Literature review on employment impacts of GHG reduction policies for transport

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CE Delft's solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

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Executive Summary

Recently a large number of studies have been published that claim that accelerated uptake of electrical vehicles (EVs) and fuel efficient cars in the market for automotive transport may have positive employment benefits. Given the sharp rise in unemployment in the EU over the last three years, these studies have attracted the attention of policy makers and environmentalists, many of whom claim that more efforts should be undertaken by policy makers, car manufacturers and consumers to increase market penetration of advanced powertrains and/or fuel efficient cars.

The European Climate Foundation has asked CE Delft to undertake a literature review on this issue and to investigate if it is possible, from this literature, to determine whether a large-scale switch to advanced powertrains would yield positive employment benefits. In this literature review we have investigated 30 studies, of which 23 studies have been identified as particularly useful. The literature review has been hampered by the fact that none of the 23 studies has taken a traditional economic analytical perspective where policy induced changes in demand for cars translate themselves into changes in quantities and prices in all relevant markets. The current literature should therefore be regarded as partial, fragmented and rather weak in its economic argumentation.

The reviewed literature mentions several direct and indirect impacts on employment (see table below). It needs to be stressed that most of the identified impacts are highly uncertain. An increase in fuel efficiency of cars with internal combustion engines (ICEs) for instance, may lead to more direct employment in the car industry due to the application of additional or more expensive components and through an increase in domestic and foreign demand. This positive impact is however, dependent on the competiveness of the EU car industry. Shifting consumer preferences, a changing oil price, a tightening or loosening of credit constraints, changing exchange rates and the response of foreign competitors may either strengthen or weaken this impact.

In turn, a switch to EVs is likely to reduce direct employment due to the lower labour-intensity of the manufacturing process as compared to traditional manufacturing, the need for new, more capital-intensive plants and the imports of batteries. The additional need for EV charging infrastructure and the lead taken on foreign competitors could however reverse this negative impact and lead to an overall positive impact on employment in the EU. Again, many uncertainties surround this result.

Although it is difficult to come with a final verdict from this literature because of all the uncertainties, we believe that employment benefits are likely because of two conditions. *First, the switch to fuel efficient cars and advanced powertrains can be done in such a way that the total costs of car owner-ship (purchase costs and mileage costs) are reduced*. This would imply that consumer spending in other sectors of the economy will rise, certainly in the short run. Given the fact that the EU is currently in a situation of decreasing consumer expenditures and underinvestment, such a process may just be healthy for the EU economy.

Secondly, a final switch to EV manufacturing should enhance the competitive position of the EU car manufacturers in the long run. An ageing population is likely to create labour shortages for some occupations, for instance a lack of qualified engineers. EV manufacturing is considered less labour-intensive than manufacturing of ICEs. EV manufacturing may be better suited to the labour situation in the EU in the long run and thus preserve the competitive edge of car manufacturing in the EU.

Overview of impacts and potential influence on employment

	Fuel efficiency/hybrids	EV
Car manufacturing	Increase	Decrease
Maintenance/recycling	Neutral	Small decrease
Fuelling	Decrease	Small increase
Infrastructure	Neutral	Increase
Higher purchase costs	Decrease	Decrease
Lower mileage costs	Increase	Increase
Consumer spending	Increase	Increase
Impacts on trade balance (oil imports)	Increase	Increase
Innovation and competitiveness	Increase	Increase
Rebound impacts labour market	Unknown	Potentially increase

1 Introduction

1.1 Background

Over 12 million people in the EU depend on European vehicle manufacturing for their livelihood of which manufacturing directly employs about 2.2 million people.[1] The global growth in vehicles is very strong, 26% in 2011, and some European vehicle manufacturers are highly profitable and expanding as a result. However, parts of the industry have been hit hard by the economic crisis as demand for vehicles has fallen sharply in some home markets and possibilities to finance credits have been reduced. As transport is a major emitter of greenhouse gas emissions, the challenge for the automotive sector is to maintain competitiveness compared to manufacturers in other parts of the world whilst stimulating innovation and R&D towards cleaner modes of automotive transport.

There are many benefits from lowering CO_2 emissions from cars through efficiency improvements or large scale hybridisation and electrification of automotive transport . Environmental concerns are one dimension, but especially in light of the current economic situation, economic benefits (higher employment and economic growth) have become more important as have securing the energy supply. In the past few years, several studies have been undertaken that have investigated the economic impact of fuel efficiency measures in the transport sector - such as emission standards - on the economy. This study examines what we can learn from the current literature. Specifically, it asks: Are there employment benefits from improving current ICE (Internal Combustion Engine) technology and increasing efficiency through hybridisation? And what is the impact of further steps towards full electrification of the powertrain?

This study examines merits and weaknesses of the literature and tries to formulate an answer to the question of whether economic and employment impacts will be positive. . We do this for two scenarios:

a Improving current internal combustion engine (ICE) technology and hybridisation (when moving towards a CO2 emissions limit of 95 g/km and beyond).
b Electrical vehicles.

In many cases impacts may not differ between both scenarios, but in some important aspects they differ quite substantially. When impacts are similar, they are taken together in the argumentation. Impacts are only distinguished in this study when they differ..

1.2 Followed approach

The literature reviewed in this study gives only partial answers on the potential employment benefits from lowering CO_2 standards and/or the switch to electrical vehicles (EVs). The reason is that none of the literature reviewed applies a full economic model to analyse the potential impacts. Most studies

[1] Employment in car part manufacturing, car sales and maintenance services, car rental services, fuel sail services and road transport is included in this figure. It excludes employment in raw materials manufacturing, driving schools, car insurance etc. according to the ACEA (European Car Manufacturers' Association).

take an engineering perspective: they analyse the potential impacts on costs and labour input of the cars that are to be produced in the future and then upscale this to the whole economy level. Such an analysis is partial, because it neglects that due to a change in the cost structure of cars, prices will be altered, both for the cars, but also for all economic variables that play a role in producing and usage of the car (e.g. the price of labour, gasoline, electricity, exchange rates, etc.).

It is outside the scope of this literature review to provide a comprehensive analysis of all potential impacts of a switch to more fuel efficient cars to economic growth and employment. However, some general lines can be sketched here. In general, economic growth and associated impacts on employment can occur from three different sources:

a Volume driven growth: the use of unutilised inputs in the production process (e.g. labour and capital) can imply a growth in the economy. Clearly, an employee that used to be unemployed will stimulate economic growth additionally if being employed. Also factories standing idle will become a source of economic growth if being utilised fully.
b Innovation growth: if the current factors to production are being utilised more efficiently, this will stimulate economic growth and through this also employment. Innovation driven growth turns out to be the major source of economic growth in the long run.
c Composition growth: where economic growth occurs when activities that generate mostly value added and employment in foreign countries are being replaced by activities that generate mostly value added and employment domestically. Although these impacts tend to be very substantial in the short to medium run (e.g. 1-10 years ahead), they tend to become smaller in the long run because of changes in the relative prices of the factors of production. In other words: if more labour is demanded to produce goods domestically this may have an upward pressure on wages that in the end reduces employment compared to the baseline scenario.

The available literature is very much oriented on this latter aspect of compositional growth. It compares the static impacts of producing EVs or more fuel efficient ICEs and hybrids with traditional car making and then draws conclusions. Almost no feedback mechanisms through the price mechanism are included in analysis conducted so far. This is in sharp contrast with the literature on renewable energy production that seems to be much more mature in terms of economic impact analysis.

In order to examine the impacts on employment, this study considers three impacts:

a Direct static compositional impacts: what would happen to employment if the current ICE engine is being replaced by hybrid or electrical vehicles.
b Behavioural impacts: what would be the response of consumers driving cars and how would this affect employment?
c Indirect economic impacts: what would happen to employment from all the economic mechanisms that would follow from the two above impacts? This focusses in particular on impacts on the energy market, the labour market and the balance of trade (exchange market).

1.3 Delineation

The literature review undertaken in this study only focusses on automotive passenger transport using vehicles. Given the fact that most studies that have been undertaken take primarily an engineering perspective, lacking a broader economic perspective, we cannot derive a final conclusion on whether a switch to EVs is positive or negative for employment. Savings on car ownership could be an additional channel for economic growth and employment in sectors other than car manufacturing, provided that the purchase prices of EVs fall due to an increase in production volumes and oil prices keep rising.
The results from this literature review are necessarily reflecting the current state of the art in the literature and no additional calculations have been performed by CE Delft in order to substantiate certain claims.

The value added of this literature review is that it is the first attempt to interpret previous research in an economic context. Such efforts have not been undertaken sufficiently detailed yet. Therefore we believe that this literature review is useful for anybody to study further the economic impacts of policy plans to stimulate EVs beyond what is being done at present.

2 Overview of the literature review

2.1 Introduction

In total, a number of 30 studies have been reviewed. Of those, 20 studies on some aspects of the employment impact of GHG reduction measures in transport were particularly useful, whereas three others concerned the macro-economic impacts of reduced oil imports specifically. Seven studies were discarded: some of them were merely reproduction of earlier conducted studies while others did not provide any quantitative estimation or new insights on the mechanisms through which more stringent fuel efficiency norms may impact employment.

The range of studies reflects commissioned reports, either by governments or lobby groups. In some cases articles from journalists interviewing people from the car manufacturing industry have been included. No studies have been published in the scientific literature so far that specifically address employment impacts from EVs. As a consequence, most studies lack a peer reviewed context from independent specialists. This may have affected the overall quality of the research negatively (see also Par. 2.3).

