Fuelling Europe's Future

How the transition from oil strengthens the economy

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Disclaimer

The stakeholders who contributed to this study shared the aim of establishing a constructive and transparent exchange of views on the technical, economic and environmental issues associated with the development of low-carbon technologies for cars. The objective was to evaluate the boundaries within which vehicle technologies can contribute to mitigating carbon emissions from cars in Europe. Each stakeholder contributed their knowledge and vision of these issues. The information and conclusions in this report represent these contributions, but should not be treated as binding on the companies and organisations involved.

Executive Summary

The transition from petroleum-based energy to renewably sourced energy will strengthen Europe's economy. At present, the European Union imports 89% of its crude oil, the vast majority of which is used for transport fuel. This exposes the economy to the volatility of global crude oil prices; increases the trade deficit, and has wide-ranging geo-political ramifications.

For every €10 spent at the pump, €5.30 goes to the government as tax revenues, €1.50 goes to the refiners and distributors of fuel, and €3.20 leaves the European economy to pay for petroleum imports. Replacing imported oil with domestically-produced energy will keep many billions of euros recirculating in the European economy (€49 billion of avoided spending on oil in 2030 in our central scenario).

The problem of rising CO_2 levels is severe and well-documented. In 2016, the transport sector became Europe's biggest source of CO_2 at 27%, eclipsing the power sector[1]. At the same time, air pollution is a deadly problem. The European Environmental Agency estimates that over 85% of the population have been exposed to air pollutant concentrations above the World Health Organization guidelines for fine particulate matter (PM2.5)[2].

Tackling these three issues - climate change, air pollution and energy security - has rightly been prioritised by the European Union. The transition to clean mobility demands a systemic approach, taking into account solutions and transport modes beyond the automotive sector. However, it is already clear that this transition will not be successful without profound changes to the technologies used to power vehicles. Cars will need to become more efficient, with varying degrees of electrification. In the longer term, cleaner fuels such as electricity and hydrogen will need to become the norm. It is these changes that this study seeks to explore, and in particular the changes to socio-economic factors, such as household spending, taxation, employment and GDP.

We found that from the driver's perspective, the total cost of Zero Emissions Vehicles (ZEVs) is likely to converge with that of hybrids and traditional combustion engine vehicles during the next decade. In some particular use-cases (e.g. taxis), parity might even occur in the early 2020s, especially if governments encourage this convergence by way of smart policies.

The transition to clean mobility causes a wide range of impacts to employment across several sectors. The analysis shows that the transition to electricity and hydrogen will create new jobs, for example in manufacturing and installing the charging infrastructure or producing more renewable energy, but it will also reduce jobs in manufacturing combustion engines and the gasoline and diesel needed to power them.

Employment in the automotive sector will remain stable until 2030 in our central scenario, where climate goals are met by shifting to a balanced mix of efficient hybrids and electric-drive vehicles. While some ZEVs are less complicated to construct, reducing jobs, other low carbon cars such as hybrids are more complex to build, increasing employment. These two factors largely cancel out each other in our central technology scenario until after 2030. But from 2030 onwards, the structural changes become much more profound and uncertain. For example, the location of future battery manufacturing will have a significant economic impact, but what proportion of the battery value chain will be located in Europe is difficult to predict.

Overall, in this study, the net impact on employment was found to be positive (206,000 net additional jobs by 2030), but this should not be allowed to mask the significant transformational changes. Efforts must be made to ensure workers who are currently producing legacy technologies are retrained for quality jobs in producing the technologies of the future.

Charging infrastructure is a condition for deployment of ZEVs, and investment therefore needs to be accelerated from today's low levels. A determined and joint effort between industry, government and civil society is needed to achieve this goal. Electricity grids will need to be reinforced and modernized as part of sector coupling, but these costs could be reduced by implementing smart charging to moderate peak electricity demand.

While this study has not analysed impacts on the competitiveness of European companies, participants agreed that the European auto industry needs to remain at the cutting edge of clean technology innovation to remain competitive and thereby to maintain its share of a rapidly evolving market.

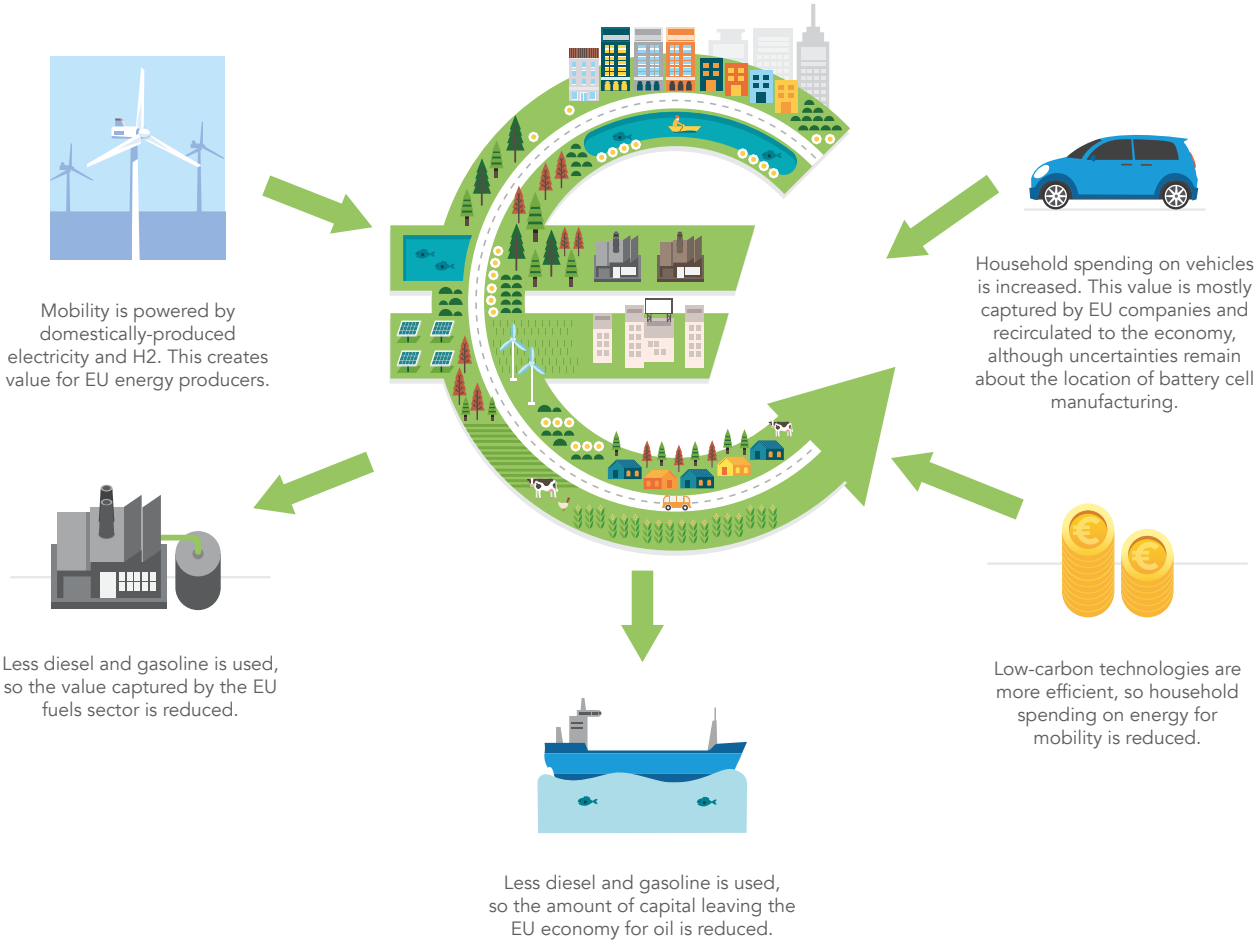


Figure 1. Main economic impacts of the transition to low-carbon vehicles in Europe.

Introduction

The Paris Agreement seeks to hold average global temperatures to well below 2 degrees Celsius, largely through cutting the use of fossil fuels. The European Commission's "Strategy on Low Emissions Mobility" foresees a fundamental shift away from petroleum towards greener energy sources. China and California have set ambitious targets for ZEVs. Several European cities have announced impending bans on diesel cars and a number of governments have announced deadlines for phase-out. It is clear that change is coming fast.

It is inevitable that much of this change will be achieved via the adoption of new vehicle technologies. For Europe, with many national economies heavily invested in automotive production, such goals will have profound and far-reaching consequences. With this in mind, the European Climate Foundation (ECF) convened a project to examine the main social, environmental and economic impacts of a technology-led transition to low-carbon cars.

While this study focuses on vehicle technologies, we acknowledge that the transition to low-carbon mobility will also require many other solutions, such as shared mobility. To help inform the assumptions and review the emerging evidence, the ECF convened an expert panel comprised of individuals from industry and civil society. From the automotive value chain were experts from BMW, Renault-Nissan, Toyota, Eurobat, European Aluminium, LeaseEurope, Michelin, and Valeo; from the energy and engineering sectors ABB, Air Liquide, Enedis and Siemens; workers were represented by ETUC and IndustriAll; and civil society was represented by the European Consumer Organisation (BEUC) and the European Federation for Transport and Environment (T&E).

This expert panel met on five occasions during 2017 to advise an analytical team, which was tasked with answering the following key questions:

- What are likely deployment scenarios for clean technologies for cars and to what extent can they contribute to meeting the EU's climate goals?

- What is the range of possible impacts on consumers from changes to vehicle purchasing costs and overall vehicle running costs?

- How much would the EU need to invest in charging infrastructure for the agreed vehicle technology scenarios, including reinforcing the electricity grid?

- What is the likely range of overall impacts on GDP and employment?

It is also worth noting three potential impacts that this study has NOT attempted to quantify:

- It has not tried to measure the impact on the competitiveness of the EU auto industry, either from outpacing or from lagging behind the global transition to clean mobility.

- It has not tried to measure changes to the number of cars that might result from potential changes in mobility patterns.

