010 diesel vehicles without particle filters are additionally subject to a particle emission fee of 1,000 DKK/year. More details, e.g. on other vehicle types, are available from (Ministry of Taxation, 2013).

The third taxation component is a *tax on fuel for driving*. The mineral tax on petrol is currently 4.095 DKK/l and 2.615 DKK/l for diesel (Ministry of Taxation, 2011a). In addition there is a CO<sub>2</sub>-tax and NO<sub>x</sub>-tax of 0.37 and 0.042 for petrol, and 0.41 and 0.045 DKK/l for diesel (Ministry of Taxation, 2011b and 2011c). The per-litre fuel taxes and are listed in Table 1. The levies include VAT and account for approx. half of the cost for the end consumer. There are no driving related taxes on electricity for electric cars until 2015.

**Table 1: Levies on petrol and diesel**

DKK/litre	Mineral tax	CO <sub>2</sub> levy	NO <sub>x</sub> levy
Petrol (lead free)	4.095	0.393	0.042
Diesel	2.615	0.435	0.045

The replacement of the yearly weight levy with the green owners levy based on the fuel consumption in 1997, has probably increased the average energy efficiency of vehicles. Unfortunately fuel efficiency statistics are not available further back than 1997. The adjustment of the registration based on the mileage of the vehicle in 2007 has been very effective in increasing the vehicle efficiency of new cars in Denmark. As shown in Figure 1, the specific consumption of new cars in Denmark followed the European average before the legislation but fell notably below starting in 2007 and onwards. In 2012 the energy consumption of new cars in Denmark (5.08 l/100 km) was the third best in EU. Portugal had 4.96 l/100 km and France had 5.05 l/100 km.



**Figure 1: Specific consumption of all new cars in Denmark and the European Union (fuel type not specified). (Odyssee, 2013)**

The Danish level of car registration levies is the highest in Europe (second highest in world after Singapore). This has also been the case historically and hence there was a larger potential than in other countries to give incentives by reducing the levies for the most efficient cars. This also means that it may be hard for other countries to copy such legislation unless there is a willingness to increase the levies on the least efficient cars significantly. While the efficiency of the new cars has increased in Denmark, we cannot conclude yet that this has affected the emissions from the sector as such. This is dependent on the use of the cars and on the use of older cars in the vehicle fleet.

The goal of the change is to gradually replace existing vehicles with more fuel efficient vehicles and to lower the CO<sub>2</sub>-emissions from the sector. This makes small and fuel-efficient vehicles relatively much cheaper than previously. Critics have argued that more “average” families will buy small vehicles as a “second car” than before leading to higher total CO<sub>2</sub> emissions and more congestion. There are indications of this happening, as the number of vehicles has increased – even in the time of the international financial crisis.

The high car taxation has also caught some attraction from battery electric vehicle producers, as there is a tax exemption for electric vehicle and fuel cell vehicles until 2015. The relative difference between regular vehicles and electric vehicle should create a larger incentive to buy electric vehicles, however it has proven to be hard as the charging infrastructure is still being spread and efficient regular vehicles are rather low costs in competition.

### 3. National policies for reducing energy demand and GHG emissions from road transport

The constant increase in road transport has caused increase in congestion levels, energy demand and CO<sub>2</sub> emissions (see Figure 2) and drove two consecutive governments to propose strategies on the matter.

In December 2008 a strategy called “Bæredygtig Transport – bedre infrastruktur” (Sustainable Transport – better infrastructure) was launched by the Danish Government (Government, 2008). The document was a response to the 50% increase in Danish traffic in the previous 20 years. The strategy did not aim to counter the increase, but to put down a strategy for how to mitigate the problems associated with it.

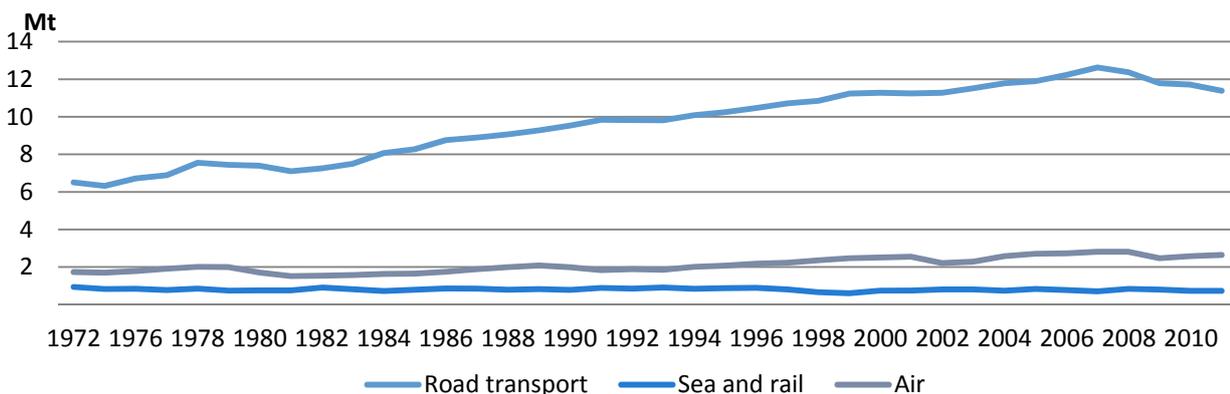


Figure 2: CO<sub>2</sub> emissions from the transport sector (Danish Energy Agency, 2013)

In January 2009 the strategy laid ground to a broad agreement “A green transport policy” between the Government and most of the Danish parliament (Government et.al, 2009). 93 billion DKK was put into an Infrastructure Fund and more than two thirds was planned to finance investments in public transport. This agreement is the first governmental strategy for the CO<sub>2</sub> emissions reductions in Denmark. The document was negotiated prior to the international financial crisis. Due to this, some of the initiatives have been partially implemented while others have longer perspectives. This report gives a list of selected initiatives presented in the 2009-agreement and describe the state of the situation by the beginning of 2013. Recently in March additional focus has been put on major changes in the Danish Infrastructure investments as the current government proposed to use funding from taxation of oil production for Togfonden DK (Train fund DK), which major task is to use 28 billion DKK for reducing travel time to one hour between all major cities in Denmark (Ministry of Transport, 2013).

The goals in the 2009 agreement “A green transport policy” are:

- Reduction of the CO<sub>2</sub> emissions from the transport sector (instead of an expected increase).
- Reconstruction of car taxation to support greener traffic.
- Public transport should cover a major part of the growth in transport demand. Rail roads should be more reliable, safe and modern.
- The road capacity should be expanded where it is needed the most, i.e. where the largest congestion problems are, but also where future growth can be expected due to business and societal developments.
- Biking is to be promoted as a choice where this is a realistic option.

- Denmark should be a green technology laboratory for transport
- Bridges, roads and railroads should not destroy irreplaceable nature.
- Noise and air pollution in cities should be reduced.

It is worth mentioning here, that this political agreement represents a change from the statements and recommendations from the Infrastructure Commission (Infrastrukturkommissionen), the previous Government established and which made its final report in January 2008. The recommendations here were focused on traditional “predict and provide” methodologies and high prioritisation of road transport (Infrastructure Commission 2008).

In March 2012 the current Government set a goal to change to 100% renewable energy in 2050 including transport, which will have significant influence on future changes in the transport policy.

The following sections will analyse the current state of the goals mentioned above.

### 3.1 Green registration levy, fuel efficiency and CO<sub>2</sub> emissions

As mentioned previously, the taxation structure for cars is threefold. The government’s strategy for the future is to make it cheaper to buy an energy efficient car, but more expensive to use cars in general. Altogether the tax-revenue from car taxation should not increase and the idea is to reduce congestion in rush hours using price signals. These initiatives are expected to reduce CO<sub>2</sub> emissions from the transport sector while increasing demand for public transportation.