Many studies have been undertaken for a particular country. Only a few studies have assessed the impact on a global scale. Table 1 gives the range of studies with respect to coverage.

Table 1 Geographical scope of 23 studies taken in this literature review

Distribution of studies	
World	7
US	6
EU	4
Germany	4
UK	1
France	1
Austria	1

The review of the literature has examined a number of aspects including: details on the study , the analytical basis, GHG reduction measures considered, the main impact channels and assumptions used in the study, the main outcomes of the study and a short discussion/appreciation of the study. These aspects are summarised in Annex 1 for each study. In the remaining paragraphs of this study we will discuss the general outcome of these studies (Par. 2.2) and elaborate on the technical quality of the studies (Par. 2.3).

2.2 Main outcomes of the studies

The overwhelming majority of the studies conducted so far have concluded that positive employment impacts are likely. This implies that employment would rise if a large-scale shift to hybrid and electrical vehicles would take place in the future. Table 2 gives a generalised one-line summary of the conclusions from each study. Table 2 is by definition limited in scope and should only be seen as a quick overview of the studies that have been taken into account in this literature review.

Table 2Overview of studies

Title (first part)	Authors	Year	Coverage (country)	Analytical basis: theoretical/empirical/modelling	Main conclusion
Less Traffic, More Jobs	Friends of the Earth	1997	UK	Modelling using three scenarios	The employment impacts of ultra low emission vehicles and EVs is positive. The largest increase in jobs takes place in the assembly phase, as new production lines will have to be set up parallel to the old ones.
Zukunft der deutschen Automobilindustrie	Friedrich-Ebert-Stiftung	2010	Germany	Theoretical, literature study	Hybrid cars may stimulate employment, EVs will reduce employment.
Beitrag der Elektromobilität zu langfristigen Klimaschutzzielen	McKinsey & Company	2010	Germany + World	Modelling different scenarios regarding uptake of EVs and new technologies	EV is more expensive and leads to more value added and hence results in employment benefits.
Baden-Württemberg auf dem Weg in die Elektromobilität	Fraunhofer-IAO et al.	2010	Germany, Baden-Württemberg	Theoretical/literature study using meta-analysis	Compared to present situation, automobile industry will see increased market volumes due to solutions to reduce CO2 emissions.
Automotive landscape 2025	Roland Berger Strategy Consultants	2011	Worldwide automotive industry	Interviews with automotive industry experts	Shortage of labour implies that switch to EV is desirable for competitive position EU car industry. Automotive-related industries such as transportation, retail and other services will create an additional one million jobs in Europe, outweighing the loss in manufacturing jobs.
Boost! Transforming the powertrain value chain	McKinsey & Company	2011	Worldwide automotive industry	Modelling: developing and employing a value chain model	By 2030, an additional 420,000 FTE will have been created in the powertrain industry globally. In high-wage countries (e.g. EU) the low labour intensity will make EV production attractive. In the EU, 110,000 new jobs will be created in production and R&D, especially in chemicals and electronics.
More jobs per gallon:	CERES and MISI	2011	US	Modelling using input-output (I-O) model analysing four GHG reduction scenarios	Greater reductions come at greater incremental vehicle costs but lower costs over lifetime due to fuel savings. In total additonal jobs will be created.

Title (first part)	Authors	Year	Coverage (country)	Analytical basis: theoretical/empirical/modelling	Main conclusion
The Economic Benefits of Investing in Clean Energy	PERI and Center for American Progress	2009	US	Theoretical/ input-output modelling	Study investigating impact from US initiatives on clean energy investments. Clean energy investments generate more jobs than investments in fossil fuel because of higher labour intensity, more domestic demand and more entry-level jobs.
Driving Growth: How Clean Cars and Climate Policy Can Create Jobs	The Planning Edge and MMTC	2010	US	Theoretical/lobbying document	Impact from 2 US Acts requiring new vehicle fleet average fuel consumption to fall by 30 per cent from 2012 to 2016. This will make cars more expensive and boost employment. Just under 40 per cent of these jobs will be in the auto and auto parts sector, the other part in other sectors.
La voiture électrique menace les garagistes	Le Figaro	2010	France	Newspaper article based on interviews/literature study	According to Renault, electric vehicles require only half the maintenance of conventional vehicles which could imply a loss of 20% of jobs in maintenance
Second report of the German Natrional Platform for Electric Mobility	NPE	2011	Germany	Lobbying document	Early adaptation of EVs will lead to an increased domestic and international market share of German EHV manufacturers and manufacturers in the supply chain creating additional jobs, partly in building infrastructure.
Elektromobolitat	TU Wien and Fraunhofer Austria	2011	Austria	Technical report	The direct impacts of the production of electric vehicles and loading infrastructure leads to 14,800 fulltime jobs in the electric car industry, loading infrastructure industries and supplying industries (e.g. electronics, metallurgy and machinery) by 2030. Indirect impacts could be as high as 20,800 additional jobs by 2030.
The impact of lower oil consumption in Europe on world oil prices	Enerdata	2009	World	Modelling through POLES	Reduced oil consumption leads to lower variable costs for conventional ICE vehicles, but a higher investment cost. The total cost of conventional cars in 2030 per km (inv. cost + variable costs) is 33% higher in scenario 80gr/km2 compared to baseline.
Estimating the Energy Security Benefits of Reduced U.S. Oil Imports	ORNL	2007	US	Theoretical using oil premium calculation method	The oil premium is estimated to be $13.58 per barrel ($2004), of which $8.90 is a monopsony component (the fact that the US is such a large buyer that it influences the world price) and $4.68 the cost of macro-economic disruption

Title (first part)	Authors	Year	Coverage (country)	Analytical basis: theoretical/empirical/modelling	Main conclusion
Oil Prices, Exhaustible Resources, and Economic Growth	Hamilton	2012	Worldwide oil market	Theoretical (using some empirical evidence)	Future oil supply and oil prices are very uncertain, oil shocks have negative macro-economic impacts and therefore moving away from oil dependence is a good thing to do.
Natural Resources: Curse or Blessing?	Van der Ploeg	2010	World	Theoretical/empirical	In general natural resources abundance negatively impacts on all other sectors of the host economy due to increasing terms of trade and less diversification efforts, more corruption and conflicts and less political reforms.
EUELECTRIC's Vision for the Development of the Necessary Electric Infrastructure for EV	EURELECTRIC	2009	EU	Presentation in conjunction with the EU Sustainable Energy Week 2009	A price of petrol of 1.5 euro per litre is sufficient to make the total cost of ownership of EVs lower than for ICEs. Additional CO_2 reductions from 80 gCO_2/km in 2005 to 25gCO_2/km in 2030 as a result of growth in EV ownership are envisioned if the suppliers of electricity in the EU shift towards renewable energy.
Plugged In: The End of the Oil Age	WWF	2008	World	Lobbying document	Electrification of transport benefits countries who are net importers of oil, who produce energy domestically, who have large transport and automotive industries and who are committed towards reducing carbon emissions.
Analysis of GHG Emission Reduction Potential and costs of LDV technologies in the EU 2020-2025	Ricardo	2012	EU	Technical report	The study evaluates different types of technology to reduce emissions by the year 2020. Results are obtained for based a response surface simulation model. It aims to provide reliable estimates for the reduction of emissions for various LDV technologies.
Light-Duty Vehicle Technology Cost Analysis – European Vehicle Market	FEV	2012	EU	Technical report	The report calculates the additional production costs for various technologies. The study shows that learning costs are substantial indicating much lower costs in the future for clean technologies

Title (first part)	Authors	Year	Coverage (country)	Analytical basis: theoretical/empirical/modelling	Main conclusion
Support for the revision of Regulation EC443/2009 on CO2 emissions from cars	TNO et al.	2011	EU	Technical report	The relatively low additional manufacturer costs that are found in this study, lead to the conclusion that the 147 gCO2/km target for LCVs is less challenging for the manufacturers than the 95 gCO2/km target for passenger cars.
The U.S. Smart Grid Revolution: KEMA's Perspectives for Job Creation	KEMA	2008	US	Technical report	An initial imbursement of $ 16 billion in Smart Grid initiatives is expected to generate a total of $ 64 billion worth of smart grid projects. The projected (direct and some indirect) effects on employment are the creation of 280.000 jobs many of which are high value.
2030 Impact of Fuel Efficiency and Global Warming Polluting Standards	Union of Concerned Scientists	2011	US	Lobbying report based on technical reports	The savings in fuel during the first five years of ownership are higher than the additional vehicle cost for the technology needed to reduce fuel use and emissions in the first year due to the under all four scenario's. Car sales would increase due to the savings.

2.3 Methodological remarks

The methods that the studies have employed differ widely in scope (see Table 2). However, none of the studies have employed a full economic model, such as a general equilibrium model or a time-series econometric model. General equilibrium models are better at describing labour market impacts, since the labour market always returns to equilibrium in the long run. However, general equilibrium models are very complicated and therefore may present various practical problems in their use.