- While the study does provide calculations of the net impact on the economy as a whole, it does not provide a detailed analysis of the changes in employment within the automotive sector itself.

As such, the main result of this study is an overview of a structural change to mobility whereby there is an increase in efficiency, a change in drive-train technologies and energy infrastructure for cars, and a shift from imported oil to domestically produced electricity and hydrogen.

Methodology

The modelling approach used in this project is described in detail in the technical report, and is summarised in Figure 2. An expert panel was convened to help construct a series of plausible technology deployment scenarios, considering historic evidence of diffusion rates for low-carbon technologies, as well as the range of existing projections for future technology diffusion.

These scenarios do not attempt to be forecasts, but instead they represent "what if?" scenarios that are designed to achieve long-term climate policy objectives. Such changes need to be driven by standards and economic instruments at least until the total cost of new technologies reaches parity with existing technologies.

The panel also advised on the most relevant input data on mobility, vehicles, energy, infrastructure and economy. These are described in later chapters. The agreed datasets were then fed into a stock model, which determined changes to Europe's overall stock of capital assets and energy consumption per drive-train technology on an annual basis under each of the scenarios. Finally, the outputs from the stock model were fed into the macro-economic model E3ME.

The E3ME model embodies two key strengths relevant to this project. The model's integrated treatment of the economy, the energy system and the environment enables it to capture two-way linkages and feedbacks between these components. Its high level of disaggregation enables relatively detailed analysis of sectoral effects. E3ME delivered outputs in terms of changes to household budgets, the energy trade balance, consumption, GDP, employment, CO_2, NO_x and particulates.

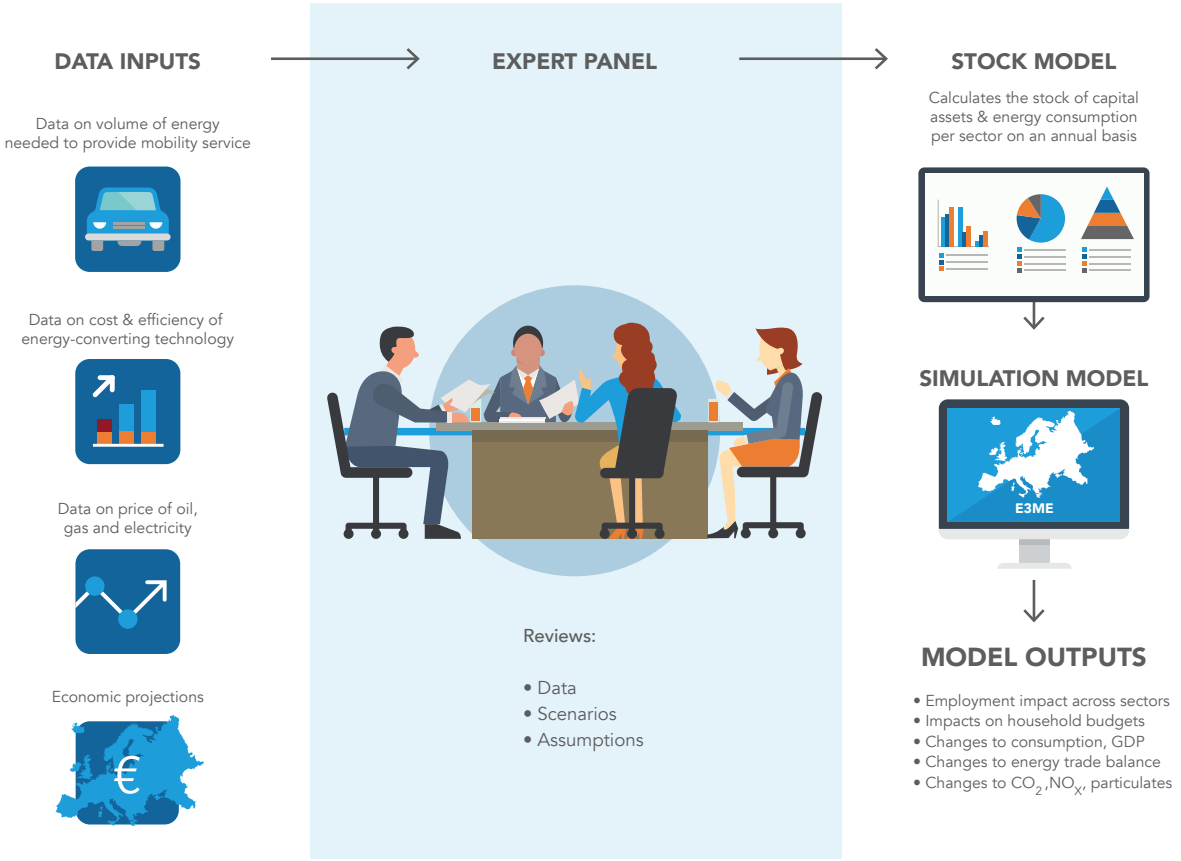
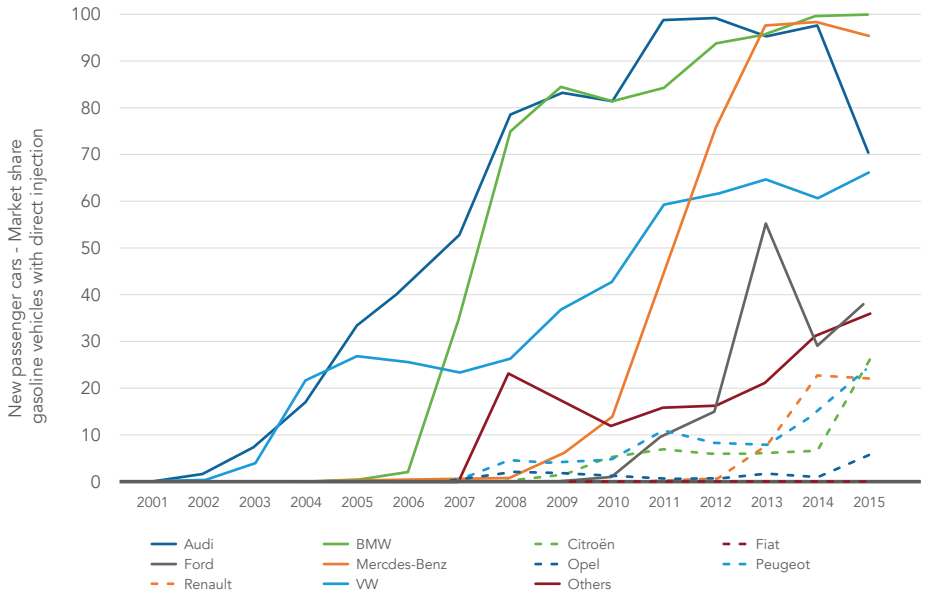


Figure 2. An overview of the modelling approach used in Fuelling Europe's Future.

Technology Deployment & Environmental Impacts

There is a wide range of uncertainty about future deployment of low- and zero-emissions technologies, which will be impacted by changes to technology costs, energy costs, the level of taxes and incentives, and consumer preferences. In seeking to determine plausible scenarios for technology diffusion, the expert panel drew on past evidence of technology deployment rates in the auto sector (Figure 3), showing that previous engine technology improvements have taken around 10-15 years from first deployment to full mass-market penetration.

Further to this, there have been many projections of ZEV deployment, of which some are based on modelling of consumer preferences. This project has not involved such sophisticated modelling of consumer responses to technology evolution, but instead has relied upon the previous studies and the best estimates of its diverse expert panel. The panel has agreed a central vehicle technology scenario that is considered plausible, achievable and broadly in line with the goals of the Paris Agreement, when combined with other measures to reduce transport CO_2.



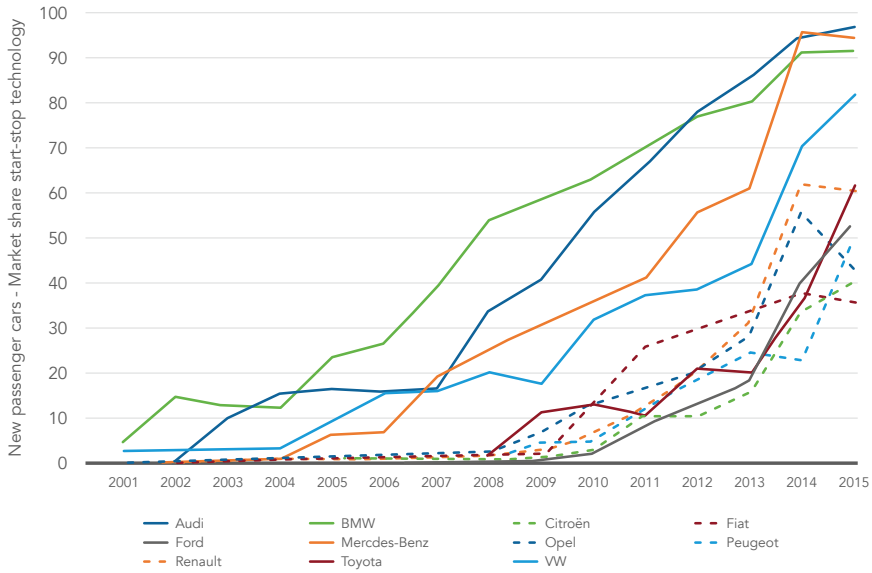


Figure 3. Historical deployment of start-stop and gasoline direct injection technology in Europe to meet regulatory emissions limits. (Source: ICCT)

To reflect the inherent uncertainties, we also modelled scenario variants. These scenario variants were used to explore the sensitivity of the results to oil prices and the location of manufacturing, and they are presented in the final chapter.

In the agreed central scenario TECH (Figure 4) the European car fleet changes from one that is dominated by diesel and gasoline vehicles in 2018 to one in which a quarter of new vehicle sales are ZEVs by 2030, namely Plug-in Hybrid Electric Vehicles (PHEVs), Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs) and a quarter are fully hybridised. Electricity is assumed to be decarbonised in line with the EU's 2050 climate goals. Hydrogen is assumed to be produced in Europe, predominantly using renewable electricity.