In general the fuel consumption of newly registered cars has been decreasing since 1997 as shown in Figure 3. The annual efficiency improvements after 2007 for diesel vehicles have been considerable as results of the taxation changes mentioned in the previous chapter and more moderate for newly registered petrol cars, see Table 2.

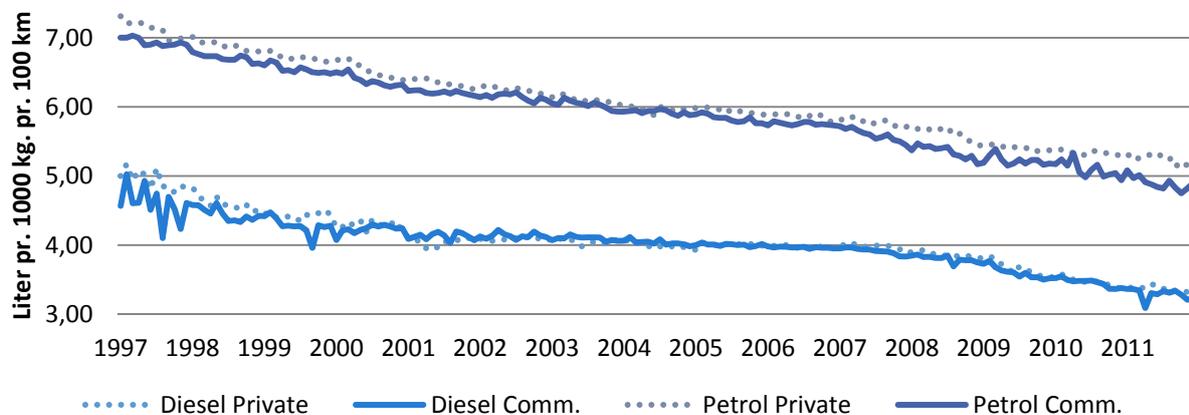


Figure 3: Fuel consumption in newly registered cars (Statistics Denmark, 2012).

Both road and air transport have experienced a drastic increase in CO<sub>2</sub> emissions in the period from 1972 to 2007 (94% and 62% respectively) reaching the peak in the 2006-2008 followed by the emission decrease in 2009-2011. Meanwhile the CO<sub>2</sub> emissions relating to sea and rail transport have decreased over the entire period by 23%, mainly due to the lower usage of these modes of transport (see Figure 2). The recent decrease in emissions from road transport cannot be attributed to the new regulation since most vehicles in use are older than the regulation. It is a consequence of the international financial crisis. The calculated average annual improvements of the efficiency of new cars can be seen in Table 2. For private petrol cars the reductions do not contribute enough to counter the increase in vehicle usage during the analysed period.

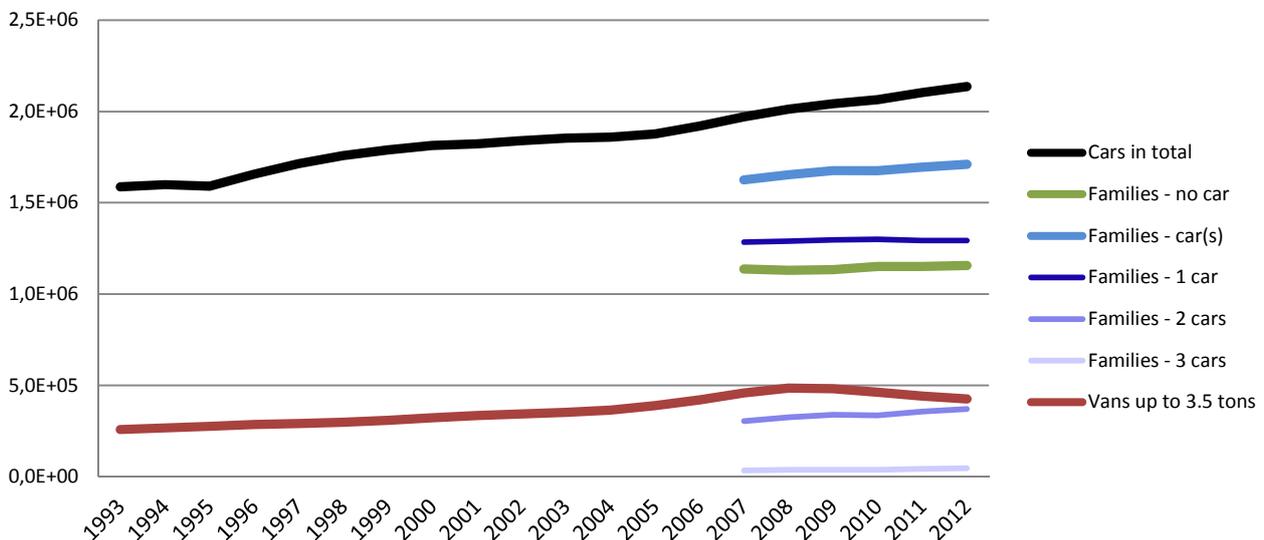
**Table 2: Reduction in the annual average fuel consumption of the car fleet. Based on (Statistics Denmark, 2012)**

	Diesel private	Diesel Commercial	Petrol Private	Petrol Commercial
<b>1997-2006</b>	1.9%	1.2%	1.8%	1.6%
<b>2008-2012</b>	3.2%	3.7%	2.1%	2.5%

Comparing these reductions to the 2.4% annual increase in the vehicle km travelled from 1980 to 2011, it is evident that yearly increases in the car efficiency has to be equal to or greater than currently experienced in order to reduce net emissions. In this period the passenger km travelled has increased by 1.2% annually indicates that the load factor has decreased parallel with increased car ownership (Statistics Denmark, 2012).

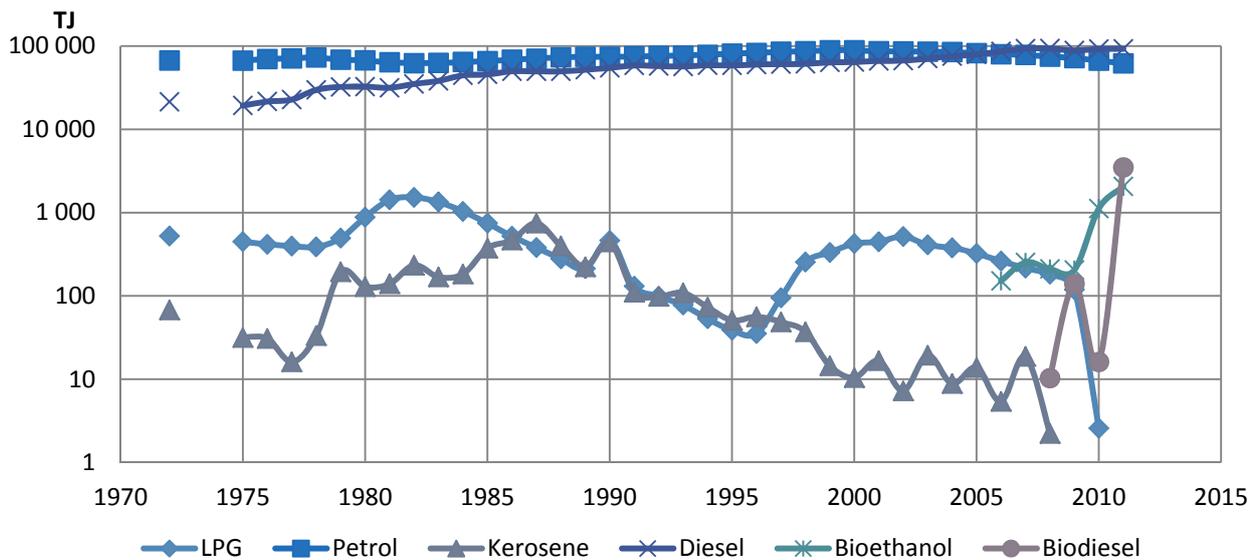
In conclusion, the new regulation on green car registration improved efficiency and reduced the CO<sub>2</sub> emission per-vehicle beyond what could be expected without the new regulation, but only marginally enough to hardly enough to compensate for the increase in road vehicle kilometres by diesel vehicles and commercial petrol vehicles when looking at a longer period than the last 3-4 years. The largest group of vehicles, the private petrol cars, have experienced a reduction below the growth rate and, thus, have not achieved a net CO<sub>2</sub> reduction.