Most of the studies take an orientation that economists would label as 'an engineering perspective' that is being applied to economics. Economic impacts are derived from efficiency standards for cars, car parts and car manufacturing rather than estimated by means of general equilibrium or econometric models. Indeed, the following reasoning seems to hold for the method that the majority of the studies have employed: EV cars for instance are more expensive, hence resulting in more value added and additional employment (see e.g. McKinsey & Company, 2010; Fraunhofer-IAO et al., 2010). This type of analysis takes a very static approach and lacks many aspects that normally are important in economic analysis:

– The question where the additional money comes from to buy these more expensive cars. The investment needed must come from somewhere and the foregone consumption of other goods has not been taken into account.
– The impact of the more expensive cars on car ownership and the impact of the lower mileage costs on car usage is lacking.
– The impact on prices of labour, oil and the currency markets have not been included in the analysis.

Moreover, it can be questioned if the reasoning that more expensive cars result in additional jobs when compared with traditional car making is valid at all. Probably manufacturing of electrical and hybrid cars is more capital intensive, which implies that increased value added needs not be accompanied by a larger share of labour.

Indirect impacts from electrification of automotive transport have been largely neglected or improperly handled in the literature. The literature has focussed mainly on impacts for the automotive industry rather than for the whole economy. The most sophisticated studies (two from the US) have employed input-output analysis to trace down indirect impacts. While this gives an indication of the economic impacts for marginal changes (e.g. if prices remain the same), large-scale transitions towards new technologies that are characterised by changing prices cannot be assessed fully using input-output analysis.

The study that assesses the impacts using input-output tables (CERES and MISI, 2011) comes to an important conclusion. Strong CO_2 reduction targets may result in net benefits over the lifetime of the car, resulting in additional savings and consumer spending that stimulate the rest of the economy.

3 Interpreting the literature review

3.1 Availability of the literature

In this chapter we interpret the findings from the literature review in an economic context to determine whether more stringent GHG standards and a switch to EVs can be beneficial for European employment. First we discuss the method of analysis (Par. 3.2). Then, in Paragraph 3.3 we discuss in more details the potential impacts that we can derive from the literature. Finally, (Paragraph 3.4) contains an overview of the findings.

3.2 An economic analysis in theory

An economic analysis consists of comparing a baseline scenario with an alternative scenario and determining the economic differences between both scenarios. Some studies have compared the alternative scenario to the present situation. Although this is attractive in terms of ease of interpretation, it adds little insight to the additional gains that can be expected from more fuel efficient ICEs, hybrids and EVs. Baseline scenario's would need to take account of future developments within car manufacturing, absent any changes in efficiency standards for ICEs of rising share of hybrids and EVs.

There is no consensus in the literature what the baseline scenario should be. Options include the stand-still principle, or existing policy plans such as the Commission's upcoming proposal for a 2020 target of 95g CO_2 per kilometre. For ease of comparison we assume below that the baseline scenario will be no-policy to reduce GHG emissions of cars. Cars will become more fuel efficient due to high oil prices, but this effect will partly be offset by the continuing demand for larger cars.

This baseline scenario must then be compared with a policy plan to stimulate more fuel efficient ICEs, hybrids and/or EVs. This normally implies some type of governmental influence in the market process. However, since we do not know in detail which policy plans are to be developed beyond 2020, we merely investigate what kind of impacts can be expected from a higher share of ultra efficient ICEs or EVs in the market.

The study focuses on three important impacts:
1. Direct impacts on the markets of producers of cars, fuel, infrastructure, etc.
2. Direct impacts for the consumers of cars.
3. Indirect impacts: the total influence these direct impacts will have on the economy through other markets, such as the labour market or the energy markets.

3.3 Estimated impacts

3.3.1 Direct static impacts for the passenger car markets

The direct static impacts consist of comparing the baseline scenario with traditional ICE car manufacturing with the proposed policy plans. For example, the Commission's upcoming proposal for a 2020 target of 95g CO_2 per kilometre will stimulate an increase in the technology content of cars, including a small amount of hybridisation and downsized engines with turbocharging. It may also create an incentive to use lightweight materials, pending on regulatory approval, and therefore a shift from steel towards aluminium, plastics and carbon fibre. Due to these impacts, cars tend to become more expensive compared to the baseline scenario.

The static impacts refer to the situation when the same number of cars is being produced as in the baseline scenario, only containing more technology that makes the car more expensive. One can compare the static impacts for (i) car manufacturing including the supply chains; (ii) maintenance; (iii) fuelling; (iv) infrastructure. One should notice that the *final* impacts will of course not be similar to the direct impacts, because the sum of direct impacts, behavioural changes and indirect economic impacts will in the end determine the outcome.

The static impacts can be summarised as follows:

Table 3 Impacts on the automotive mobility market of more fuel efficient ICEs, hybrids and EVs

	Fuel efficiency/hybrids	EV
Car manufacturing	Increase	Decrease
Maintenance/recycling	Neutral	Small decrease
Fuelling	Decrease	Small increase
Infrastructure	Neutral	Increase

Below, these impacts will be elaborated in more detail.

Car manufacturing including supply chains
The net effect of a higher vehicle price on employment is determined by the increase in the amount of labour per vehicle due to the application of additional or more expensive components. Especially for hybrid and EV these may be substantial. The most expensive component is the battery, and it is not clear from the literature review how labour intensive the production of the battery is. Electric motors are less complex than an ICE. In the studies that use input-output models based on the present situation in the car industry, it is concluded that an increase in value added leads to an increase of employment. However, this depends on how new production facilities are set up. If they are very capital intensive, an increase in employment does not necessarily take place.

Although there is a lack of robust research into this area, a few conclusions can be drawn with respect to car manufacturing.
For cars that employ more fuel efficient ICEs and hybrids, more labour is required implying a positive impact on employment. Fraunhofer-IAO et al. (2010) expects that worldwide a market volume growth € 43.4 billion is to be expected for solutions to reduce CO_2 emissions from ICEs (stop-and-go-systems, etc.). This clearly will have positive employment benefits. However, for large-scale use of EVs in the future, less labour is required as the EV contains significantly less parts. Installation of a single battery for instance, replaces the installation of multiple components of an ICE . Employment is therefore likely to decrease in car manufacturing in the EU, unless EU manufacturers are able to obtain a larger share of global car sales.

This is also underlined by a study by Fraunhofer-IAO et al. (2010) that, based on a literature review, estimate that in 2020 the battery will account for 50% of the costs for long-range vehicles and almost 40% of the cost of small range vehicles. The electric motor together with the required motor controller takes up only 7% of total vehicle costs. Comparing 2020 with 2010, the worldwide market volume of ICEs will decrease by € 11 billion while the traction battery industry would gain about € 33 billion. If such battery industry comes from within the EU, employment may be simply shifted from car manufacturing to battery production, although the literature does not allow us to draw that conclusion too firmly as the labour intensity of the battery is unknown.

Maintenance

For more fuel efficient ICEs and hybrids, maintenance costs are equivalent to the baseline scenario, implying a negligible impact on employment. For EVs, maintenance costs will be lower. One article in Le Figaro interviewing experts from the automotive industry mentions that maintenance costs will be up to 50% lower implying a reduction in labour for maintenance of 20%. In a study for the region of Rennes, CODESPAR (2011) estimates that some jobs related to maintenance will be lost. However, this could be offset by an increase in jobs related to recycling as more components will be recycled.

Fuelling

More fuel efficient ICEs and hybrids will imply that less oil is consumed indicating a loss of employment in refining and gasoline stations. The switch to EVs implies that demand for oil will be reduced and demand for electricity increase. In general the employment impacts seem to be positive if renewable energy will be used for fuelling.

For a large-scale switch to EV savings of oil imports will be even more substantial because oil is being substituted for electricity. According to Pollin et al. (2009), renewable energy investments in the US generate 17 jobs per $ 1 million value added, compared to 5 in refining. Although this benefit will be mitigated to some extent due to the fact that EV motors have higher rates of efficiency than ICEs, it can be expected that additional employment benefits may exist from this substitution. The general conclusion from the literature seems to be that electrification of transport benefits those countries who are net importers of oil, who produce energy domestically, who have large transport and automotive industries and who are committed towards reducing carbon emissions (WWF, 2008). This of course, includes a significant proportion of the EU.
It should be noted though, that under the current energy policy framework until 2020, mainly coal and gas will be used to produce the required additional electricity for EVs (Enerdata, 2009). If the transition towards EVs is to be successful, the energy policy frameworks must be adjusted.

Infrastructure

The impact on infrastructure construction is sometimes missing in the literature and at other times only briefly discussed. As much of the EV charging infrastructure still has to be constructed, the employment impact is likely to be positive. This is potentially a large source of employment. In a study for the region of Rennes, CODESPAR estimates that an additional 1,000 employees are required to build this infrastructure between 2015 and 2020. For more efficient ICEs no additional infrastructure is required.

KEMA (2008) estimates that for the US in total 280,000 jobs could be created due to the development of a smart grid. However, this study is not very transparent from a methodological perspective and it is difficult to assess how reliable these estimates are (see also Annex A).

3.3.2 Behavioural impacts

Greater hybridisation and electrification will make cars more expensive in purchasing costs and reduce the mileage costs of cars. In terms of economic impacts this should mean that fewer cars will be newly bought but these cars will be used more intensively. Shared-ownership will become more popular under this scheme. The impacts on congestion and modal shift may be uncertain. On the one hand, the lower mileage costs may stimulate some additional private car use (a potential rebound effect) but the higher costs of car ownership may discourage car use in comparison with public transport. According to UCS (2011), a fall in fuelling costs of 10% leads to a 1% increase in travelled distance.