The remaining new combustion engine cars, representing half of the fleet, are themselves assumed to become mild hybrids by 2030. By 2040, all new cars sold are capable of zero emissions motoring in this central scenario. It should be noted, however, that the stock of vehicles changes more slowly than new car sales due to the slow renewal rate.

In our central TECH scenario, CO_2 emissions from cars are reduced from around 605 MT per annum in 2018 to about 70 MT per annum in 2050. At the same time, a substantial co-benefit is achieved by reducing emissions of health-damaging nitrogen oxides and airborne particulates (Figure 5). This is an important issue, because the European Environmental Agency estimates that over 85% of the population have been exposed to air pollutant concentrations above the World Health Organization guidelines for fine particulate matter (PM2.5)[3].

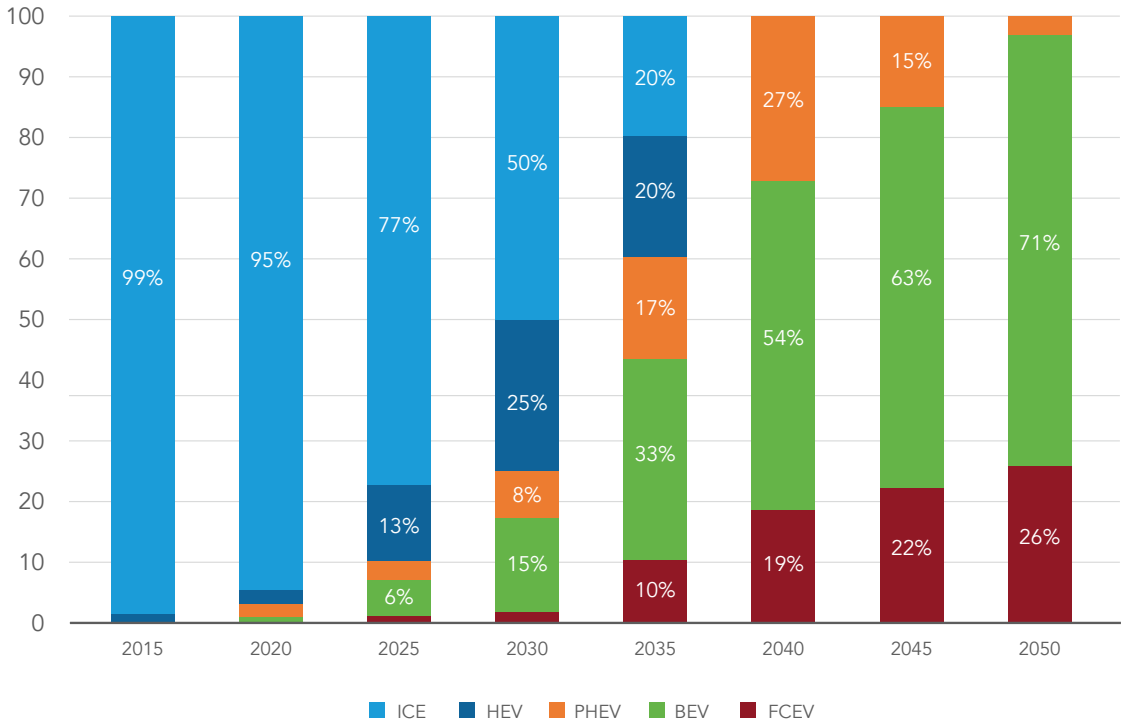


Figure 4. The evolution of new vehicle sales by technology type until 2050 in our central TECH scenario.

Technology Deployment & Environmental Impacts

Related illnesses reduce quality of life and cause about 467,000 premature deaths in Europe per year. Such illnesses create economic costs from medication, hospitalization and millions of lost working days, as well as harm to biodiversity, crop yields, buildings and monuments.

In our central TECH scenario, emissions of particulate matter from car exhausts would be cut from around 28,000 tonnes per year in 2018 to below around 750 tonnes in 2050. NOx would be reduced from 1.3 million tonnes per year in 2018 to around 70,000 tonnes in 2050. This is achieved via a combination of removing older cars from the stock and switching the energy source from diesel and gasoline to low-carbon electricity and hydrogen.

While emissions reductions are significant, there is still a large residual amount of emissions in 2030 and some in 2050. One reason is that while there is a rapid change to the technology mix in new vehicle sales, the technology mix in the overall fleet changes comparatively slowly. Vehicle lifetimes in Europe are around 16 years, and the average age of vehicles on the road today is 11 years. However, previous analysis undertaken for the ECF indicates that this scenario is capable of meeting the goals of the Paris Agreement if combined with a range of other measures to reduce transport CO_2, such as more efficient trucks and buses, advanced low-carbon fuels etc[4].

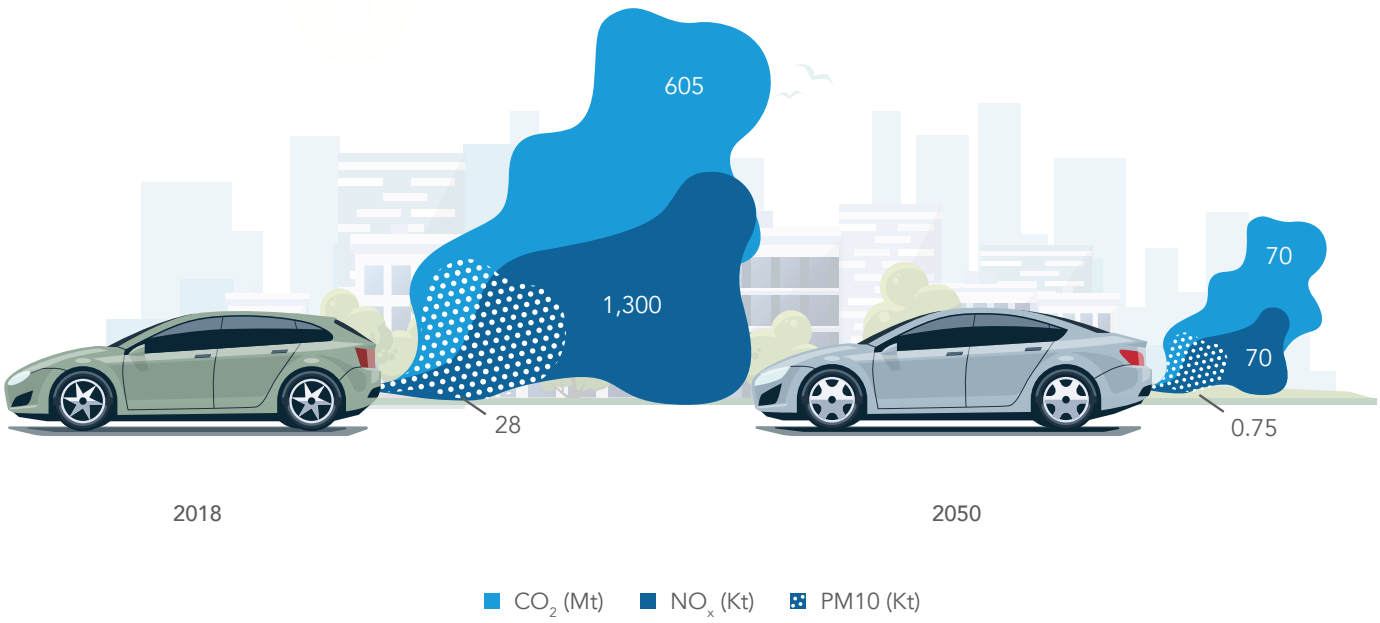


Figure 5. Reductions in European road transport emissions by 2050 in the TECH scenario, relative to the reference case.

Consumer Impacts

There is a wide range of views on the cost of vehicle technologies to reduce CO_2 emissions. Projections of the cost of improving the efficiency of diesel and gasoline cars vary widely (Figure 6). At the top end of the range of estimates is work based on industry surveys by the Institut für Kraftfahrzeuge at Aachen University (IKA), while at the lower end of the range are estimates based on detailed tear-down analysis by the International Council on Clean Transportation (ICCT). A more central view is provided by Ricardo-AEA in analysis conducted for the European Commission in 2015[5]. We have chosen this Ricardo data for the central assumptions on vehicle technology costs in our analysis, but we have also tested the impact if costs turn out to be higher or lower, in line with the views of either IKA or the ICCT.

The modelling of battery electric systems takes into account the cost of cells, wiring harnesses, containers and management systems, as well as performance improvements over time. Our baseline estimates are higher than some bullish cost projections recently published. For example, our analysis is more conservative than GM's recent estimate that the Chevrolet Bolt battery is $145/kWh at the cell level or GM's roadmap projection of a cell cost of $100/kWh by 2022. We are also more conservative than recent estimates that battery packs from the Tesla Gigafactory could reach $125/kWh by 2020.

Fuel cell cost assumptions are based on discussions with car manufacturers and a review of published data (such as US Department of Energy data). Costs are assumed to fall from the high values in today's low-volume models to approximately €100/kW in 2020, and €60/kW in 2030, subject to strong increases in production volumes. High-and low-cost scenarios have also been modeled.