From Figure 4 it is evident that the number of cars is increasing – even in the time of the international financial crises. From 2008 until 2012 the number of vehicles increased with approx. 170,000. While the number of families with one car only increased with 7,700 in the period, the rest of the increase was in families with two vehicles or more. On the other hand however, the number of passenger kilometres has decreased with 2 per cent in the period from 2008 to 2012. In total there has been a decrease of approx. 7% in the CO<sub>2</sub>-emissions from personal vehicles compared to the peak in 2007 – see Figure 2. It remains to be seen what the longer term effect is. The number of vans has decreased in the later years but is still approx. 30 per cent higher than in 1993.



**Figure 4: The total number of cars and vans, and the structure of car ownership in relation to cars pr. family (Statistics Denmark, 2012).**

The final energy demand for transport has been constantly increasing from 134 PJ in 1972 to 211 PJ in 2012, an increase of 57%. By comparison the population increased by 12% in the same period. This increasing fossil fuel dependence, together with the fast declining national reserves and the large CO<sub>2</sub>-emissions from the sector has brought the issue to the national political level.



**Figure 5: Fuels for road transport (logarithmic scale). Based on data from (Danish Energy Agency, 2013)**

The energy demand, by fuel, is shown in Figure 5. A shift in fuel consumption from petrol to diesel has taken place during the period while bioethanol and biodiesel have increased their shares (albeit from small numbers), the use of LPG and kerosene has been decreasing. LPG was previously used for busses in several cities, but in 2011 no consumption was reported. Regulation enacted in 2009 requires a minimum of 5.75% biofuel energy-wise in all fuels for private and commercial road use (Danish Energy Agency, 2011). The requirement is enforced on the producer side and calculated as the share of the total fuel production, regardless of the fuel type with consideration that some biofuels are more sustainable than others from energy perspective. The regulation is based on EU legislation seeking to cover 10% of road energy consumption from renewable energy by 2020. The legislation has been slowly phased in with increasing biofuel shares from 2010, resulting in the trend shown in Figure 5.

### 3.2 Road pricing, Congestion Ring and Congestion Commission

Denmark has no direct road-pricing. There is however a toll on the new Øresund Bridge and Great Belt bridge connections. The only taxation on vehicles usage is the fuel tax. The 2009-agreement planned to implement a comprehensive GPS based road-pricing scheme by 2013 and use the income to reduce the registration tax. The plan expects to draw experience from an equal Dutch project. The Dutch project was cancelled by the previous government in 2010 due to political as well as technical problems and no new strategy for road pricing has been debated since.

The current Government had re-started plans to have a km-based tax for trucks on Danish highways by 2015, similar to the German "Maut". The tax was expected to reduce emissions of NO<sub>x</sub>, CO<sub>2</sub> and particles as cargo is expected to some degree to be more efficient and to be moved from trucks to rail and waterways. Critics have argue that since a relatively high share of trucks load and unload in non-urban parts of Denmark, the tax will hit relatively harder on the already less developed parts of the country. It has thus been suggested to issue a compensation for these areas of the country. This scheme was also taken of the agenda as a small part of a larger growth plan to boost private businesses in February 2013.

It was the plan of the current government also to build a congestion ring around Copenhagen to limit the road congestion, as well as to limit the air and noise pollution and increase public transport. The idea was inspired by similar projects in other larger European cities. However, strong opposition in the media among other factors led the government to cancel these plans.

Instead a Congestion Commission was established to analyse the best strategies for reducing the congestion in the capitol region. The commission will deliver its report in August 2013 (see section 5.3.1).

In December 2012 an old idea of an “eastern ring road” around Copenhagen, in the form of a Harbour Tunnel with the price of 27 billion Danish DKK, was accepted by the City Council of Copenhagen based on a report made for the Ministry of Transport (Rambøll, 2012). The majority of the City Council argues that the tunnel is expected to reduce the congestion along with the air and noise pollution in central Copenhagen. Experts in traffic modelling however show that such a strategy could also increase traffic in the parts of the inner city and in part of the suburbs. Also it has been suggested that the price tag would be around 12€ per vehicle passing two times a day through the tunnel even when assuming a life time of 40-50 years for the investment. No financing has yet been found, but the Lord Mayor of Copenhagen has asked the Congestion Commission to include the Harbour Tunnel in its recommendations as contribution to congestion reduction in Copenhagen. Also many other proposals focusing on public transport have been made by Copenhagen Municipality and all of the surrounding municipalities for the Congestions Commission (Congestion Commission 2013).

### 3.3 Public transport and biking

The goal from 2008 was that the majority of the expected increase in the transport demand is covered by public transport and biking. The development in passenger transport is shown in Figure 6. Both private car and public transport increased in the period of 2008 to 2011. On the other side biking decreased slightly and heavy van transport decreased quite substantially in the same period leading to a total decline in the passenger transport.

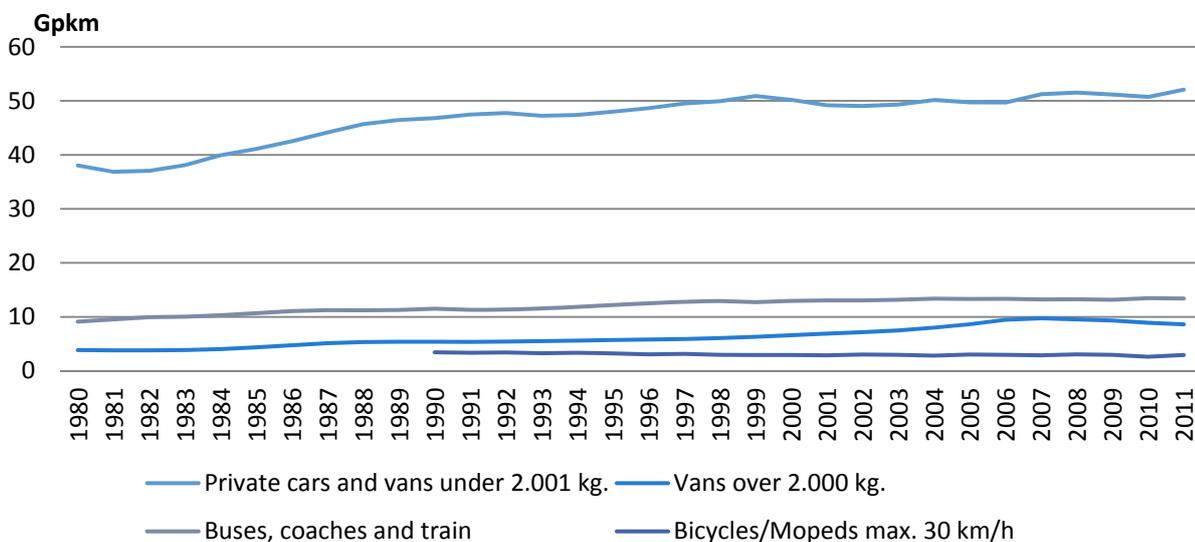


Figure 6: Total passenger transport (Statistics Denmark, 2012).

The total share of public and bike transport was 22% in 1990 and has stayed more or less in that range until today (Statistics Denmark, 2012). Thus the strategic goal of covering a larger share of the transport by biking and public transportation has not yet been met. The Infrastructure Fund however has allocated a number of projects to promote a further transition towards more biking and public transport, but this will take some years to have an effect.