The economic impacts are difficult to estimate. The change in vehicle sales as a result of the higher vehicle price of EVs as compared to ICEs is uncertain[2]. It depends on the price elasticity, which in the case of car ownership is estimated to lie between 0 and -1 (i.e. fairly inelastic). In the case of full cost pass-through, an increase in the vehicle price then leads to a less than proportional decrease in vehicle sales.

Because the behavioural impacts have not been analysed sufficiently in the literature, we cannot draw general conclusions here on the employment impacts. Clearly, if car sales would fall, this would have a negative impact on direct employment. However, if the use of the car would increase due to lower mileage costs, this would have a positive impact on indirect employment at the expense of more emissions. The employment impacts as well as the environmental impacts in the opposite direction of cars that are more expensive to buy but cheaper to own are too complex to make a viable assessment..

[2] A rational consumer would base his/her car purchase decision on the total cost of ownership, which is composed of the investment cost (the price of the car) and the variable costs (the fuel and maintenance costs). In the case of an increase in fuel efficiency, the development in the TCO is uncertain as an increase in the vehicle price is compensated by a decrease in the variable costs. Whether individuals will actually take the TCO into account (rather than basing their purchase decision on the vehicle price only) is unclear, but in any case it is likely that TCO calculations will become more familiar for customers over time. For businesses such TCO calculations are already part of their decision making process. With respect to the variable costs, there is uncertainty in the height of the variable costs, as it depends on the lifetime of the battery, as well as on electricity prices. Finally, it should be noted that car manufacturers may develop new business models when they notice that car sales are stagnant due to high vehicles prices. In the case of EV, they may sell the car without the battery, and then lease the battery to the customers.

3.3.3 Indirect economic impacts

Indirect impacts are the impacts that occur through other channels than the car market itself. The number of potential impacts is large. However, the most important impacts are:

- impacts on consumer spending;
- impacts on oil imports and the balance of trade;
- impacts on innovation and competitiveness;
- impacts on the labour market.

These will be elaborated below.

Impacts on consumer spending

The impacts on consumer spending depend on whether the switch to more fuel efficient ICEs and EVs is cost-effective to the consumer over the lifetime of the car. One study that investigated this in more detail is CERES and MISI (2011) for the US market. This study concludes that although the vehicle is more expensive to purchase, there will be net savings over the lifetime of the car because of lower consumption of fuels. The per vehicle cost increase in 2025 ranges from slightly under $ 1,000 per new vehicle for a 3% annual GHG reduction, increasing to as much as $ 3,500 per new vehicle to achieve a 6% annual GHG reduction. However, consumer savings would also increase with the lower GHG emissions and higher fuel economy. For the different scenarios analysed, the net lifetime savings to the consumer due to increased vehicle efficiency range from $ 4,900 to $ 7,400 for an average new vehicle in 2025. This would yield an additional stimulus in personal consumption expenditures that result in positive employment impacts.

Such findings can be generalised to the following observation:
If the policy plans allow innovation and R&D to develop and if the targets for new cars are set at such standards that the total cost of ownership over the lifetime of the car is lower than for traditional ICEs, there will be additional employment benefits to the economy because the savings will be reinvested into the economy through higher personal consumption.

This is not only stimulating consumption, but may also have additional employment benefits because of the composition of consumption. Due to the net savings, consumers are now able to spend more money on other goods and less on oil. As oil imports add very little to domestic employment, there will be almost no loss of employment in this direction. Mostly in such situation, high domestic employment activities, such as hotels and restaurants, tend to benefit from the reduced spending on oil. This may result in substantial employment benefits in the EU.

Impacts on oil imports (direct and rebound)

Three impacts on oil imports can be expected:

1. More fuel efficient ICEs, hybrids and EVs result in lower oil consumption compared to the baseline scenario. As most of the oil is imported in the baseline scenario, this results in net benefits on the trade balance for the EU. For EVs this impact is counterbalanced by a higher consumption of electricity compared to the baseline scenario.
2. Because of the lower oil consumption, international oil prices will fall. This results in an additional net benefit on the trade balance for the EU.
3. Because of the lower oil consumption, the economy becomes more resistant towards ‘oil shocks’ due to political instability and/or monopoly effects.

Enerdata (2009) estimates that for a scenario of 80gr/km^2 in 2030 the economic benefits of reduced oil consumption for the EU 27 are € 28 billion in 2030 which is a 12% decrease in expenditures on oil compared to the baseline. Depending on the scenario and the year considered, 84-91% of these savings would derive from a decrease in the import volume and 9-14% from lower international oil prices resulting from these European CO_2 standards. The effect on oil prices will be stronger if more countries/regions adopt stricter standards.

In another study, the so-called 'oil premium' is reduced, with positive economic effects (see ORNL, 2007). The oil premium consists of the monopsony effect (the fact that a lower demand for oil in the EU has a downward impact on the world oil price) and macro-economic disturbances from oil price shocks.

If total imports decrease, the exchange rate is likely to rise until the balance of trade is restored. This would mean that domestic goods will be more difficult to sell abroad. Some of the initial positive economic impact of reduced oil imports will therefore be lost due to this rebound effect. Another mechanism may be that EU exports to oil producing countries may be diminished due to the lower purchasing power in these countries. However, there is some evidence in the literature that becoming less resource-dependent can even be regarded as a 'good thing' for resource-producing countries as the economy can diversify in more directions yielding in general more innovation and competitiveness (see e.g. Van der Ploeg, 2010).

Impacts on innovation and competitiveness
Some studies have highlighted the importance of more stringent CO_2 standards for innovation and competitiveness of EU car manufacturing. Clearly, if other countries would adopt more stringent CO_2 standards for their car manufacturers – as currently proposed in the U.S. for the year 2025 - than EU countries would do, EU car manufacturers may be subject to a competitive disadvantage compared to other countries. However, this is not the case yet.

The economic literature is in general not very favourable towards government-induced innovation in the private sector. In order to be beneficial to economic growth, such intervention assumes that governments are better informed where potential growth-markets are than business or that business is unable to coordinate its actions (i.e. forestalling investments with good long-run prospects due to high competitive pressure today). That having been said, the situation in the US market shows that car manufacturers were not rightly anticipating the economic crisis and high oil prices. In 2009 only half of the people employed in 2000 were still working in the car manufacturing industry (Electrification Coalition, 2010). There may therefore be some economic truth in the argument that legislation in the shape of stronger climate regulations can safeguard the competiveness of the EU car industry.
In any case, stringent CO_2 targets are warranted on economic grounds as a means to mitigate the externalities from car ownership and car use.

Rebound impacts on the labour market
Employment impacts also occur through wage adaptations on the labour market. In conditions of high unemployment, wages tend to increase at a lower rate (often lower than inflation) than under the situation of tight labour markets. Roland Berger Strategy Consultants (2011) has pointed out that the future of traditional EU car manufacturing may be threatened by a lack of qualified engineers in some Western European countries due to ageing and its impact on the working population. Compared to 2008, the study estimates that

about 300,000 jobs could be lost in EU car manufacturing due to a shift of production to Asia. Such a labour shortage would make a very strong case for investing in EVs, as the production of EVs requires less engineers to produce one car than production of ICEs. Investment in programs that stimulate EVs could therefore mitigate wage increases for scarce engineers making EU car manufacturing more competitive compared to the baseline scenario.

3.4 Summary

Table 4 gives an overview of discussed impacts in this chapter and the potential influence on employment.

Table 4 Overview of impacts and potential influence on employment

	Fuel efficiency/hybrids	EV
Car manufacturing	Increase	Decrease
Maintenance/recycling	Neutral	Small decrease
Fuelling	Decrease	Small increase
Infrastructure	Neutral	Increase
Higher purchase costs	Decrease	Decrease
Lower mileage costs	Increase	Increase
Consumer spending*	Increase	Increase
Impacts on trade balance (oil imports)	Increase	Increase
Innovation and competitiveness	Increase	Increase
Rebound impacts labour market	Unknown	Potentially increase

*Assuming that total costs over lifetime of a car are smaller than in BAU.

4 Conclusions

4.1 Main conclusions from the literature

Recently, many studies have been published that deal with the employment impacts from electrification of automotive transport. The general conclusion from this literature is that employment will be enhanced by a switch to more fuel efficient ICEs and production of EVs. This review of the literature, however, has pointed out that the overwhelming majority of literature is not firmly rooted in economic science. There is a lack of studies that employ economic and/or econometric models and discuss economic impact channels and price adjustments in a meaningful way. Several studies simply assume that employment will be enhanced because the EV is more expensive. This is of course not a sound economic argument because it simply negates behavioural impacts from consumers and indirect price adaptations on markets from the higher purchase costs of vehicles.

In this literature review we have tried to re-interpret the findings from the literature in an economic framework. Although it is difficult to draw definite conclusions, we believe that employment benefits may be likely **if the switch to fuel efficient cars and EVs is done in such a way that the total costs of car ownership (purchase costs and mileage costs) are lower in the policy scenario than in the baseline scenario**. This would imply that irrational consumer behaviour (where the purchase costs outweigh the discounted stream of expected mileage costs in the perception of the consumer) is being limited and additional consumer spending can be expected in the economy. This may favour economic growth in the EU and increase employment. Moreover, since the domestic content of consumer spending (on e.g. hotels and restaurants) is much higher than on oil imports, additional employment gains can be expected, certainly in the short run.[3] Given the fact that the EU is currently in a situation of decreasing consumer expenditures and underinvestment, the boost in consumer spending should be healthy to the EU economy.