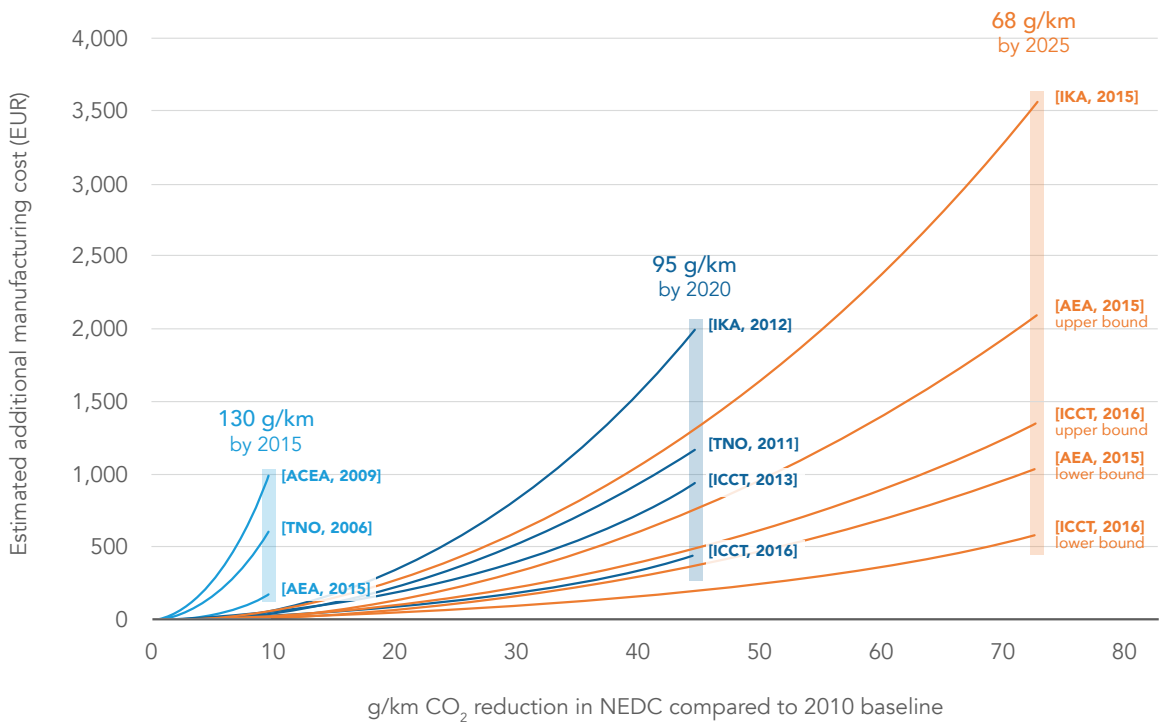


Figure 6. Cost estimates for technologies to reduce CO_2 from gasoline and diesel engines.

The cost of technologies to reduce CO_2 from cars will reduce over time as scale economies are achieved, but the aggregate costs will increase as more technologies are added to reach tighter CO_2 limits. In 2020, battery-electric and fuel-cell electric vehicles are projected to be significantly more expensive than diesel and gasoline vehicles and their hybrid variants. However, by 2030 the difference in price will be narrowed as diesel and gasoline cars become more expensive to meet air pollution and CO_2 limits and as ZEVs achieve scale economies. There is a convergence in costs in our central case, although not complete parity by 2030.

Changes to the purchase costs are just one element of the overall impact on consumers. It is also important to look at the total cost of owning a vehicle for the first owner, whose purchasing decision will determine whether the low-carbon technologies enter the European vehicle fleet or not. To understand this requires that over the initial ownership period we consider not only the purchase price, but also the costs of fuelling the vehicle, the financing costs, the charger cost if it is an electric vehicle, the maintenance costs, and amount for which it can be resold at the end of the ownership period. Figure 7 shows this perspective over a 4-year ownership period, with 15,000 km travelled per year, according to our central case.

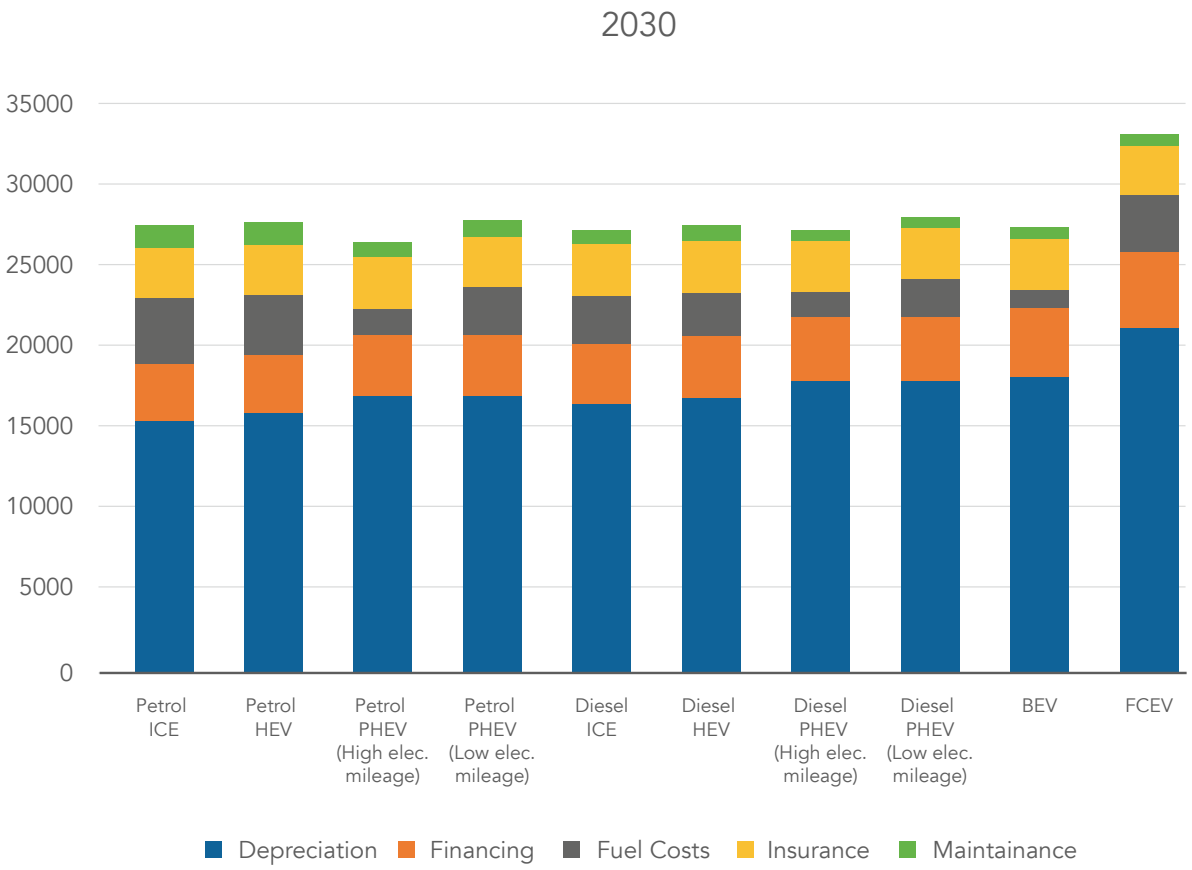


Figure 7. Total cost of owning and running a mid-size car over 4 years with various power trains in the TECH scenario in 2020 and 2030.

Consumer Impacts

The main finding is that by 2030 there is strong convergence in the cost of owning and running all types of vehicles in our central case, and this convergence is much stronger than when one considers the purchase price alone. However, it is also notable that there is a relatively wide range between the results from using the most optimistic and most pessimistic assumptions. These high-case and low-case estimates reflect different projections of the cost of diesel, gasoline, electricity and the low-carbon vehicle technologies, as well as the cost of borrowing to buy the vehicles.

It is important to note how these uncertainties might impact adoption of different powertrain technologies. For example, if the cost of reducing the environmental impact of petrol and diesel cars turns out to be at the high end of the range of uncertainty, and the cost of battery-electric cars turns out to be at the lower end of the range, then the transition might be driven by the market and occur rapidly. By contrast, if innovation leads to cheap improvements to gasoline and diesel vehicles, but battery cost reductions turn out to be slower than currently forecast, this transition will prove more challenging and will require more policy support. While we have presented average values in Figure 7, it is often more relevant to focus on use cases. Some use cases, such as inner-city deliveries and taxis, will achieve cost parity between technologies comparatively early.

There is also uncertainty about how energy for mobility will be taxed in future. Overall, there is a case for governments to reform the taxation of mobility, given the prospect of reduced fuel tax revenues in future. This will firstly be caused by improved vehicle efficiency – the agreed EU CO_2 targets for 2021 will lead to a fuel tax revenue