As part of the Infrastructure Fund two of the major decisions were made in 2009. One was to replace a very old signal system causing major delays (21 billion DKK of the 97 billion in the Fund).

Also it was decided to improve the capacity of intercity trains with new tracks for 10 billion DKK (Government et.al, 2009).

In June 2012 a broad agreement in the Parliament was made on additional projects funded by the Infrastructure Fund. The agreement is targeted on reducing prices of public transportation and public transportation infrastructure (Government et.al, 2012b):

- 20 % ticket reductions for public transport in off peak hours,
- flat-rate for public transportation for students at a low level,
- improve the metro in Copenhagen to enable it to operate 20% more often
- subsidies to “Super bike paths” to reduce barriers and speed up bike travel times (see section 4.2),
- Electrification of the remaining part of the tracks between Copenhagen and Esbjerg to reduce travel times and ensure more efficient public transport.

In addition the current government is currently negotiating an additional significant improvement to public transport in Denmark (Ministry of Transport, 2013). With a Train Fund financed by taxation of oil extraction companies, the plans is to use 28 billion DKK in addition to the Infrastructure Fund to:

- Decrease travel time with new tracks on selected part of the main railroad system.
- Electrification of all major railroad tracks
- Travel time should be one hour between Copenhagen and Odense, Odense and Århus, Århus and Aalborg.

In Copenhagen it should also be noted that currently a new circle line on the Metro is being built to be completed in 2018 with a cost of about 15 billion DKK (in 2005). These expenditures are additional to the funds mentioned above.

Another major initiative for 4-5 billion DKK, financed by the national railroad company DSB and the regional public transport companies is “Rejsekortet” (Travel Card, 2013). Currently the Travel Card (Rejsekort) is being implemented, and is now starting to replace clip-cards and individual tickets on a larger scale. The infrastructure for the Travel Card has been implemented in most parts of the country, regardless the existing debates and possibility of technology being outdated by smart phone applications and being very costly. As mentioned above the Government has ensured a push for new payment method by subsidising that the Travel Card can give a cheaper travel outside peak hours.

In total approx. 140 Billion is being spent currently which represents a change from previous years, as approx. 80% of such investments are prioritised for public transport. The investments in road transport is focused on improvements where there is already congestion problems. Also initiatives are made to reduce noise and local emissions.

### **3.4 Freight transport**

A decline in the overall freight transport has been a result of a decline in road freight transport. Rail freight transport has increased marginally in the last 3 years. The vast majority of freight transport in Denmark is still largely covered by road. The agreement from 2009 calls for an analysis of the transport rail corridor possibilities through Kastrop to Sweden along the new Femern connection from Germany. The agreement also ensures the upgrading of existing rail systems with the focus on freight and reopening of previously closed connections to smaller industrial harbours.

### 3.5 Road- and railway infrastructure investments historically

Denmark has invested increasing amounts of money in the infrastructure in recent years. Major projects are the Storebælt and Øresund Bridges, as well as the Metro in Copenhagen. Two forthcoming projects are the Femern connection from Rødby to Puttgarden in Germany and the metro city ring in Copenhagen. Below is a figure of the infrastructure investment from 1990 to 2011. The Øresund and Storebælt bridges both have a rail as well as road parts and are thus shown separately from road and railway investments. As can be seen investments in the road transport have increased drastically since 1997 as compared to investments in railways. The 92 billion DKK in the Infrastructure Fund, of which more than two thirds will be prioritised for public transport is only included in 2010 and 2011, but should be more visible in the coming years.

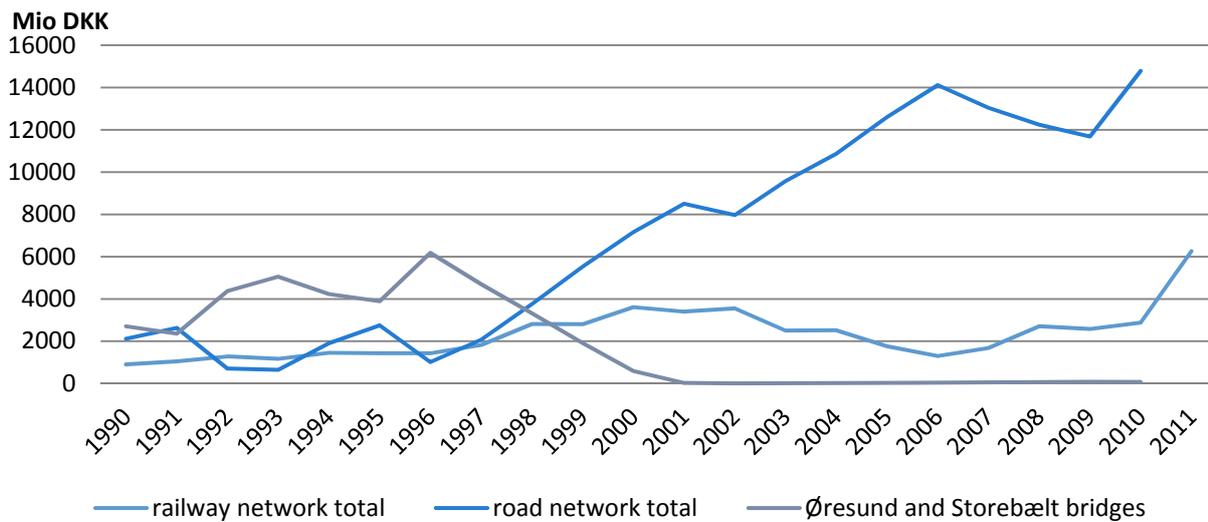


Figure 7: Infrastructure investments in 2012-prices (Statistics Denmark, 2012).

### 3.6 Summary

The purpose of the traffic related taxation in Denmark has changed over the cause of the development in the transport sector. Originally transport taxes were introduced to keep an artificially high fuel price after the price drop in the beginning of the 80's and also to compensate the fact that Denmark is not a car producing country i.e. issues related to the balance of payment and security of supply. Today however, all taxes and levies are, at least to some degree, based on environmental concerns, but also as a part of the general funding of the state welfare expenses.

The agreements from 2008, 2009, 2012 and 2013 about sustainable transport contain many goals but also many new infrastructure investments - some of which have not yet been implemented into concrete legislation. The change to a registration levy already has an effect on the fuel efficiency of new vehicles. Other initiatives such as the current heavy investments in public transport have a longer time frame, and the results remain to be seen.

## **4. Private sector and local government initiatives**

The private sector and local government has proven important in the development of the Danish transport sector. The selected projects and their results are briefly described in the following sections.

### **4.1 Light-rail systems**

In general both DSB and regional public transport companies (publically own) take many initiatives in order to increase the bus and train share. Here we present the plans for light rail, which also involves initiatives from municipalities and regional authorities.

A light-rail is a modern version of the tram system which was removed in Denmark approx. 30 years ago. While the city of Copenhagen has built a Metro in the city centre and is expanding this by constructing a Metro ring and possibly more lines, there are new initiatives in other Danish cities to introduce trams, including stretches on the street level as well as light rail in the separate lines. The plans are most advanced in Aarhus, but plans also exist for Odense and Aalborg. In addition, there have been proposals for a light rail as a solution in the Ring 3-corridor around Copenhagen and for connecting suburbs better to the centre with lower costs than the Metro-expansion.

In Aarhus concrete plans exist, and first phase could be established already in 2015. The basic idea of the phase it to connect two older local rail lines north and south of the city with several stops in the city centre. Additional phases include a western line perhaps as far as the neighbouring city of Silkeborg.

The municipality of Odense is currently conducting a pre-investigation for a light rail in the city. The preliminary plans are to connect the main rail station with a shopping mall in the city centre, University of Southern Denmark south of the city, and the coming "Super Hospital" at the nearby highway junction. The line, if decided, is expected to be finished by 2016. At the moment there are no plans to establish connections with neighbour cities.