Another argument to stimulate the pathway from more efficient ICE cars towards EVs is found on the supply side of the labour market. There are some concerns about the availability of qualified engineers in the future due to population ageing. As an EV requires less labour input per car produced, there can be gains if the EU economy slowly would move towards a higher share of EV production facilities that would replace the traditional ICE production facilities. This would imply that the EU car manufacturing industry would gain an edge in production of EV that would match the competencies of its workforce. The policy context is important, if the competitiveness of EU manufacturers is to be increased through innovation on fuel efficiency, hybrids and EV, it may require enhanced cooperation among car manufacturers, industries in the supply chain, governmental and educational institutions. The transition would also be smoothed by harmonised legislation across the EU, publicly supported pilot projects and fiscal incentive to promote the use of EV.

[3] In the long run such impacts will be counterbalanced to some extent by price adaptations on the currency and labour markets.

4.2 Suggestions for further research

1. The main suggestion is that there is a need for a thorough economic impact analysis of large-scale stimulation of EVs. The mechanisms through which such an analysis could take place have been outlined here, but this has not been studied yet in combination. Especially price impacts on oil, car sales, car usage and labour are important to take into account.
2. The labour intensity of the production of electric vehicle batteries is unknown. The high price of lithium batteries could partly be explained by the scarcity rent[4] derived from the limited supply of lithium, which suggests that material inputs constitute a large share of the production costs. On the other hand, the production of lithium batteries requires substantial knowledge and skills, so it is likely that labour costs are also an important production cost factor. Moreover, further research should also demonstrate the importance of the location of the battery manufacturers for total employment benefits. If all batteries are to be imported from, e.g., China, this may negatively impact employment in the EU. From the current literature we cannot assess how critical this factor would be.
3. The estimates of the total cost of ownership used in the literature are sometimes outdated as the costs of EVs are rapidly changing. More recent information on cost curves should be taken into account when estimating economic impacts.

4 The fact that the price of lithium is currently higher than in a perfectly competitive market, due to the market power of the suppliers.

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Annex A Overview of the studies

Table 5 Outcome of the literature study

Title	**Less Traffic, More Jobs: The Direct Employment Impacts of Developing a Sustainable Transport System in the United Kingdom**
Authors	Friends of the Earth
Year	1997
Coverage (country)	UK
Analytical basis: theoretical/empirical/modelling	Modelling: ECOTEC tool
GHG reduction measures considered	Three scenarios concerning only passenger transport, having a reduction goal of 10% by 2010 (compared to 1999). Base scenario: more public transport and use of bicycles and walking at the expense of private transport. Technological scenario: 'clean' technologies penetrate motorised transport: 10% CNG, 15% for new low-emission petrol and diesel fuels, 11% market share of hybrid vehicles and 5% electric vehicles essentially for urban usage. A third scenario, a mix of the second with a major development of modalities of vehicle hire at the expense of the fleet of private vehicles.
Main impact channels and assumptions used	Vehicles running solely from electric power represent a fundamental shift away from traditional manufacturing methods. They will also require significant weight reductions through use of new materials. The impacts at the manufacturing stage will be much greater due to the need for additional production lines. It is unlikely that firms will be able to manufacture EPV cars with existing facilities and staff. The potential for sharing of production runs is unknown, but it is unlikely to exceed fifty to sixty per cent of the final vehicle in an optimistic scenario. Specialist units are likely to be set up within electric utilities to manage vehicles related production, and to conduct research and development. Changes in materials input would also create a small number of jobs.
Main outcomes	The employment impact of a 5% EV is positive in all categories, from the material inputs to the operational phase. The largest increase in jobs takes place in the assembly phase, as new production lines will have to be set up parallel to the old ones. Furthermore, a loss of 750 jobs from extraction and refining of petroleum is offset by the creation of 700 jobs in the electricity generation sector. The total employment change in the UK is 6,200 jobs. The employment impact of 11% hybrid vehicles is positive in most categories, except for the material inputs (-400), since unlike for EVs, a decrease in petroleum demand is not offset by an increase in electricity demand (batteries are self-charging). Again, the largest positive impacts take place in the category assembly. The total employment change in the UK is 12,100 jobs. In the case of 15% ultra-low emission vehicles, there may be a slight increase in fuel efficiency that implies a small loss in jobs in petroleum refining. The major employment impacts involve the conversion of engines and the changes in maintenance and repair. The total net impacts in the UK will be an increase of 1,000 jobs. In total, the employment impact of a high technology impact is estimated to be +20,300. An increase in public transport and cycling has the potential to increase employment with 130,000 jobs, as buses and trains need a driver, whereas most cars are private so they do not entail any salaried job
Discussion/appreciation of the study	The role of public transport in employment is interesting, as it creates many jobs according to this study. Of the different scenario's, the highest increase in employment takes place in the scenario with a large technology uptake and vehicle hire. The higher costs due to new technology or vehicle hire are not taken into account.

Title	**Zukunft der deutschen Automobilindustrie Herausforderungen und Perspektiven für den Strukturwandel im Automobilsektor**
Authors	Friedrich-Ebert-Stiftung
Year	2010
Coverage (country)	Germany
Analytical basis: theoretical/empirical/modelling	Theoretical, literature study
GHG reduction measures considered	Electrification of vehicles
Main impact channels and assumptions used	Phase 1: parallel to the further development of the combustion engine (optimisation, downsizing) the electrification of the powertrain is advanced. With hybrid concepts comes new equipment (traction battery, electric motor, power electronics). At the same time lightweight materials become an increasingly important topic. In phase 2, the combustion engine loses significance, while electrification becomes increasingly important. Suppliers and automobile manufacturers must expect radical changes in demand for their products, which in some cases may lead to bankruptcy. In Phase 3 the electric vehicle is dominant, although the timing of this phase is uncertain.
Main outcomes	Phase 1: Positive employment effects are likely. Phase 2: employment effects are uncertain. Phase 3: Employment effects are characterised by a reduction in the complexity of production, as there are less sophisticated components which can be fabricated by highly automated machines. A rough comparison: current German plants of ICE vehicle produce approx. 200 motors/employee annually. A new German plant producing electric motors (by Continental) can produce 1500 motors/employee. Employment is therefore likely to decrease.
Discussion/appreciation of the study	The description of the different phases in the electrification of vehicles and their impact on employment is useful, as most studies only describe developments in the near future. The conclusion that the electric car industry is less labour intensive than the conventional one is very important.
Title	**Beitrag der Elektromobilität zu langfristigen Klimaschutzzielen und Implikationen für die Automobilindustrie**
Authors	McKinsey & Company
Year	2010
Coverage (country)	Germany and World
Analytical basis: theoretical/empirical/modelling	Modelling
GHG reduction measures considered	Different scenarios regarding the uptake of EV and new technologies in general
Main impact channels and assumptions used	By 2020: The industry producing conventional mechanic components of cars will have lost -13.8 billion of value added globally. On the other hand, the industry producing new components wins, as global value added increases with approx. 75 billion
Main outcomes	Assuming that per 300.000 euro value added 1 job (FTE) is created, this leads to the following world-wide job impact: the conventional car industry loses 46.000 jobs, the new car industry creates 250.000 jobs, on balance: 204.000 jobs will have been created by 2020.
Discussion/appreciation of the study	The job estimate by McKinsey is a very rough job estimate. Using a constant value added/job ratio is tricky, given the fact that such ratios change with new production technologies and the conventional ICE industry is more labour intensive than the production of electric vehicles. Furthermore, the estimate is for 2020, a year in which innovative technology is used alongside the conventional car technology. In later years, the impact may be larger as the conventional ICE industry is gradually disappearing.

Title	**Strukturstudie BWe mobil: Baden-Württemberg auf dem Weg in die Elektromobilität**
Authors	Fraunhofer-IAO et al.
Year	2010
Coverage (country)	Germany, Baden-Württemberg
Analytical basis: theoretical/empirical/modelling	Theoretical/literature study
GHG reduction measures considered	This study describes the expected development of electro-mobility.
Main impact channels and assumptions used	The estimation of costs of the individual components was performed by a meta-analysis of published studies. In 2020, the battery will account for 50% of the costs for long-range vehicles and almost 40% of the cost of small vehicles. The electric motor together with the required motor controller take up 7% of total vehicle costs. Comparing 2020 with 2010, the worldwide market volume of ICE will decrease by 11 billion euro. On the other hand, a market volume growth 43.4 billion € is to be expected for solutions to reduce CO_2 emissions from ICE (stop-and-go-systems, etc.). The traction battery industry will gain about 33 billion euro.
Main outcomes	On balance, in 2020 the world market volume of the car industry willy have increased by approx. 111.5 billion euro. Assuming that per 300.000 euro value added 1 job (FTE) is created, this leads to a worldwide creation of 371,800 additional jobs compared to the current situation. The region Baden-Wurttemberg is assumed to make up 5% of the worldwide car industry. For the regional distribution of jobs, a critical factor is the location of battery production facilities.
Discussion/appreciation of the study	Similar to McKinsey (2010), this study presents a very rough job estimate, with a constant value added/job ratio. The analysis presented is much more elaborated than in McKinsey (2010), and the presented impact on market volume is much more positive.
Title	**Automotive landscape 2025: Opportunities and challenges ahead**
Authors	Roland Berger Strategy Consultants
Year	2011
Coverage (country)	Worldwide automotive industry
Analytical basis: theoretical/empirical/modelling	Interviews with automotive industry experts
GHG reduction measures considered	The study describes developments in the automotive sector, such as demotorisation and powertrain electrification. In the most positive of all cases, electric vehicles will account for around 10% of new vehicle sales by 2025, hybrids will reach 40% share – internal combustion engines will still account for 50%
Main impact channels and assumptions used	
Main outcomes	By 2025, a shift of production to Asia will potentially lead to a loss of 300,000 jobs in Europe. This process is stimulated by the lack of engineers and specialists in some EU countries (e.g. Germany, the Netherlands). Countries with shrinking and aging populations will find themselves with a higher average employee age and a lack of graduates on the job market. Demographic change will result in a particular lack of graduates in STEM disciplines – science, technology, engineering and mathematics. The war for talent will escalate, with a negative effect on the cost of labour. Diminishing labour resources and stagnant productivity will put mature markets' production capacities under pressure, and it may become too expensive to export. At the same time, automotive-related industries such as transportation, retail and other services will create an additional one million jobs in Europe, outweighing the loss in manufacturing jobs. On balance, there will be an increase of 700,000 jobs in the European automotive sector in 2025.
Discussion/appreciation of the study	This study is one of the few that analyses the employment situation at least partly from a supply side perspective (e.g. the shortage of engineers) rather than a demand perspective where the creation of value added automatically leads to a certain number of jobs.