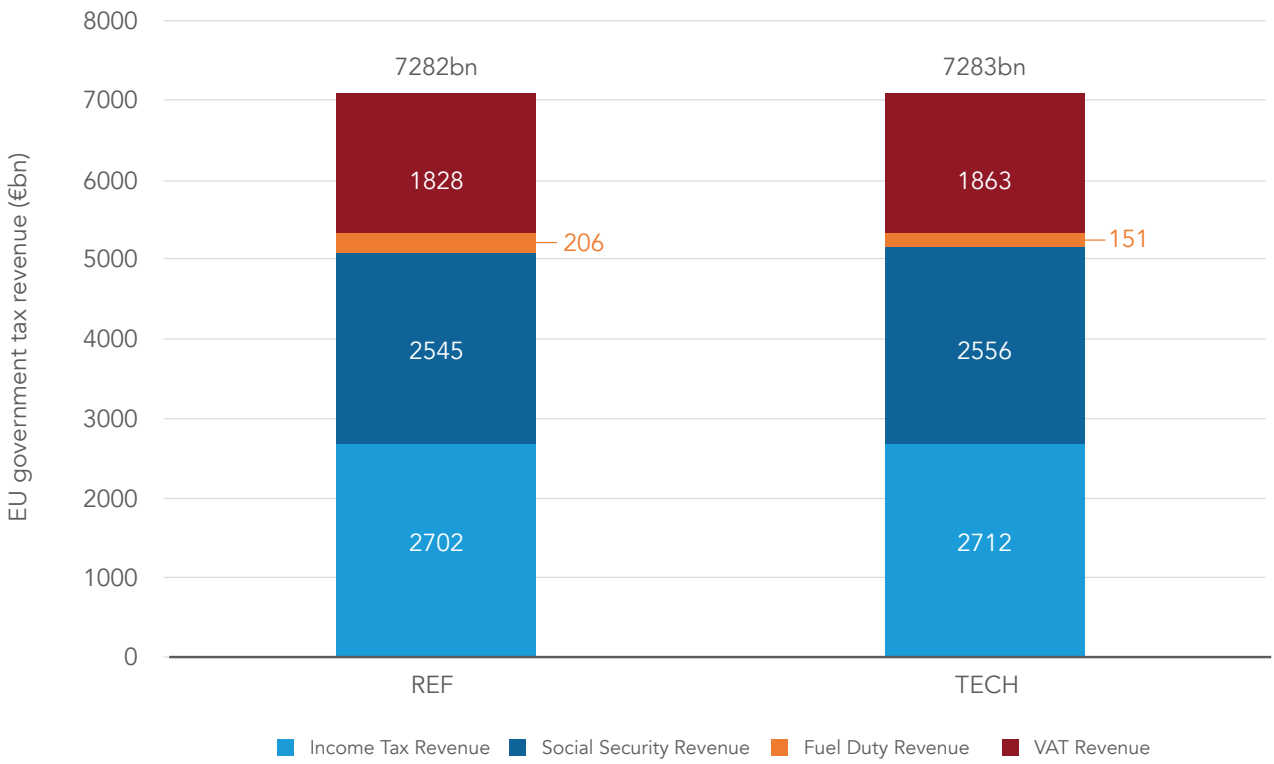
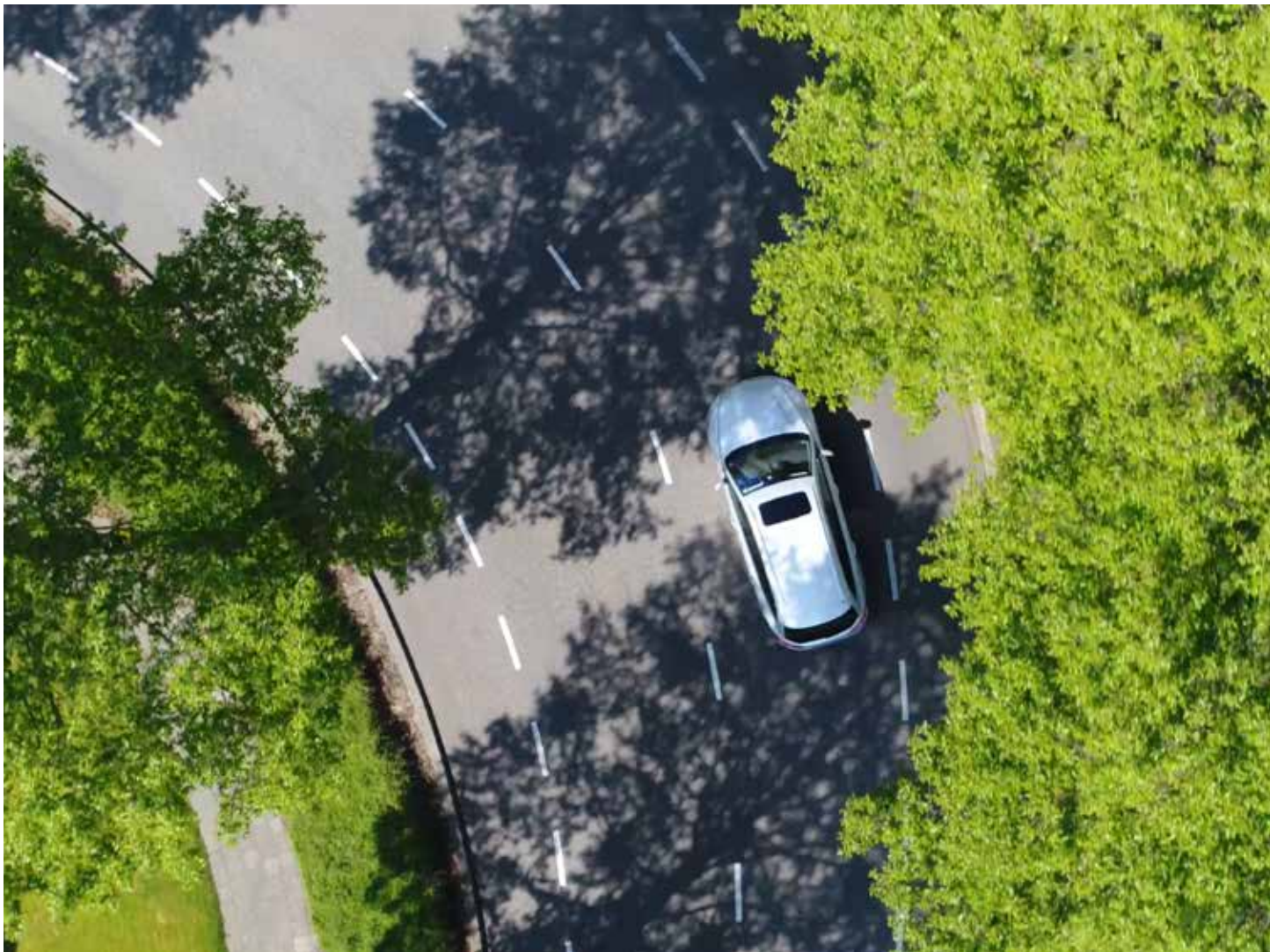


Figure 8. Government tax revenues in 2030 in our business-as-usual reference case (REF) and our low-carbon scenario (TECH).

shortfall of around €31 billion by 2030. And the deployment of ZEVs, as foreseen in our TECH scenario, would reduce fuel tax revenues by a further €24 billion. However, as described later, the structural shifts created by this transition away from oil towards domestic energy sources leads to an economic boost, and the tax revenues from this additional economic activity will entirely offset the accompanying reduction in fuel tax revenues by 2030, according to the analysis conducted in this project (Figure 8).

While economic modelling shows this to be the case, it is unlikely to be so clear from the perspective of the treasuries, which will simply observe dwindling fuel tax revenues. Their future approach is difficult to predict. As government revenues from the taxation of diesel and gasoline are reduced, it seems plausible that treasuries might seek to tax other energy sources for mobility, most notably electricity and hydrogen. On the other hand, the European Union has ambitious CO_2 reduction goals and transport has become the biggest source of emissions[6].

It therefore seems unlikely that taxes will be set in such a way that significantly impedes the deployment of clean vehicle technologies. Road charging, tailored to reflect the carbon-intensity of vehicles, or a bonus-malus approach could be potential solutions to address this issue without creating economic distortions. For the purposes of this economic analysis, the approach is not important provided it is done in an equitable and revenue neutral manner.



Investment in Grids and Chargers

To try to understand the infrastructure investment needs for this transition, we start by assuming that each EV sold has, on average, either a residential wall box or a workplace charging post installed. In addition, we have consulted widely with companies investing in this area and concluded that there will be roughly two public charging posts in urban areas for every 10 EVs on the road.

For rapid charging, there are two elements that impact the required number of charging points. The first is the minimum geographic coverage needed to provide full mobility to EV drivers on long journeys. For reference, there is over 71,000 km of highway in Europe, and to provide rapid charging sites on each side of the highway, with a spacing of 60km on each side of the highway, implies that around 2,400 rapid charging sites are needed. When we also take into account the charging needs on national roads, we determine that around 7,100 rapid charging sites will be needed in total.

It should also be considered that the rapid charge network should serve sufficient vehicles per day without unacceptably long queues. The details of our calculations are included in the technical report for this study, but in summary we assume that after an initial deployment of 14,000 individual rapid charge points before 2025, the number of rapid charge points is in proportion to the number of BEVs in the fleet. This takes into account the need to cater to peaks in traffic flows, both at rush-hour and in holiday periods, to avoid excessive queues. Initially, we assume a ratio of approximately 300 BEVs per rapid charging point, but the ratio of BEVs to rapid charge points will gradually increase as higher power chargers come onto the market

It should be noted that these rapid charger assumptions are based on the arrival of relatively high range vehicle (300km and 500km for medium and large cars respectively), and the use of home or destination charging where possible in preference to en-route rapid charging.

Having calculated the infrastructure density required, we have multiplied this by the projected cost for installing each type of charger, including costs of site preparation and connection to the grid. The main finding is that up to around €23 billion of cumulative investment in EV charging infrastructure could be required in Europe by 2030 in our central TECH scenario, of which €9 billion would cover publicly accessible chargers (Figure 9). However, the figure might be lower if more efficient business models are found. Such numbers can appear prohibitively high, but to put them in context, nearly €100 billion was invested in European transport infrastructure in 2014 alone[7].

Assumptions regarding investments in hydrogen refuelling stations are based on current corporate announcements up to 2030, after which charging stations are deployed in proportion to the number of FCEVs in the stock. This is based on an assumption that an average FCEV will consume 0.5kg of hydrogen per day and therefore a 200kg/day station would be capable of supporting around 400 FCEVs. As with rapid chargers, we assume a gradual penetration of larger stations: Stations of 500kg/day are the dominant size in 2035, but after 2040 stations of 1000kg/day start to dominate.

Understanding the need for investment in infrastructure also requires an exploration of the upgrades that will be needed to the electricity grid. Previous analysis has shown that there is a large difference in investment needs between a situation in which EVs are charged immediately when they arrive at their destination and a situation where charging is managed to avoid creating excessive loads on the system (Figure 10). If EV owners charge on arrival at home (unmanaged charging), this would significantly increase evening peak demand for electricity, requiring investments in grid reinforcement, and peaking plant capacity. Fuel required to meet the additional EV charging demand would increase electricity costs and grid CO_2 emission factors.