Aalborg Municipality is conducting a pre-investigation for a bus-road/light rail through the city. Plans are first to establish a bus-way and later upgrade it to a regular light rail. The route is planned to propagate eastward from the main rail station, under the E45 motor highway to Aalborg University's main campus and onwards to the coming new Aalborg University Hospital. The bus-way to the university will be finished in the upcoming months.

### **4.2 Biking and walking in Denmark**

One of the world's first pedestrian streets is Strøget in Copenhagen. Its introduction caused massive debate among the public and in the media. Opponents feared that the shopping would decrease and lead to the closing of many shops. Instead shopping increased and several adjoining shopping streets have been turned into the pedestrian streets in the meanwhile.

The Danish Biking Association was established in 1905. The organisation has had a major effect on the promotion of bike paths in Denmark and on promoting biking as a primary means of transportation. Today the organisation mainly functions as a consultancy regarding bike related issues.

The two major bike cities are typically mentioned are Copenhagen and Odense, but all Danish Cities have a very strong presence of bike lanes (Odense Municipality, 2013). An example is Odense, where in the period from 1999 to 2002 the city was officially named the "National bike city of Denmark" and received 10 million DKK in support in addition to 10 million DKK of local funding. In the following four-year period, more than 50 bike projects were developed and implemented in Odense. This resulted in a 20% increase in bike trips and this development has continued. Also it

was assessed that the project resulted in 33 million in health cost savings. The results can be seen here: [www.cykelby.dk](http://www.cykelby.dk).

The Bike Super Pathways (Cykelsuperstier.dk) project was initiated in 2009 by Copenhagen Municipality and developed by the Capitol Region and 22 cooperating municipalities. The goal of the project is to build a grid of high-speed bike paths with few intersections as possible with air and repair stations on route to boost bicycle commuting on distances longer than five kilometres. To date only one super bike route has been opened, but the response has been very positive. In April 2013, the second super bike path will be open. There are currently 28 routes planned, forming in total 494 km of bike paths. According to the project, the bike paths have a potential of increasing bike commuting by 30%. In the agreement from 2012 the Government decided to support this initiative on a national scale with 189 million DKK (Government et.al, 2012b). The subsidy can be obtained in combination with local co-funding.

### **4.3 Public and industrial partnership on alternative fuel vehicles**

There are many private, or half private / half public organisations working within new alternative fuels. Here some of these initiatives are listed.

The Danish electric car committee (Dansk elbil komite) is an organisation for electric car owners. It was established in 1980 to "disseminate knowledge and use of electric cars and other road vehicles, promote the production of such and components as well as an exchange of experiences among users of electric vehicles". Both private persons as well as public and commercial companies are permitted as members. (Danish electric car committee, 2013)

Another organisation within this field is the Danish alliance for electric cars. It is an industry corporation, under the industry association Danish Energy (Danish Electric Vehicle Alliance, 2013). The alliance promotes a massive increase in electric vehicles in Denmark and currently hosts 53 actors in the Danish market. Many industrial actors are represented, such as auto manufacturers, electricity companies, other industrial partners, university divisions and electric leasing companies. The purpose of the organisation is to make Denmark a front-runner in electric vehicles, including plugin-hybrid vehicles, and to achieve synergies across the many actors. The alliance functions as a representative for its actors towards politicians, the media and other organisations as well as a conductor of hearing statements to relevant legislation proposals. The alliance has four main working areas: (i) increasing the share of intelligent electricity meters in households to prepare for the establishment of a smart-grid. (ii) Standardisation of the charging plug and outlet to allow charging on three phases together with an intelligent back-in system. (iii) To Up-hold subsidies to allow for the rollout of quick-charging stations and battery exchange stations until a critical mass of electric vehicles (due to economy of scale) together with battery technology makes it unnecessary. (iv) changing the attitude of the population to a positive modus for electric vehicle driving.

There are several interesting private initiatives regarding electric vehicles. The Israeli-Californian company *Better Place* which sells electric cars, leases the battery and provides access to battery charging stations is also very active in Denmark. Better Place is economically backed-up by the partly state owned electricity producer DONG. Several other companies have similar products in Denmark. *Clever* is company owned by six electricity companies and provides charging infrastructure. Together with the auto rental company Sixt, Clever also leases electric cars. A third electric vehicle company is *Clean Charge*, who represents the German electricity company RWE in Denmark. *Clean Charge* exclusively sells intelligent charging stations to companies.

As discussed in section 5.2.1 and 5.3.3 a cornerstone in a 100 % renewable transport sector, together with electrification, is the use of fuels generated from biomass. The Bio Refining Alliance is an organisation attempting to promote research and public funding in efficient production of second-generation biofuels (Bioregining Alliance, 2013). The partnering companies DONG, Haldor

Topsøe, Novozymes and Landbrug og Fødevarer (Danish Agriculture and Food Council) are major players in Denmark and internationally.

Car sharing is a concept in growth. Many actors exist in the Danish market, privately, publicly and commercially based. The concept is to pay for consumption plus monthly fees rather than privately owning a car. Additionally one can reserve the car best suited for the task. The concept saves public space as the cars are rarely parked unused, as opposed to privately owned cars. The majority of the car-sharing clubs and initiatives are collected in the organisation Danish Car-sharing (Danske Delebiler) (Danish Car-sharing, 2013).

#### 4.4 The status on alternative fuel vehicles

The registration levy on new cars in Denmark applies only to fossil-fuels vehicles (e.g. E85, biodiesel, plugin-hybrids and so forth). The exception of other vehicles, e.g. EV and FCEV has been extended several times, with the latest until 2015. This relative advantage for electric and non-fossil fuelled vehicles, have led many international companies to invest in test-centres in Denmark to promote their technology (see section 4.3).

As hybrid and plugin hybrid vehicles are not exempted for the registration tax, they are relatively more expensive and thus quite rare in Denmark. Currently hybrid vehicles are experiencing a higher growth in market share on the world market compared to pure electric vehicles.

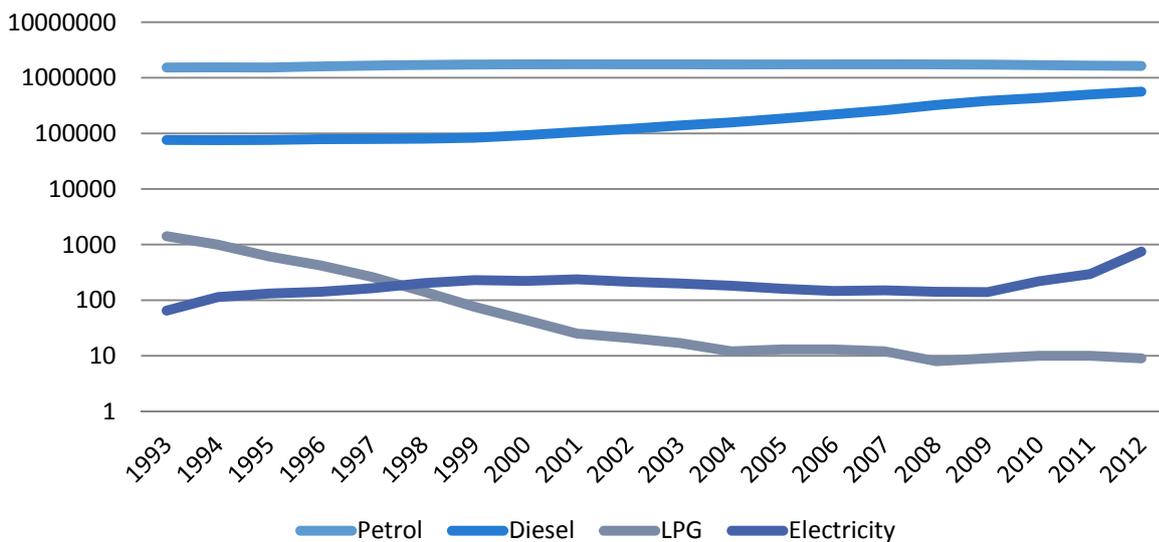


Figure 8: Stock of passenger cars by energy carrier. Logarithmic scale. Source: Danish Statistics.