Title	**Boost! Transforming the powertrain value chain - a portfolio challenge**
Authors	McKinsey & Company
Year	2011
Coverage (country)	Worldwide automotive industry
Analytical basis: theoretical/empirical/modelling	Modelling: developing and employing a value chain model
GHG reduction measures considered	Stricter CO_2 regulation, which results in optimisation of current ICE technology (smaller, highly-charged engines, etc.) as well as electrification of the powertrain. The main employment results are presented for the 'below 40' scenario: strong CO_2 emission reduction to 40 g/km in 2050.
Main impact channels and assumptions used	
Main outcomes	By 2030, an additional 420,000 FTE will have been created in the powertrain industry globally. More than half of these additional jobs will be located in India and China. In high-wage countries (Europe, North America and Japan), the low labour intensity will make EV production attractive. In the EU, 110,000 new jobs will be created in production and R&D, especially in chemicals and electronics, whereas the mechanics-dominated industries will stagnate. The estimation is based on typical employment intensities by component and region; without taking significant shifts in imports/exports into account and assuming that all components are produced in the country of car production.
Discussion/appreciation of the study	The report is not very transparent on the value chain model used. The conclusion that its low labour intensity will make EV production in high-wage countries attractive is interesting.
Title	**More jobs per gallon: How Strong Fuel Economy/GHG Standards Will Fuel American Jobs**
Authors	CERES and MISI
Year	2011
Coverage (country)	US
Analytical basis: theoretical/empirical/modelling	Modelling: the MISI model is based on a widely used economic modelling technique, the economic input-output (I-O) model.
GHG reduction measures considered	The study analyses four GHG reduction scenarios: 1) the EPA/NHTSA/California Air Resources Board (CARB) 6% annual scenario—the highest standard under consideration by the agencies, which implies a 143 gram per mile CO_2-equivalent GHG standard and a CAFE standard of about 54-56 mpg7 by 2025; 2) a three per cent annual scenario (the lowest under consideration) in 2025; 3) a four per cent annual scenario; and 4) a five per cent annual scenario.
Main impact channels and assumptions used	Greater reductions come at greater incremental vehicle costs. The per vehicle cost increase in 2025 ranges from slightly under $1,000 per new vehicle for a three per cent annual GHG reduction, increasing to as much as $3,500 per new vehicle to achieve a six per cent annual GHG reduction. However, consumer savings would also increase with the lower GHG emissions and higher fuel economy. For the different scenarios analysed, the net lifetime savings to the consumer due to increased vehicle efficiency range from $4,900 to $7,400 for an average new vehicle in 2025. Because in all CAFE/GHG scenario cases the additional costs of the vehicles are less than the additional costs of the fuel, residual consumer expenditures were allocated to the final demand category of personal consumption expenditures.

Main outcomes	Under the CAFE/GHG scenarios, the consumer is purchasing more expensive LDV's outfitted with better technology; and under the Reference scenario, the consumer is purchasing more liquid fuel for the vehicle. Thus, as shown in Figure IV-3, each of the four enhanced CAFE/GHG scenarios results in economic and jobs benefits to the U.S. economy in 2030. The greater the improvements in fuel economy and GHG emissions, the larger the benefits to the economy. The 3% scenario shows a job creation of 352,000.
Discussion/appreciation of the study	On the positive side, the input-output model used seems to be thorough and in the report, the employment effects are calculated for the whole economy rather than just for the automotive industry, as alternative spending patterns are taken into account. However, it is a static model: there are no general equilibrium movements in the model. For example, when cars become more fuel efficient, the mileage does not change. It is also not clear which people take up the newly created jobs: are they sufficiently skilled? Finally, a large share of the employment effect is caused by the fact that the US currently imports a lot of oil whereas cars are produced domestically, and the input-output model is calibrated on this present situation. However, the effects are presented for 2030. If a large share of the car industry has moved to Asia by 2030 (e.g. because batteries are produced in Asia), then the results could be dramatically different.
Title	**The Economic Benefits of Investing in Clean Energy: How the economic stimulus program and new legislation can boost U.S. economic growth and employment**
Authors	PERI and Center for American Progress
Year	2009
Coverage (country)	US
Analytical basis: theoretical/empirical/modelling	Theoretical/ input-output modelling
GHG reduction measures considered	Two recent government initiatives, which could generate $150 billion per year in new clean-energy investments in the United States over the next decade. This includes government funding but is notably dominated by private-sector investments. Clean-energy investment areas include: Energy efficiency, Building retrofits, Smart grid, Public transportation, on grid renewable electricity, off grid renewable electricity, off grid renewable, alternative motor fuels
Main impact channels and assumptions used	The employment estimates are figures generated directly from 2007 data from the US Commerce Department's surveys of businesses, and organised systematically within their input-output model. There are three reasons why clean energy investments generate more jobs than investments in fossil fuel. 1) Relative labour intensity. Relative to spending within the fossil fuel industries, the clean energy program—including the direct spending on specific projects plus the indirect spending of purchasing supplies—utilises far more of its overall investment budget on hiring people, and relatively less on acquiring machines, supplies, land (either on- or offshore) and energy itself. 2) Domestic content. The clean-energy investment program—again, considering direct plus indirect spending—relies much more on economic activities taking place within the United States—such as retrofitting homes or upgrading the electrical grid system in communities throughout the country—and less on imports than spending within conventional fossil fuel sectors. 3) Pay levels. Clean-energy investments produce more jobs for a given dollar of expenditure due to the larger number of entry-level jobs relative to the fossil fuel industry. Workers thus benefit through the expansion of job opportunities at all levels within the U.S. labour market.

Main outcomes	Clean-energy investments generate approximately 17 jobs per $1 million whereas for fossil fuel spending this figure stands at 5 jobs. An annual $150 billion clean-energy investment level would generate a total of about 2.5 million jobs. By contrast, spending the same $150 billion within the fossil-fuel industry would produce about 800,000 jobs. This is a difference of roughly 1.7 million jobs, and equivalent to a fall in the unemployment rate from 5.8% to 4.7%. This greater than one percentage-point reduction in the country's unemployment rate would generate a rise in wages across the board—particularly for low-income workers. According to the body of research surveyed by Timothy Bartik of the W.E. Upjohn Institute, a one percentage-point fall in the unemployment rate will in turn lead to a rise in average earnings of about two per cent. Bartik notes that this positive wage effect is likely to be somewhat stronger at the lower end of the labour market, because other than the falling unemployment rate itself they are not likely to have other tools to help them raise their bargaining power.
Discussion/appreciation of the study	This is the only study in our analysis of which the authors acknowledge the weak points of the study and even try to refute these arguments. For example: "There are certainly weaknesses with our use of the input-output model. The most important are that it is a static model, a linear model, and a model that does not take into account structural changes in the economy. But these flaws in our approach need to be considered in the context of alternative approaches that operate with even more serious deficiencies." Furthermore, "supply constraints could create problems for our estimation methods if the U.S. economy begins to approach full employment", but they argue that in times of high unemployment the argument of supply constraints does not hold. Finally, they present counterarguments to the claim that the job expansion comes at a stiff price since it occurs through promoting low productivity, protectionism, and low wages. The counterargument is that for the unemployed, productivity rises from zero to something and that there are externalities (GHG emissions) that are not taken into account. The report does not only estimate direct employment, but also indirect employment (suppliers) and induced employment (employees spend their money on goods, which in turn creates employment). Estimating the last two categories is really only useful in times of high unemployment. On a critical note, it is not clear who exactly pays for this $150 billion. Part of it is tax money, and the cost of taxation should also be taken into account. Investment costs by companies will result in higher product prices, in turn lowering demand.
Title	**Driving Growth: How Clean Cars and Climate Policy Can Create Jobs**
Authors	The Planning Edge and MMTC
Year	2010
Coverage (country)	US
Analytical basis: theoretical/empirical/modelling	Theoretical/lobbying document
GHG reduction measures considered	The United States recently adopted standards to increase the fuel efficiency of the new vehicle fleet after more than two decades of inaction. The first measure, contained in the Energy Independence and Security Act of 2007, would have increased fleet wide fuel economy to at least 35 miles per gallon (mpg) by 2020. This standard was strengthened in May 2009 through a new program that established national harmonised fuel economy and greenhouse gas tailpipe standards. Under the latter program, the new passenger vehicle fleet will achieve, on average, 250 grams of CO_2 equivalent per mile by 2016. This is roughly equal to 35.5 mpg, requiring new vehicle fleet average fuel consumption to fall by 30 per cent from 2012 to 2016.
Main impact channels and assumptions used	The move to greater fuel economy means greater labour content per vehicle and higher employment across the fleet. This will include new investment in a host of incremental improvements to conventional gasoline powered internal combustion engines, from new controls for valves and timing, to variable speed transmissions and advanced electronics. It will also include entirely new systems like hybrid drive trains and advanced diesel engines. In 2014, this will add about $848 to the manufacturing cost of each car and light truck