The level of EV deployment in our TECH scenario is 17 million EVs in 2030, rising to 170 million in 2050. Using Germany as an example, unmanaged charging leads to an increase in peak demand of 3 GW in 2030 and 22 GW in 2050, which is significant compared to a typical 2050 system peak demand of approximately 80 GW without EV charging. We find the cost of

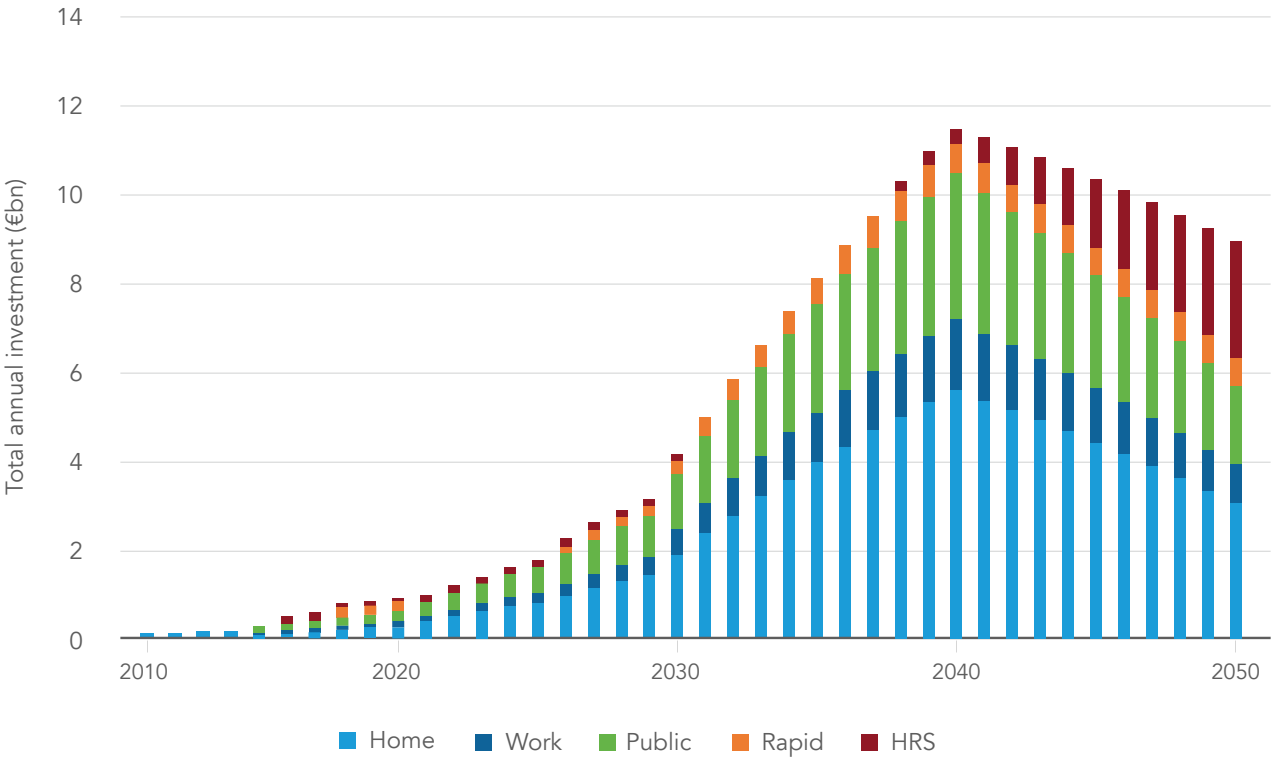
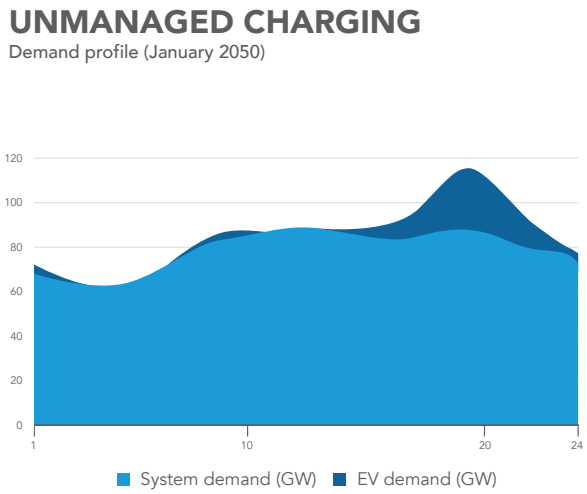
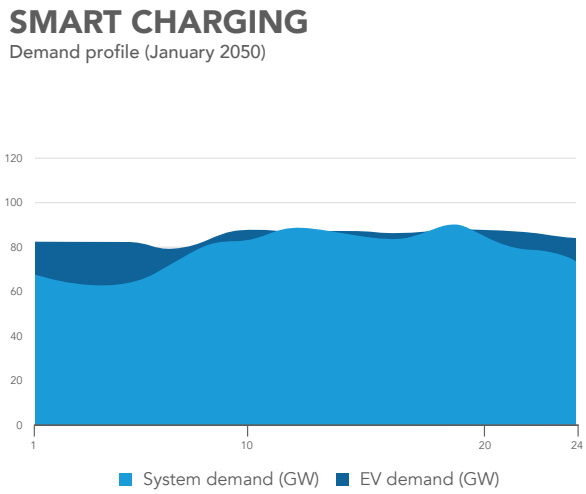


Figure 9. Investment needs for chargers and hydrogen refuelling stations to service the vehicle fleet defined by our TECH scenario.



Unmanaged charging increases demand and network load at peak times



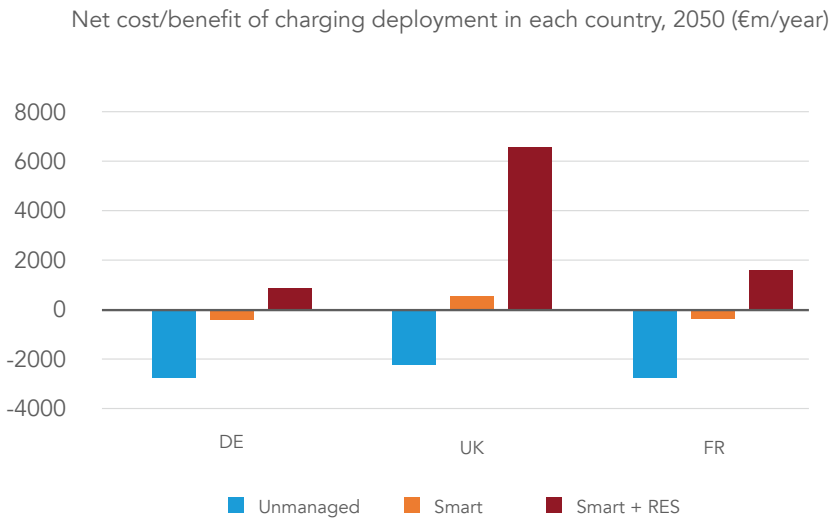
Smart charging avoids an increase of peak demand and enables EVs to provide balancing services

Figure 10. The profile of EV charging under both managed (right) and unmanaged scenarios (left).

investments to handle unmanaged charging would be more than €2 billion per year in Germany in 2050. This is consistent across countries in scenarios with high EV deployment.

By contrast, we find that smart charging of EVs would avoid such costs to a large extent by avoiding new peaks in demand (Figure 11). Although fast charging cannot be shifted, the vast majority of charging in our scenarios is slow charging that occurs where it is cheapest, namely at home or in the workplace. The timing of much of this slow charging can be shifted. The costs of implementing smart charging can be offset by providing grid stabilisation services that EVs can provide to the system operator in each country. In their simplest form, such services remotely switch EV charging on and off to help manage peaks and troughs in electricity supply, and to help maintain a stable frequency of electricity. These services will become increasingly important as Europe makes the transition to a renewables-led electricity system.

The net benefit of service provision varies across member states, primarily because of market conditions. For example, some countries, such as



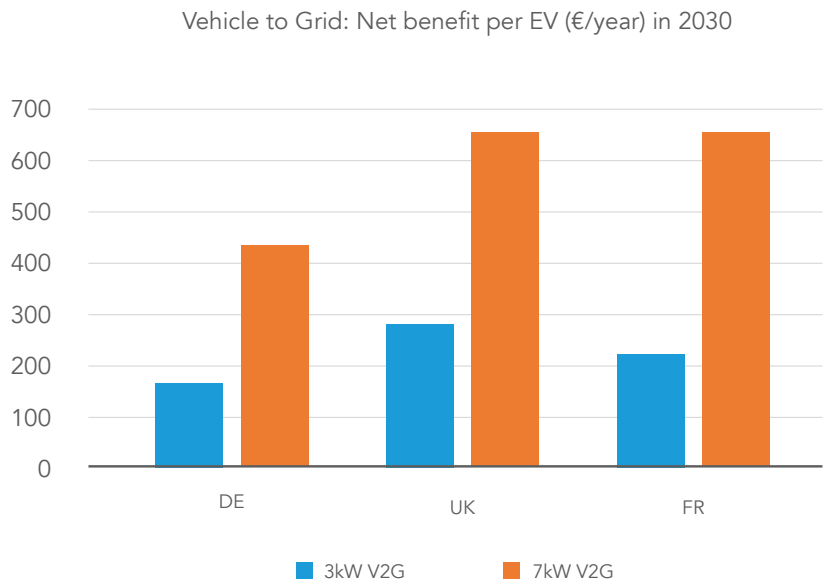


Figure 11. Top: Net cost/benefit of charging deployment in each country in 2050, in €m/year;

Bottom: Net benefit per year of grid services provision with V2G in the investigated markets.

Poland, do not currently have a competitive liberalised market for grid services. In countries with existing markets for these services, service provision with unidirectional charging could provide a net benefit of up to several hundred euros per EV per year. Figure 11 shows that smart charging can be economic in countries with competitive markets for ancillary services (e.g. Germany, Britain, France).

In countries where there are established markets for these services, such grid services could provide early revenues for EV owners. This could be crucial for the roll out of smart charging technology as it provides a financial incentive for EV owners to share control of vehicle charging with a third party. However as more EVs connect to the grid, the EV fleet acquires the potential to provide a large share of a country's grid services requirement. This is likely to lead to a reduction in prices in the market for grid services and it will therefore be necessary to keep transaction costs at a minimum to offer a sufficient financial incentive to EV owners. It should also be noted that in the market for grid services, EVs will need to compete against other service providers such as second-life batteries and other types of stationary storage. System access fees could play a key role in reflecting system costs and providing simple incentives.