As can be seen in Figure 8, the stock of electric vehicles has increased drastically over the past twenty years. However, the share is still very small compared to those of petrol and diesel vehicles. Over the same period the stock of diesel vehicles has increased by 645%, while petrol cars have increased by only 7%. The stock of LPG vehicles has decreased drastically from 1411 units in 1993 to only 9 in 2012. No data is available on the stock of natural gas vehicles since they are grouped together with diesel vehicles by the Danish Statistics. However since no public available infrastructure for natural gas vehicles exists, the stock is likely very small.

The agreement from 2008 has to some degree succeeded in making Denmark a laboratory for green vehicle technology. However the share of non-fossil vehicles has not reached the desired levels yet.

On the 22<sup>nd</sup> of March 2012 an agreement on the Danish energy policy for the years 2012 to 2020 was signed by all but one party in the Danish parliament (Government et.al, 2012a). It was agreed that the goal of energy supply based on renewables requires initiatives on increasing energy efficiency in all sectors. In the longer term transport must, according to the agreement, undergo a radical transformation from fossil fuels to new fuels such as electricity and biofuels. A strategy will be developed to promote energy efficient vehicles such as hybrid plug-in electric cars. The strategy anticipated 70 million DKK for the period of 2013-2015 to support the roll-out of charging stations for electric cars, infrastructure for hydrogen and gas infrastructure for freight transport. The biofuel legislation was altered for implementing 10% of biofuels in 2020. However, it will not be introduced until an analysis of alternatives to reach the EU goals has been finished in 2015.

In January 2013 the Danish Government reported a goal to build 5000 publicly available charging stations and to reach the level of 200,000 electric vehicles by 2020.

## **5. Analysis and research programs**

### **5.1 Pre year 2000 research**

In the early 1970's there was a strong public debate on the continuing growth in economy and resulting increase in the road vehicle kilometre by private cars and cargo trucks. This led the academy for technical sciences to engage in the project: "Traffic 2000: A research project about the traffic development under different social conditions" (Academi for Technical Science, 1977). One of the prerequisites of the report is the fact that the massive growth in the car ownership has indeed led the smaller cities in Denmark to grow, but in a way that resulted in longer distances between dwellings, shopping areas and workplaces making biking and walking less feasible. This led to investments in public transport for shorter distances, but as the report states: "People without access to cars are put in a bad place today, where the placement of housing, industry and services are laid out on the premises of the car". The report also outlines that additional private car transport leads to an increased number of traffic accidents and deaths along with an increase in energy consumption, which are both a threat to the national economy. The project formulates five scenarios for the growth of traffic towards the year 2000, depending on economic growth (high, varying and planned) and traffic planning (individual and collective). The report argues that since little is known about the future, the scenarios should only be seen as a lay out of different directions in which the transport sector could go. The results from the scenarios are different in many ways, but what is found to be in common for the scenarios will likely be true, the report argues. The project finds the expected traffic use to be in the interval 20-70 billion pkm in year 2000. The actual number were 75 billion pkm (however 68 billion pkm in 1999 and 71 billion pkm in 2011). The expected share of public transportation was 10-20 %, actual number was 17%. The expected shares of walking and biking were 8-13 %, actual value 4%. The expected share of private cars was 65% to 82% the actual number was 66%. The report also states scenarios results for the car park, energy consumption, freight transport, accidents, infrastructure investments and employment in the transport sector. The report is strictly non-political and includes no suggestion as to what scenarios are preferable.

In 1992 a national transport council was established (Transportrådet). It was active until 2002. One of the first publications focused on the need for a coordinated effort on transport planning and the need – in the longer term to have a lower growth in transport demand and have more growth in public transport (Danish Transport Council, 1993).

In 1999, the Danish road directorate released a report on the city structures effect on cyclists (Jensen et.al, 1999). The city structure was defined as population density, size of city, topography of city and location of functions. It was found that the most critical factors for bike traffic were population density, city form and topography. The size of the city matters is negligible for cities with

more than 10,000 inhabitants. In smaller cities bike share falls drastically with population. In the metropolitan area and major provincial cities the bike share was found to be higher when workplaces are located in the central districts. However, the location in relation to public transport nodes has no significance for the extent of cycling. Experience shows that the bike share increases with integrated transport and land use planning. On the one hand, the cycle network and public transport services must be expanded, simultaneously with reduction in the road network and the availability of parking spaces. On the other hand, the development must continue and transport-creating functions must be placed in the city centre and / or near public transport hubs - and with good access from the cycle network.

## 5.2 Recent Publications

The following section includes newer studies on the whole energy sector including either the whole transport sector or on parts of it.

### 5.2.1 *Studies, research and reports focusing on the entire transport sector*

In 2006, the Danish Engineers weekly newspaper *Ingeniøren* (The Engineer) launched an article series on future traffic in Denmark. As part of this, DTU Transport produced a report on future scenarios for transport in Denmark as background material for the articles (Nielsen et.al, 2006). The report is based on a series of scenarios depicting a range of possible future traffic situations in Denmark. The report's analysis and numbers are primarily built on the author's experience from the traffic sector and use of older model calculations and scenarios. The scenarios discussed are: *Business as usual*, *Regionalisation*, *Accessibility and mobility*, *The golden age of the car*, and *Environment in focus*. The report discusses the possibility and consequences of the sketched scenarios together with societal trends and relevant means to achieving the scenarios. The authors find the *Business as usual* scenario also called the *worst-case scenario* to be the most likely scenario. Their conclusions are based on historical political hesitance on the matter eventually leading to more and more congestion.

In 2006, the Engineers union of Denmark published the IDA Energy Plan 2030 (Lund and Mathiesen, 2006). The plan is the first of its kind to include the entire energy system including the entire transport sector. The plan sketches how an expected increase of total primary energy use from 800 PJ/year in 2004 to 1000 PJ/year in 2030 could instead be reduced to 600 PJ/year together with a CO<sub>2</sub> emission reduction of 60% compared to 2006 levels. Oil prices and CO<sub>2</sub> prices were varied in the analysis, but in all simulations the proposed solution was found to be a socio-economically cheaper option than the other business-as-usual alternative. The report states that transport has always been the most difficult to solve for energy policy. While the overall energy use has been stable in Denmark for many years, the energy use for transport has constantly increased. The energy use of transport is almost exclusively based on oil, and if no action is taken, the report stresses that the transport sector will undermine Denmark's attempt to reduce its CO<sub>2</sub> emissions and uphold its energy self-sufficiency. The plan suggests how to reduce energy consumption for transport by 20% compared to 2006, among other things replacing 20% of petrol by biofuel and using 20 % electric vehicles. The increase in energy consumption can be stopped by stabilizing passenger transport by car, by shifting some road transport to rail and by increasing the energy efficiency of the car fleet. The transport part of the project was further described by Mathiesen et al. (2008). The report has found that no single technology could solve the problem of ever-increasing CO<sub>2</sub> emissions from transport, and proposed a coherent effort to integrate transport into energy planning, using multiple means for promoting sustainable transport. Moreover, it has concluded that a 100 % renewable energy transport system is possible but would be connected to significant challenges in the path towards it. In a short-term proposal for 2030, Mathiesen et al. concluded that it is possible both to reduce CO<sub>2</sub> emissions substantially and, at the same time, gain economic benefits. The authors found that biofuels cannot solve the problems of the transport sector alone.

In 2009, the report was followed up by the IDA Climate Plan 2050 on achieving 100 % renewable energy in 2050, including the transport sector (Mathiesen et.al, 2009). In the IDA Climate Plan there are sufficient domestic biomass resources, however, in 2050 the resource consumption constitutes a challenge. The 285 PJ can potentially be supplied with national resources, but will not leave many resources for anything else. In this plan significantly more focus was put on breaking down the transport sector to make achievable measures in each part of the sector.