	assembled in North America. If this cost is applied across 13.3 million North American assemblies, $11.3 billion more in content will be added to North American-built vehicles. In 2020, achieving 40.2 mpg by MY 2020 would add an additional $1,152 to the manufacturing cost of each vehicle, for a total increase of $2,000 over 2008. The study uses a U.S. jobs-per-100,000 vehicles ratio of 17,000 for 2014 and 2020. Furthermore, J.D. Power & Associates report for 2008 a median new car and light truck pre-tax transaction price of $25,594. Based on prior analysis, TPE and MMTC estimate that 20 per cent of this amount is attributable to brand marketing, transportation, dealer mark-up, warranty repair, interest, and other costs that apply to full vehicles but not to their components. The cost to design, manufacture, and test each vehicle averages about $20,000, which is a critical number to the analysis. TPE and MMTC assume that employment is proportional to cost. Thus, a fuel-saving technology that adds $500 to the cost of each vehicle is associated with 2.5 per cent of the $20,000 vehicle cost. It is therefore associated with 2.5 per cent of the 17,000 jobs per 100,000 units. If the technology is applied to 1 million vehicles, it would create 4,250 U.S. jobs.
Main outcomes	In 2014, the increase in vehicle costs will create 62,000 additional jobs, of which 20,000–54,000 will be in the United States. Just under 40 per cent of these jobs will be in the auto and auto parts sector. The remaining 60 per cent will be either in the broader manufacturing supply chain, including raw materials such as steel or intermediate goods (stamped, machined, moulded, cast and forged parts), or in nonmanufacturing jobs elsewhere in the economy. Recaptured energy expenditures could provide further economic benefits, though those effects have not been modelled in this study. In 2020, The added production of $15.4 billion in vehicle content (a total of $26.6 billion over 2008) across North American assemblies will have produced 191,000 jobs compared 2008, of which 49,000-151,000 will be in the United States. Roughly 40 per cent of the domestic jobs will be in the auto sector, the balance will be in other industries such as services and the broader manufacturing supply chain. While it is certain that the production of new technology will create demand for workers, where those jobs locate will be the product of policy choices. Of the over 190,000 jobs anticipated by 2020, the number of domestic jobs created could vary greatly. Fewer than 50,000 jobs might go to American workers, or, with different incentives, more than three times that number, as many as 150,000 U.S. workers, could find employment as a result of new investments in the engineering and production of the technology needed to improve fuel economy. Many additional benefits of energy independence do not even figure in this calculation.
Discussion/appreciation of the study	A number of assumptions in this study are tricky. The production forecasts are based on a 2014 market size (U.S. sales) of 15.7 million, substantially higher than the current sub-10-million level, though well below the 1998–2006 average of 16.7 million. Secondly, the analysis conservatively assumes that gasoline and diesel prices will remain at today's level, in real terms. Thirdly, as in other studies higher vehicle costs do not lower demand. In general, there is a protectionist edge to the argumentation in the study.
Title	**La voiture électrique menace les garagistes**
Authors	Le Figaro (Cyrille Pluyette)
Year	2010
Coverage (country)	France
Analytical basis: theoretical/empirical/modelling	Newspaper article based on interviews/literature study
GHG reduction measures considered	Electrification of vehicles
Main impact channels and assumptions used	According to Renault, electric vehicles require only half the maintenance of conventional vehicles (€500 per year instead of €1000).
Main outcomes	According to Sia (the French society of automotive engineers), every 1 million electric vehicles in circulation destroys 1000 jobs in car maintenance. In total, 13,000 to 23,000 maintenance jobs could be lost by 2020 compared to now, with acceleration from 2015 onwards. This is equal to about 20% of the total current jobs in maintenance.

Discussion/appreciation of the study	This is only a brief newspaper article and the employment figures appear to be rough estimates. Still, the notion that electric vehicles require only about half the maintenance (in terms of euros) as conventional vehicles is interesting.
Oil Imports	
Title	**The impact of lower oil consumption in Europe on world oil prices**
Authors	Enerdata
Year	2009
Coverage (country)	47 countries or regions, with a detailed national model for each EU Member State (25), four industrialised countries (USA, Canada, Japan and Russia) and five major emerging economies (Mexico, Brazil, India, South Korea and China)
Analytical basis: theoretical/empirical/modelling	Modelling: POLES (Prospective Outlook on Long-term Energy Systems) is a partial-equilibrium world model of the energy sector
GHG reduction measures considered	Baseline scenario: 130 g/km by 2012, subsequent further improvement. Scenario 2: delayed implementation of 130 g/km until 2015, scenario 3: 2012 objective plus 95 g/km in 2020, scenario 4: 80 g/km by 2020 and 60 g/km by 2025
Main impact channels and assumptions used	Reduced oil consumption leads to lower variable costs for conventional ICE vehicles, but a higher investment cost. The total cost of conventional cars in 2030 per km (inv. cost + variable costs) is 33% higher in scenario 4 compared to the baseline. In 2030, the percentage of conventional cars decreases to 88% in Scenario 2 (the least constraining) compared with 66% in Scenario 4 (the most stringent). In terms of final energy consumption, fossil fuels (excluding oil) are not sensitive to fuel efficiency standards for cars. The consumption of electricity and hydrogen will rise. In terms of primary consumption, greater use is made of natural gas and coal in Scenario 4 in 2030 than in the Baseline. In fact, the road transport sector consumes 16 Mtoe of electricity in the former and 6 Mtoe in the latter. This additional electricity consumption is provided mainly by gas and coal plants, which reduces the positive environmental impact. Overall, emissions still fall.
Main outcomes	In scenario 4 (the most stringent), the economic benefits of reduced oil consumption for the EU27 are €28 billion in 2030, which is a 12% decrease in expenditures on oil compared to the baseline. Depending on the scenario and the year considered, 84-91% of these savings would derive from a decrease in the import volume and 9-14% from lower international oil prices resulting from these European CO_2 standards. The effect on oil prices will be stronger if more countries/regions adopt stricter standards.
Discussion/appreciation of the study	The POLES model seems fit to describe developments in the energy market, although it appears that possible rebound effects of lower variable transport costs (higher demand for transport/mileage) have not been taken into account. Secondly, the conclusion that the total cost of ownership of ICE cars per km in 2030 are possibly 33% higher than in the baseline scenario is significant, and the impact of this on vehicle purchases will counteract the positive macro-economic effects from lower oil consumption. This is not taken into account, as the total number of cars in the economy is only related to GDP in the model (see appendix 1).
Title	**Estimating the Energy Security Benefits of Reduced U.S. Oil Imports**
Authors	ORNL
Year	2007
Coverage (country)	US
Analytical basis: theoretical/empirical/modelling	Theoretical: Using an oil premium calculation methodology which combines short run and long run costs and benefits.
GHG reduction measures considered	
Main impact channels and assumptions used	The oil premium is a measure of the quantifiable per-barrel economic costs which the U.S. could avoid by a small-to-moderate reduction in oil imports. The premium does not estimate the value of introducing a radical new technology, which may entail a major shift in supply or demand curves, or a substantial change in the long run or short run flexibility of supply or demand

Main outcomes	The oil premium is estimated to be $13.58 per barrel ($2004), of which $8.90 is a monopsony component (the fact that the US is such a large buyer that it influences the world price) and $4.68 the cost of macro-economic disruption. A sudden increase in oil prices triggered by a disruption in world oil supplies has two main macro-economic effects: it reduces the level of output that the U.S. economy can produce using its available resources; and it causes temporary dislocation and underutilisation of available resources, such as labour unemployment and idle plant capacity. Dislocational effects include the unemployment of workers and other resources during a period of their intersectoral or interregional reallocation, and pauses in capital investment due to uncertainty. These adjustments temporarily reduce the level of economic output that can be achieved even below the "potential" output level that would ultimately be reached once the economy's adaptation to higher petroleum prices was complete.
Discussion/appreciation of the study	As noted by the author, these calculations can only account for small changes in demand for oil. For a complete shift away from petroleum based transport, the model is less suitable. Still, it is clear that the oil premium is substantial. Taken together, the EU member states could have a similar monopsonic impact on the global oil price as the US. The cost of macro-economic disruption as described in this paper is interesting and very relevant.
Title	**Oil Prices, Exhaustible Resources, and Economic Growth**
Authors	Hamilton
Year	2012
Coverage (country)	Worldwide oil market
Analytical basis: theoretical/empirical/modelling	Theoretical (using some empirical evidence)
GHG reduction measures considered	
Main impact channels and assumptions used	
Main outcomes	Hamilton (2009b) noted that what happened in the early stages of the 2007-2009 recession was quite consistent with the pattern observed in the recessions that followed earlier oil shocks. Spending on the larger domestically manufactured light vehicles plunged even as sales of smaller imported cars went up. Had it not been for the lost production from the domestic auto sector, U.S. real GDP would have grown 1.2% during the first year of the recession. Coping with a final peak in world oil production could look pretty similar to what we observed as the economy adapted to the production plateau encountered in the period 2005-2009. That experience appeared to have much in common with previous historical episodes that resulted from temporary geopolitical conflict, being associated with significant declines in employment and output. If the future decades look like the last 5 years, we are in for a rough time.
Discussion/appreciation of the study	From the study it becomes clear that future oil supply and oil prices are very uncertain, oil shocks have negative macro-economic impacts and therefore moving away from oil dependence is a good thing to do. However, the negative impact of the oil shock on the U.S. automotive industry in the 2007-2009 period could have been less severe if the industry had adequately responded to the shift in consumer demand towards smaller cars.