Figure 11 also shows the very positive impact that smart charging could have on renewable electricity generation. In addition to lowering electricity production costs of the existing generation fleet, EV smart charging could make additional renewable capacity economically viable due to the ability to absorb excess generation of renewable energy sources, which would otherwise have to be curtailed. A scenario with additional renewable capacity, made economically viable due to smart charging, has also been investigated (smart + RES). Net benefits in such a scenario may be very large in countries where the EV charging hours correlate well with hours of high renewables output. Smart charging algorithms will be able to schedule charging to these hours, to benefit from lower electricity prices and lower CO2 emissions.

Another solution for maximising this opportunity could be through bi-directional, or Vehicle-To-Grid (V2G) charging. This is because bi-directionally charged EVs are able to offer their full charge capacity for the duration of their available charge window, subject to the constraint of being fully charged at departure time. Providing grid services using V2G technology could be an attractive source of revenue for EV owners, particularly in competitive markets. Assuming that V2G is fully enabled through investment and legislative changes by 2030, V2G would offer net benefits of around €650 per EV per annum in the UK and France for a 7kW charger (even after accounting for the cost of the necessary hardware, electricity losses and battery degradation costs).

Economic Impacts

While there is uncertainty about many of the factors within this transition, we have tried to capture this uncertainty within the range of assumptions used for the macro-economic modelling. This has allowed us to identify the main changes that would occur within the European economy during the transition to low-carbon vehicles.

Firstly, there is increased investment in capital assets. The shift towards hybrids, PHEVs and FCEVs during the 2020s increases the investment in automotive technology and generates additional value for Europe, both from cars sold domestically and from exports to other countries pursuing the decarbonisation agenda. While these cars are more expensive for consumers, this is quickly offset by savings on fuel spending.

By contrast, the increasing penetration of BEVs is likely to generate slightly less value for Europe than the petrol and diesel cars they replace, depending on the degree to which battery cells are imported. This is somewhat balanced out by investment in the charging infrastructure for BEVs, which creates additional value.

The second major economic impact is an efficiency gain throughout the road transport system. The vehicle fleet becomes increasingly efficient, due to improved combustions engines, more hybrids, and because electric motors are inherently efficient in their own right. This occurs both as a result of existing climate policies (e.g. the EU's 2020 CO_2 standards), and anticipated policies to meet future climate goals. More efficient use of energy leads to lower mobility costs for European households, allowing them to shift their spending away from mobility budgets towards other areas. Economic data shows that such spending would on average create more domestic value-added than if the same amount were spent on petroleum fuels.

The third main economic impact is the shift away from petroleum, which is imported from outside Europe, towards electricity and hydrogen, which are largely produced domestically, meaning that Europe starts to capture a greater share of the value from energy used in mobility. Figure 12 shows the evolution of energy use in the central TECH scenario.

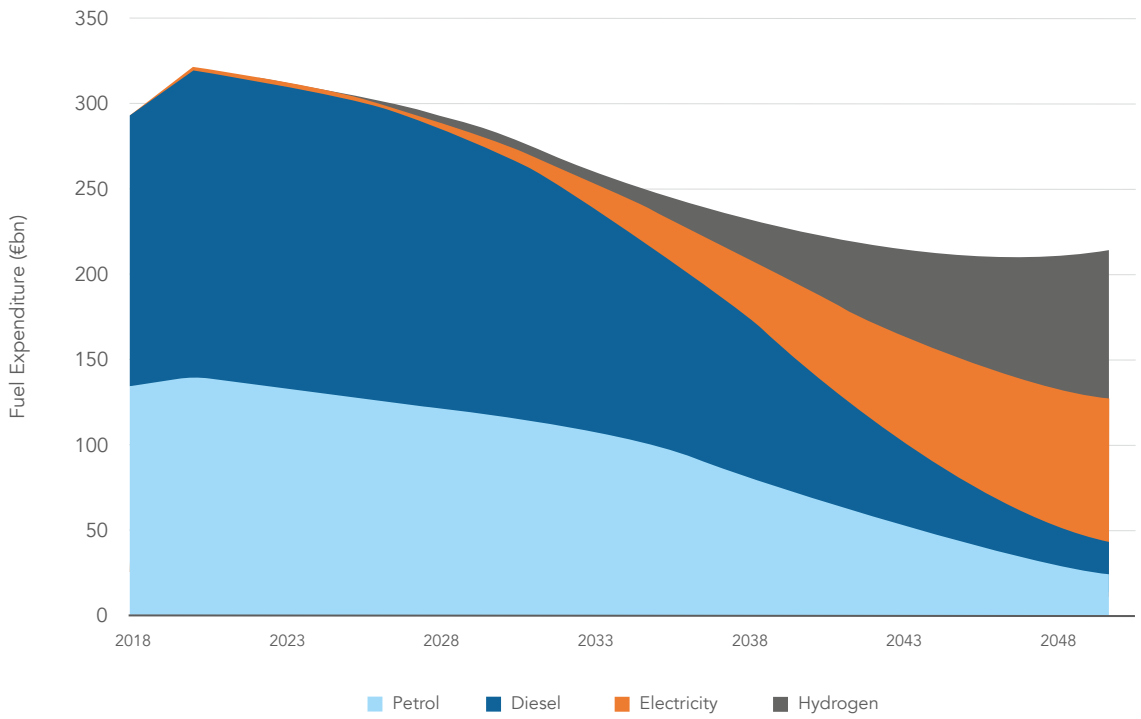


Figure 12.
Energy expenditure for mobility under our central TECH scenario.

Petrol and diesel consumption is strongly reduced during the 2020s as a result of existing EU CO_2 standards, and after that as a result of anticipated climate policies to meet the Paris Agreement, as foreseen in our TECH scenario. By 2050, it is largely replaced by electricity and hydrogen, both produced domestically.

Using the macro-economic model E3ME, we have measured the net economic impact of this transition, compared to a reference case in which cars remain unchanged from today (Figure 13). The economic impact is sensitive to the location where battery cells are produced in future. It is also sensitive to changes in the future oil price, because this alters how much the avoided spending on oil imports is worth. These sensitivities are explored in the following section. Overall, however, it can be seen that in all three scenario variants this transition leads to a mild increase in GDP.

Overall, there is a net increase in EU GDP as a result of making the fleet of cars more efficient to meet the EU's 2020 CO_2 standards (CPI vs REF), equivalent to an additional 0.1% of annual GDP in 2030. Further innovation to meet future climate goals would further increase national GDP after 2025. This leads to an 0.2% increase in annual GDP in 2030 and a 0.5% increase by 2050 (TECH vs REF).

The impact of this transition on employment is linked to changes in value-added between sectors, as described above, but it also needs to account for variations in employment intensity between sectors. These employment intensities are taken from Eurostat data and are shown in Figure 14. At the low end of the range is the extraction and refining of petroleum, which creates 4-6 jobs per million euros of value added. At the high end of the range is the construction sector, creating 27 jobs per million euros of value added.

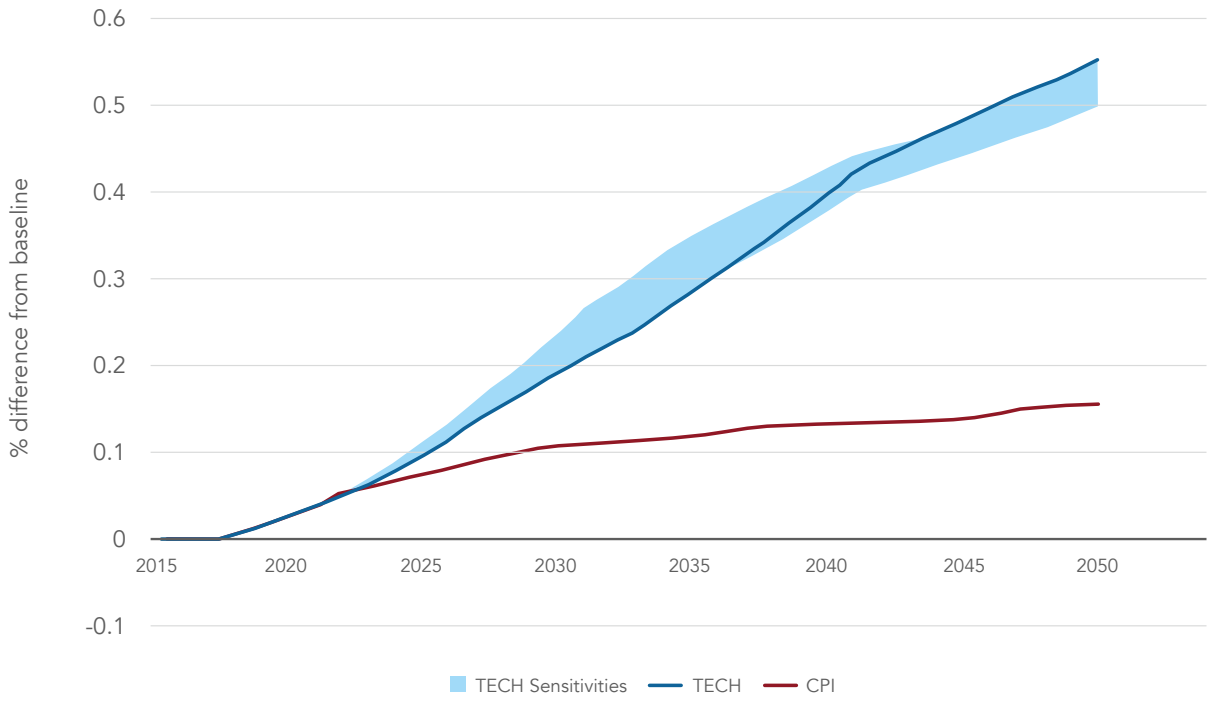


Figure 13. The impact on EU GDP of scenarios for lowering the carbon impact of cars.

Economic Impacts

There is a trend towards increasing automation of the auto industry, leading to lower jobs overall, regardless of the low-carbon transition. There are also nuances between different vehicle types. Building BEVs is expected to be less labour-intensive than building the gasoline and diesel vehicles they will replace. Our modelling accounts for this by taking the labour-intensity of manufacturing electrical equipment and applying it to parts of the automotive value chain within the model. By contrast, constructing hybrids and PHEVs is expected to be more labour intensive than building traditional combustion cars. Our modelling shows that the net employment impact for the auto sector from this transition will depend on the balance achieved between these various powertrain technologies, and the degree to which they are imported or produced in Europe.