In 2010 the Danish Commission on Climate Change Policy of 2010, launched by the previous government of Denmark finished their report on converting Denmark to 100% renewable energy in 2050. The report includes domestic road transport sector but not international travel form e.g. ships and aviation. The commission gave 40 concrete recommendations, three of which relate to the transformation of the transport sector from fossil fuels to electricity and biofuels (Danish Commission on Climate Change Policy 2010). Alternatives to transforming the transport sector to electricity and/or biomass was also analysed but deemed not sufficient by the commission. The three recommendations related to transport are: (i) The exemptions of registration levy on non-fossil vehicles should be continued after 2015 to ensure clear frames for car manufacturers and the market over a longer period. The exemption should be continued until 100,000 such vehicles have been registered to allow economies of scale without jeopardising the national economy. The exemption should also, already from today, include plug-in hybrid vehicles and can later be expanded to other alternative fuel vehicles. (ii) That a grand plan for the rollout of a network of charging stations, quick-charging stations and battery-exchange stations be made. (iii) That demonstration projects on retrofitting high-consumption vehicles with limited infrastructure demands (no examples are given) to biogas/natural gas or other alternative fuels are supported. In general the Commission recommends that new car taxations systems should be designed to help the long-term transformation to a society independent of fossil fuels.

In 2010, the consulting engineering company COWI produced the report *Climate strategy – initiatives in the transport sector* for the Capital Region on reducing the CO<sub>2</sub> emissions from the transport sector (COWI, 2010). In an initial literature study COWI found that: Carefully coordinated actions of many initiatives have a greater chance of success and sustainable results than single actions. Combination of carrot and stick provides the most effective results. The most effective projects, from a climate perspective, were not headlined as CO<sub>2</sub> reduction projects. Based on the literature study, the report lists 34 single initiatives to reduce CO<sub>2</sub> emissions from transport. For all initiatives the impact on CO<sub>2</sub> emissions and the worst/best case price is calculated. The result is a sorted list with price per ton of CO<sub>2</sub> reduction. The most cost-effective initiatives was car-pooling, changes in taxation to promote more efficient cars, removal of transport tax-deduction (giving as incentive to get job a job longer from home), bus lanes, car sharing, parking fees and congestion ring.

In April 2012 the municipality of Copenhagen released a report on “Expansion of public transport in Copenhagen”. The report is produced by the company Tetraplan and includes a traffic model with different scenarios, including congestion rings or not, large expansions of public transport etc., for the years 2009, 2018, 2025, 2032 and 2040 on city growth and expansions of the public transportation networks (Tetraplan, 2012). The report documents the traffic related consequences (congestion, CO<sub>2</sub> emissions and air and noise pollution) of a step-by-step expansion in the context of the expected gradual growth in the population and workplaces in Copenhagen. The model calculates the traffic and its distribution on different means of transport and routes. The report also includes a chapter on the consequences of free public transport in and outside of the cities. The report found, as were also found in previous studies (Danish Board of Technology, 2006) that the health benefits and thus positive socio economic would only just be balanced by the loss in revenue due to the modal shift from mainly walking and biking and only to a lesser extend from driving.

### **5.2.2 Research related to road transport**

The 2008 transport strategy planned to implement a comprehensive GPS-based road-pricing scheme by 2015 with a similar Dutch project as a role model. The Dutch project was however dropped in 2011 due to political and technical problems and no new strategy on the matter has been politically discussed since. In 2009 when it was clear that the Dutch model would be severely delayed the Danish green think tank CONCITO, suggested a low-tech solution in the report "Road-pricing in Denmark – when and how?" (CONCITO, 2009). After examining various options, including higher gasoline taxes, CONCITO points to a simple kilometre tax as the most optimal solution. The tax is levied by sealing the odometer in new cars and reading it once a year - just as done with most electricity meters today. It was found that from a climate point, this is a better solution than the alternatives due to low implementation costs and fear of increased inter border trade with higher fuel taxes. It was suggested to use the revenue to reduce the high Danish registration levies in continuation with the 2008-strategy. The CONCITO-solution would thus not help prevent increasing congestion.

The recommendations of the Climate Commission's report regarding road transport were the basis of the 2012 report "Danish transport without coal and gas – how?" (Danish Board of Technology, 2012). The purpose of the project was to address what is required to transform the transport sector to 100% renewable energy as well as the influence on everyday life, environment, welfare and socio-economy. A scenario is designed with 100% renewable energy, but limited to the biomass that can be produced domestically without changing the national food production. When completing the analysis the model used required that energy costs remain reasonable and that mobility must not be reduced. It is found that by reducing the expected growth in transport—especially in personal cars - the energy demand can be reduced enough to be satisfied by electricity and biofuels.

In May of 2011 the consulting company Ea Energy Analyses released a report on "Scenarios for the transport sectors energy consumption in Denmark" for the Energy and Oil Forum (Hethey et al., 2011). The report lists three scenarios for 2020, 2030 and 2035 for achieving reductions in emission and energy use higher than forecasted from current trends and EU agreements. The scenarios were High-efficiency, High Biofuel utilization and High Electric Vehicle use. Each scenario had aggregated initiatives bordering the possible. The energy efficiency scenario was found to give the lowest CO<sub>2</sub> emissions and at costs lower than the reference scenario.

### **5.2.3 Bike related research**

In 2008, DTU Transport released a report on "The potential for the transformation of short car trips to biking and walking" (Christensen and Jensen, 2008). The project was ordered by the Danish road directorate and used the traffic habit survey as data source. The report described the factors having the greatest impact on selecting biking/walking or driving for trips shorter than 22 km. The hills and temperature seem to be of importance, in addition to the car-ownership. Also the number of kids seemed to be an important factor. The means to increase bike utilisation was concluded to be increasing the cycling speed (i.e. improving infrastructure) while rising travel distance and expenses for the motorists).

A 2009 COWI report has calculated the social and personal economic costs and benefits of biking compared to car driving (Copenhagen Municipality, 2009). It was found that riding a bike in general saves society 1.22 DKK/km mostly due to the health benefits. By comparison car driving in the city costs society 1.13 DKK/km, which is taxed with 1.18 DKK/km. When comparing the costs for public transport, driving a personal vehicle and cycling a specific 3 km route in Copenhagen, including the cost of lost work hours, the bike is found to be the cheapest, followed by the car and the bus. The prices were 5.4 DKK for biking, 15.9 DKK for driving and 28.5 DKK for the bus ride. This could explain why upgrading the infrastructure networks is not sufficient to perform a modal shift towards public transportation. Finally, the report also analysed the potentially reduced externalities per km

by transforming different types of transport to biking. The result was 0.73 DKK for an average car, and 1.98 DKK for peak-hour cars, 0.36 DKK for bus, 0.13 DKK for electric trains, and 0.18 DKK for diesel trains. There is a socioeconomic benefit in transforming all types of transport to biking, however, the by far the greatest potential lies in the conversion of the peak-hour car trips.

One way of reducing private car driving is to combine biking with public transport for longer trips. A 2009 report by the Danish Transport Authority - Trafikstyrelsen, "Better interaction between bicycle and public transport", presents several ideas for how this could be achieved (Danish Transport Authority, 2009). To many people the bike is a natural or necessary extension of the public transport system. Every fifth train passenger cycles between home and train station, but only every twentieth cycles from the station to their destination. The report finds a large potential for increasing public transportation by making bikes easily usable at both ends of the trip and makes several suggestions how to achieve this goal.

### **5.3 On-going research and analyses**

In this section different on-going research is presented. The main part of transport research in relation to climate mitigation is based at DTU (DTU Transport, DTU Management Engineering) and Aalborg University (Department of Development and Planning, Department of Architecture, Design & Media Technology, Department of Energy Technology, C-Mus - Center for Mobilities and Urban Studies).