Other	
Title	Social efficiency of electric vehicle subsidies
Authors	Joel Kroodsma
Year	2012
Coverage (country)	The Netherlands
Analytical basis: theoretical/empirical/modelling	Theoretical
GHG reduction measures considered	EV vehicle subsidies, in the Netherlands this means a reduction in sales tax (BPM) and registration tax (MRB)
Main impact channels and assumptions used	
Main outcomes	Given the current tax system, the environmental and energy security benefits of the marginal electric vehicle on the road, are outweighed by the direct and indirect costs to the public revenue. In other words, the current subsidies are welfare-decreasing. The implicit CO_2 price of 685 euro/tonne CO_2 is much higher than the marginal abatement costs in other sectors of the economy (+/- 25 euro)
Discussion/appreciation of the study	The significance of this study lies in the fact that it illustrates that vehicle subsidies come at a cost in the Netherlands.
Not very useful	
Title	**Etude « Filières vertes »: Les filières industrielles stratégiques de la croissance verte**
Authors	MEEDDM et CGDD
Year	2009
Coverage (country)	France
Analytical basis: theoretical/empirical/modelling	Unclear
GHG reduction measures considered	Decarbonisation of vehicles. According to the report, France is positioning itself on the market for fully-electric vehicles, rather than PHEV.
Main impact channels and assumptions used	
Main outcomes	The report presents the opportunities and challenges involved with the decarbonisation of vehicles. One of the obvious risks mentioned is that economic activity and employment in the ICE supply chain will decline.
Discussion/appreciation of the study	This study is not very useful for the purposes of this study
Title	**Climate Change and employment: Impact on employment in the European Union-25 of climate change and CO_2 emission reduction measures by 2030**
Authors	ETUC et al.
Year	2007
Coverage (country)	UK
Analytical basis: theoretical/empirical/modelling	Heavily based on the Friends of the Earth (1997) study
GHG reduction measures considered	Same scenarios as in Friends of the Earth (1997) study

Main impact channels and assumptions used	For the car, the technical ratios take into account the whole of the automobile branch: automobile manufacturers, suppliers, associated services (fuel distribution, repairs, etc.), infrastructure and all inputs (materials and fuels). For road and rail public transport, the ratio takes into account not only jobs induced in the construction and repair of material but also jobs induced by investments in infrastructure.
Main outcomes	Overall, policies aiming on the one hand to restrict transport activity and on the other hand to rebalance transport modes in favour of rail in particular for both freight and passenger transport, far from being unfavourable to employment, these policies would lead to a growth in overall employment of around 2% on average per year over the period 2000/2030 for passenger transport and 1.25% for freight transport. For the UK, the increase in jobs could lie between 87,000 and 122,000. On the subject of employment within the automobile branch, this would be stable as a result in particular of the increased added value linked to the spread of clean technologies (of course this effect may be more or less strong depending on the rate of coverage of the European market).
Discussion/appreciation of the study	This study is very heavily based on the Friends of the Earth (1997) study, it does not contribute anything to the discussion.
Title	**Mobilité décarbonée : quels impacts pour les emplois et les compétences? sur le bassin d'emploi de Rennes à l'horizon 2020**
Authors	CODESPAR
Year	2011
Coverage (country)	France (Rennes)
Analytical basis: theoretical/empirical/modelling	Literature study/expert interviews
GHG reduction measures considered	Measures to decarbonise transport (electrification)
Main impact channels and assumptions used	The report presents figures/estimates on job creation or destruction. E.g. "According to Sia (the French society of automotive engineers), 300 maintenance jobs would be threatened around Rennes. However, according to Véhipole and GNFA, certain factors could offset some or all of this job destruction (aging of the car park, the increasing complexity and diversification of engines, including electrification and increased use of electronics ...)."
Main outcomes	In the summary table on employment, impacts of new technologies on employment in different sectors of the automotive sectors are summarised. On balance, the result seems to be a fairly constant employment growth up to 2020. Employment related to ICT in mobility grows, employment related to maintenance declines.
Discussion/appreciation of the study	The study is not much more than a summary of results from other studies/expert interviews. Furthermore, it only looks at maintenance of the car, not the design and production of it. There is not much valuable information in it.
Title	**Étude prospective sur le développement des activités et des emplois dans les secteurs de l'efficacité énergétique et des énergies renouvelables en Ile-de-France**
Authors	Arene
Year	2006
Coverage (country)	France
Analytical basis: theoretical/empirical/modelling	Literature study
GHG reduction measures considered	GHG reduction measures related to energy efficiency and renewable energy
Main impact channels and assumptions used	

Main outcomes	From a literature study, the employment ratios (FTE/million) that emerge are: - 10 to 16 FTE in programs related to the structure of buildings (insulation and replacement heating systems); - 8 to 14 FTE in programs improving the energy efficiency of heating systems; - 10 to 20 FTE in programs related to the construction of bioclimatic buildings or high-performance energy; - 7 to 14 FTE in programs related to the improvement of the effectiveness of appliances and lighting systems; - 14.7 FTE in programs related to the development of energy from wood. - 20.7 FTE in programs related to the installation of solar water heaters. 75% of these jobs would be national, and added to that one operating / maintenance job per thousand TOE installed.
Discussion/appreciation of the study	The studies reviewed in this report date form 1998 to 2002 and are therefore not very much up-to-date. Also, the automotive industry was not included. However, it is one of the few studies that look at employment in 'green' sectors in France.
Title	**Environmental impacts and impact on the electricity market of a large scale introduction of electric cars in Europe - Critical Review of Literature -**
Authors	ETC/ACC
Year	2009
Coverage (country)	EU
Analytical basis: theoretical/empirical/modelling	Theoretical/literature study
GHG reduction measures considered	The study tries to describe future developments with respect to a possible large scale introduction of electric cars in Europe
Main impact channels and assumptions used	
Main outcomes	Some economic considerations that are mentioned: While the higher investment costs of electric vehicles are apparent for purchasers, running costs of different vehicle types are less transparent and not fully factored in at the moment of vehicle purchase. These economic considerations finally determine the penetration rate of electric vehicles and are therefore of main importance with regard to the overall potential of electrically substitutable mileage (mobility sphere). A large-scale introduction of electric vehicles would result in a considerable demand for new materials for battery production. Currently, there is a controversial debate about the global lithium supply and production in the context of a large-scale introduction of electric vehicles.
Discussion/appreciation of the study	This study is less useful for our purposes: it does not describe developments in employment.
Title	**Supplying Ingenuity: U.S. Suppliers of Clean, Fuel-Efficient Vehicle Technologies**
Authors	NRDC et al.
Year	2011
Coverage (country)	US
Analytical basis: theoretical/empirical/modelling	Lobbying document
GHG reduction measures considered	Improvements in fuel economy standards in current en future years
Main impact channels and assumptions used	Growth in the U.S. automotive sector jobs depends, as it always has, on continued innovation to keep demand high for U.S.-made vehicles and parts.

Main outcomes	According to statistics from the first five months of 2011, the automobile industry in the United States directly employs an average of 694,000 workers. But even after beginning to recover from the 2009 crisis, automotive employment is only half what it was in early 2000. This one-sector collapse predates the financial crisis, caused by the loss of market share by domestic firms and increased imports, and the relocation of production and engineering jobs overseas. More than 427,000 of those jobs are at automotive suppliers—companies that design, engineer, and manufacture the parts that are eventually assembled into cars and light trucks.
Discussion/appreciation of the study	This report is not useful for the purposes of this literature review
Title	**Fleet Electrification Roadmap: revolutionising transportation and achieving energy security**
Authors	Electrification Coalition
Year	2010
Coverage (country)	US
Analytical basis: theoretical/empirical/modelling	Lobbying document
GHG reduction measures considered	A scenario in which 75 per cent of light-duty vehicle miles travelled would be electric miles by 2040.
Main impact channels and assumptions used	As a result of reduced sales and declining domestic output, the number of U.S. workers building vehicles and their components has dropped dramatically. Between 2000 and 2009, total American workers employed in motor vehicle and auto parts production fell by more than 50 per cent, from 1.13 million to approximately 560,000. Electrification of transportation offers a rare opportunity to counter these dynamics. Recent history has repeatedly demonstrated that oil price shocks frequently result in recession, public debt expansion, and high unemployment for the United States.
Main outcomes	The argument is simply the following: Investments in electric vehicle technology have a positive effect on employment and oil dependence.
Discussion/appreciation of the study	The analysis is fairly weak, no quantification of job impacts is provided.