#### **5.3.1 Congestion commission**

In 2012 the Government initiated a Congestion Commission that should focus on reducing congestion and pollution in the capitol region. The commission is comprised of a broad range of experts, businesses, commuters, NGO etc. (Congestion Commission, 2013). The commission gathers existing knowledge and makes new analyses. There is a list of relevant references on the homepage. In February 2013 a report with ideas to the final recommendations was launched. The final recommendations are due in August 2013.

#### **5.3.2 Traffic habit survey**

The national Danish traffic habit survey (Trafikvaneundersøgelsen - TU) has been conducted since 1975, however in its current form only from 1992 (DTU, 2013). Every day, year round, a number of people, age 10-84, living in Denmark are asked about their traffic actions on the previous day, as well as normal background information, including car-ownership. The respondents are selected to represent the population. In short, the survey answers the following five questions relating to transport habits: How much?, How?, Where?, When? and Why?

What makes the survey unique, compared to similar surveys is the very large amount of data. Since 1992 270,000 Danes have provided detailed information on more than 750,000 trips, which makes the survey one of the largest of this kind in the world. The survey is the primary source on the Danish biking and pedestrian traffic. The survey provides data on the purpose of the trips, the person classification, transport behaviour and the exact geography of the trips.

#### **5.3.3 The Coherent Energy and Environmental System Analysis (CEESA)**

The Coherent Energy and Environmental System Analysis (CEESA) is a multidisciplinary co-operation, which combines the forces of leading Danish researchers in the fields of energy and environment (CEESA 2013). The project is partially financed by the Danish Council for Strategic Research. In the project there is a specific focus on 100% renewable energy systems and the role transport plays in such transitions. The project is described on the homepage as follows:

"The CEESA Transport Scenario tool is a national transport scenario-modelling tool developed as part of work package 2 of the CEESA project. It consists of a single MS Excel spread sheet providing the user with a detailed overview of the various inputs and outputs. The tool enables the

creation of transport and energy demand scenarios related to the activities of Danish citizens, in Denmark or abroad, and goods consumed in Denmark towards 2050. The resulting transport and energy demand is available for 2010, 2020, 2030 and 2050. The tool contains detailed information with regard to transport and energy demands for passenger and freight transport, specific energy consumptions, coefficients of utilisation and the share of different fuels for a wide range of transport modes, including subdivisions of several transport modes according to transport distance and purpose (work and leisure). The tool makes it possible to vary the projections of the transport demand for different modes of transport, change vehicle-specific energy consumption, include a technology efficiency factor, change the coefficients of utilisation and to perform modal shifts between selected modes of transport for the periods of 2010- 2020, 2020-2030, and 2030-2050. Furthermore, it is possible to introduce pre-selected new or future vehicle and fuel technologies. For optimum utility, the model requires that the user has detailed knowledge of the transport system, demand and energy projections, possibilities to improve efficiencies of technologies, and the possibility to implement modal shifts and new technologies.”.

A major challenge in converting the transport sector to renewable energy is the problems of transforming the plentiful electric resources into vehicle performance, due to insufficient capacity in automobile batteries. A recent project called “Feasibility of synthetic fuels in renewable energy systems” also addressed this issue raised in CEESA (Ridjan et.al, 2013). According to CEESA the main reasons for avoiding the direct usage of biomass in the transport sector, i.e. producing biomass derived fuels, are land use shortage, limited biomass availability, interference with food supplies, and other impacts on environment and biosphere. Hence, it is essential to do a detailed analysis of the transport sector in order to match the demand and to meet the criteria of a 100% renewable energy system in 2050. CEESA points out that it is necessary to include wind power and PV in future bio-derived fuels (gaseous or liquid) specifically for the sectors that cannot use battery electric cars (ships, truck and aviation).

#### ***5.3.4 Alternative Propellants***

In 2007 the Danish energy agency launched the “Alternative Propellants” (Alternative Drivmidler) project (Danish Energy Agency, 2007). The purpose of the project was to provide a systematic foundation to evaluate which alternative propellants for transport seem to have the greatest technological and economical long-term potential. As part of the project, the Danish Energy Agency maintains a technical and economic database for different transport fuels and vehicles. This was the first project of its kind by a Danish governmental agency. In 2012 the project and the underlying model were upgraded to a much more comprehensive edition. The Danish Energy Agency is planning to keep updating the model and the database to secure a good source of information on the matter.

#### ***5.3.5 EcoGrid Bornholm***

EcoGrid Bornholm is a project in which 2000 Bornholm consumers test new possibilities to control their electricity consumption (EcoGrid Bornholm, 2013). The purpose of the project is to see to what degree consumers will reorganise their electricity consumption for non-time-critical purposes relative to the electricity price, reflecting the relative over- or under- production of power from wind and solar. The setup is a low-tech smart-grid solution, necessary to facilitate a high share of intermittent energy in the energy system. In a future smart-grid the battery of the electric vehicles may play a major role in storing intermittent energy produced during night time, to be used both for transport the next day and to top-up the daily peak.

#### ***5.3.6 The new Danish transport model***

In 2010 DTU Transport began working on a national traffic model (DTU Transport, 2013). The new model will be able to give predictions on which transport forms people will choose, where they will want to go and what route they will take. The purpose of the model is thus to generate scenarios for anything from great infrastructure projects like building a new bridge to a smaller projects such

as changes the time schedule of a local bus route as well as national traffic behaviour projects such as congestion rings and road-pricing.

### ***5.3.7 Nordic Energy Technology Perspectives***

"The Nordic Energy Technology Perspectives" is a special report from IEA and Nordic Energy Research in addition to the "Energy Technology Perspectives 2012" from IEA. The report focuses on Denmark, Finland, Iceland, Norway and Sweden (IEA et.al, 2013, 2013). In the transport section of the report, the current legislation as well as the future goals are listed for the five countries. This is followed by a scenario analysis of different means to achieving 100 % renewable energy in the transport sector by 2050. It is found that in all scenarios around 4000 billion USD is needed to develop, run and maintain the transport sector between 2010 and 2050. Pursuing the carbon-neutral scenario is actually slightly less costly than the non-carbon neutral. The report lists several challenges for the strategies to be met:

- The growth in demand for transport must be reduced. Recent statistics indicate that this is already the case but uncertainty exists for the long term.
- The economy and performance of EVs need to be improved in order to make them competitive and attractive to consumers in the medium term. This is critical in scenarios depending on their high efficiency and use of renewable energy sources that are not based on biomass.
- Modal shifts must be accelerated. Current policies of the Nordic countries are ambitious in the long term, but it is difficult to see how the policies currently being implemented will enable the carbon-neutral scenarios proposed. Therefore, milestones for 2020 or 2025 must be set.

### ***5.3.8 Formula M***

The Formula M project is working to reduce pollution from private car ownership, improve access to public transportation and reduce congestion. Formula M is constituted of municipalities, private companies and research institutions. The work of Formula M is focused on mobility management. The idea behind mobility management is to affect transport behaviour by combining information with physical initiatives such as better public transport and better possibilities for changing between transport modes. The approach has an actor perspective on transport and has focus on affecting the trip, before it starts, in order to influence the choice of transport mode as well as to streamline the transport. The final goal is to make all transport more energy efficient and to have the existing infrastructure utilised in the best way possible. In this project already finished cases of such initiatives is gathered and new test cases are being made (Formel M, 2013).

### ***5.3.9 National transport planning - sustainability, institutions and tools (SUSTAIN)***

DTU Transport hosts a project focusing on sustainability and transport planning. The goal of SUSTAIN is to expand this research and consolidate a framework on three core domains for a National Sustainable Transport Planning (NSTP): 1) sustainability, 2) institutions and 3) tools. (Sustain, 2013)

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