Figure 14 shows how employment would evolve in Europe as a result of the transition to low-carbon cars in 2030 and 2050 under our central TECH scenario, relative to the reference case. As a result of the economic shifts described above, there is a net increase in employment in the following sectors: construction, electricity, hydrogen, services and most manufacturing sectors.

The increase in employment in the services sector is due to a shift in spending away from imported petroleum fuels towards other areas of the European economy, although some partners in the project voiced uncertainty about how automation will affect future employment intensity in the various services sectors. The model does reflect some changes to employment intensity over time.

Employment in the fuels sector is reduced throughout this transition. Employment in the automotive manufacturing sector is increased until 2030, but decreases thereafter.

In our TECH scenario, net auto sector jobs are increased in 2030, because diesel and gasoline engines are built to greater levels of sophistication and efficiency to meet climate goals; and because of the increasing deployment of hybrids; PHEVs and FCEVs, which contain increasing technological

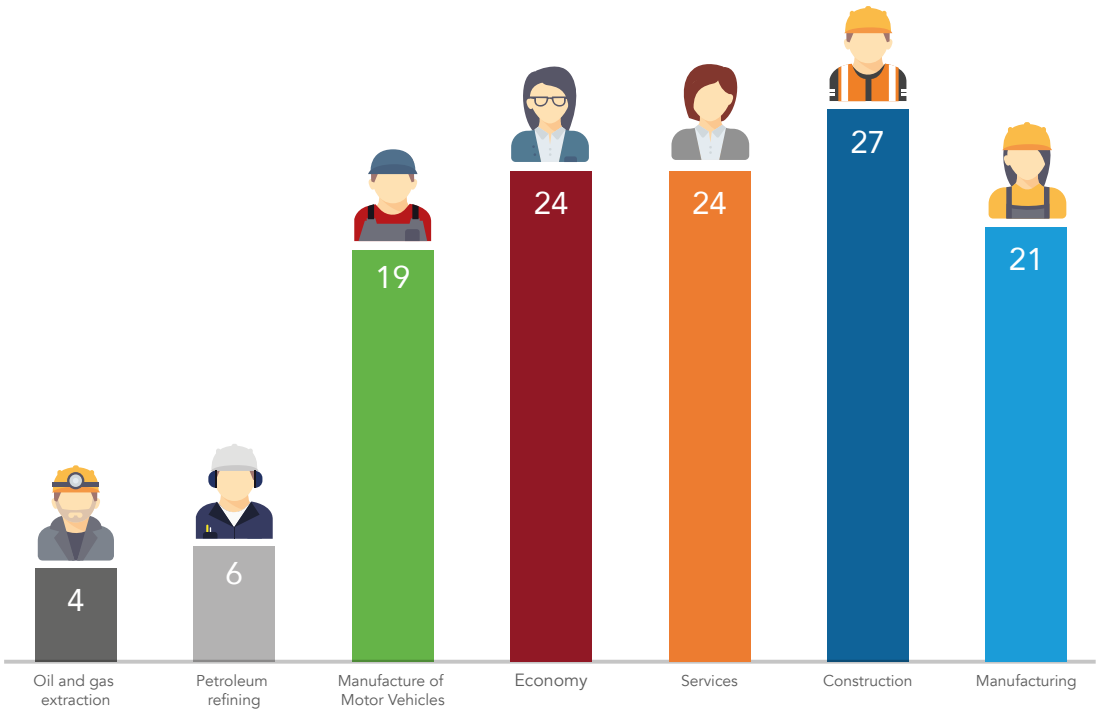


Figure 14. Comparison of the relative labour intensity of different sectors of the European economy (jobs per €million of value added). (Source: Eurostat, E3ME)

complexity. However, by 2035, the net impact on jobs starts to enter negative territory in our TECH scenario, because hybrids are increasingly replaced by BEVs, which are less complicated to build and therefore generate fewer jobs.

We have also explored a scenario in which PHEVs remain dominant for longer (TECH PHEV). In such a case, European workers continue to benefit from building more complex vehicles for longer, and the net employment impact in the auto sector remains positive for longer. While it is tempting to conclude that this indicates that Europe should prioritise PHEVs to maximise employment, this should be evaluated carefully. Such a scenario could underestimate the speed of the transition to full electrical powertrains, leaving Europe with insufficient BEV production capability to tackle worldwide competition. With the right incentives, the customer could be motivated to charge their PHEV more often, thus maximizing the CO2 reduction. Nevertheless, there remains a risk that PHEV owners would not travel in electric mode to the optimal extent, which would reduce both the economic and environmental benefits of electro-mobility.

Employment impacts within the European auto sector are an important issue and deserve further analysis. The benefit of using a macro-economic modelling approach is that it allows us to assess the economy-wide impacts of this transition, but this comes at the expense of detail within sectors. For the low-carbon transition to be successful, care will need to be taken of those who will lose their jobs in technologies that are superseded. We thus recommend further analysis to explore how a "just transition" can be achieved in the auto sector, where these changes will take place against an overall background of increasing automation.

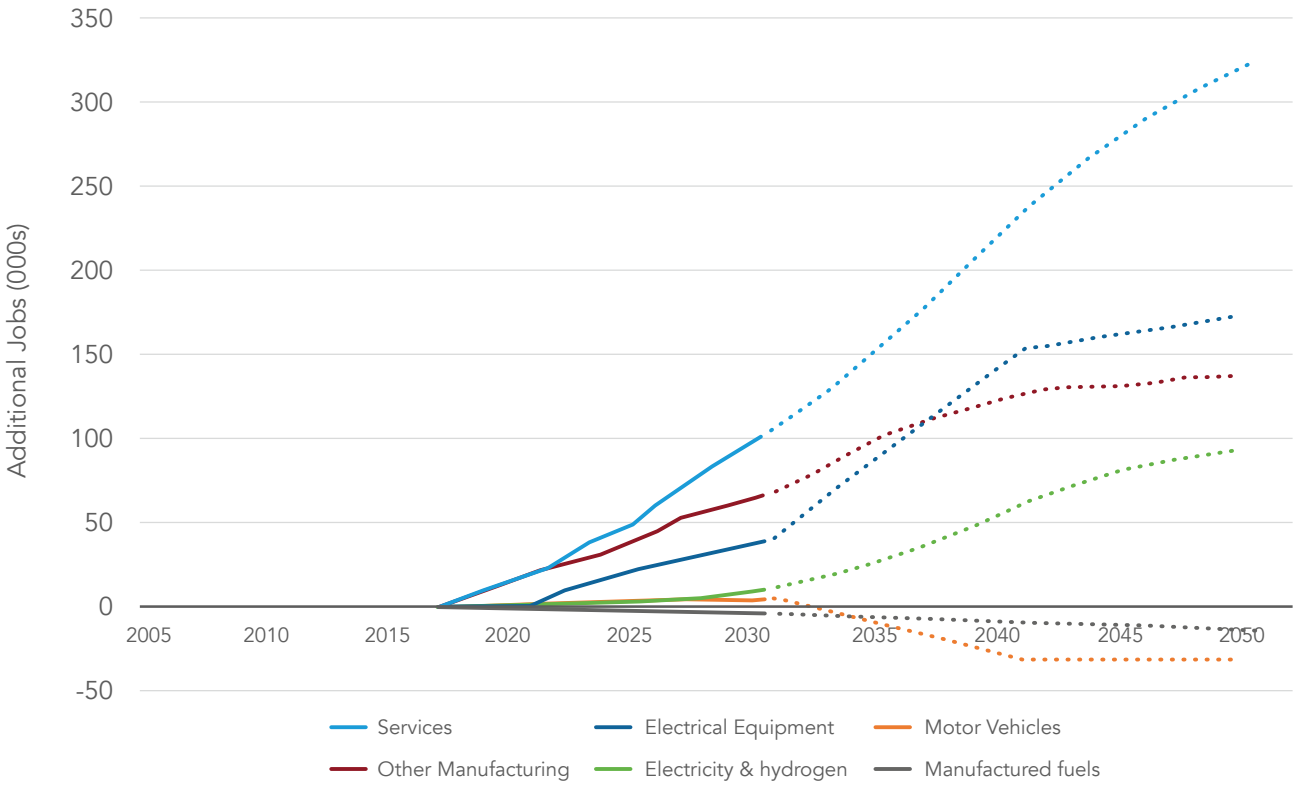


Figure 15.
The employment impact per sector in Europe of the transition to low-carbon cars (thousands).
Dashed lines reflect the increased uncertainty after 2030.

But What if...?

We have already acknowledged the wide range of uncertainties around many of the assumptions used in this study, among them the future price of crude oil; and the location where new technologies, such as battery cells, might be manufactured. Rather than make optimistic assumptions, our approach has been to use assumptions in the middle of the range of future projections and to test the likely outcomes under high- and low-case assumptions.

Oil prices are one such uncertainty. Driven by the balance between supply and demand, they are notoriously difficult to predict. On the supply-side, geopolitical events such as those of the Arab Spring, can have instantaneous effects. Our central case is based on the IEA's 2017 World Energy Outlook. If, due to external factors, oil prices are assumed to be 30% lower than that, the value of avoided spending on oil is reduced, and as a result much of the GDP gain is eroded (Figure 16). Conversely, if due to external factors, oil prices are assumed to be 30% higher than in the central case, then the GDP impact of avoiding oil use is more significant. At the same time, the transition to a low-carbon economy is itself expected to impact on global oil markets. Previous analysis shows that in a global low-carbon transition, similar to our central scenario, oil prices would be 9-15% lower by 2030 than in a business-as-usual world of high oil demand. This creates its own additional economic benefit[8].

For the economic analysis, it is also important to establish the location where low-carbon vehicle technologies will be manufactured in future. Figure 3 showed just two of many examples of European companies successfully deploying clean powertrain

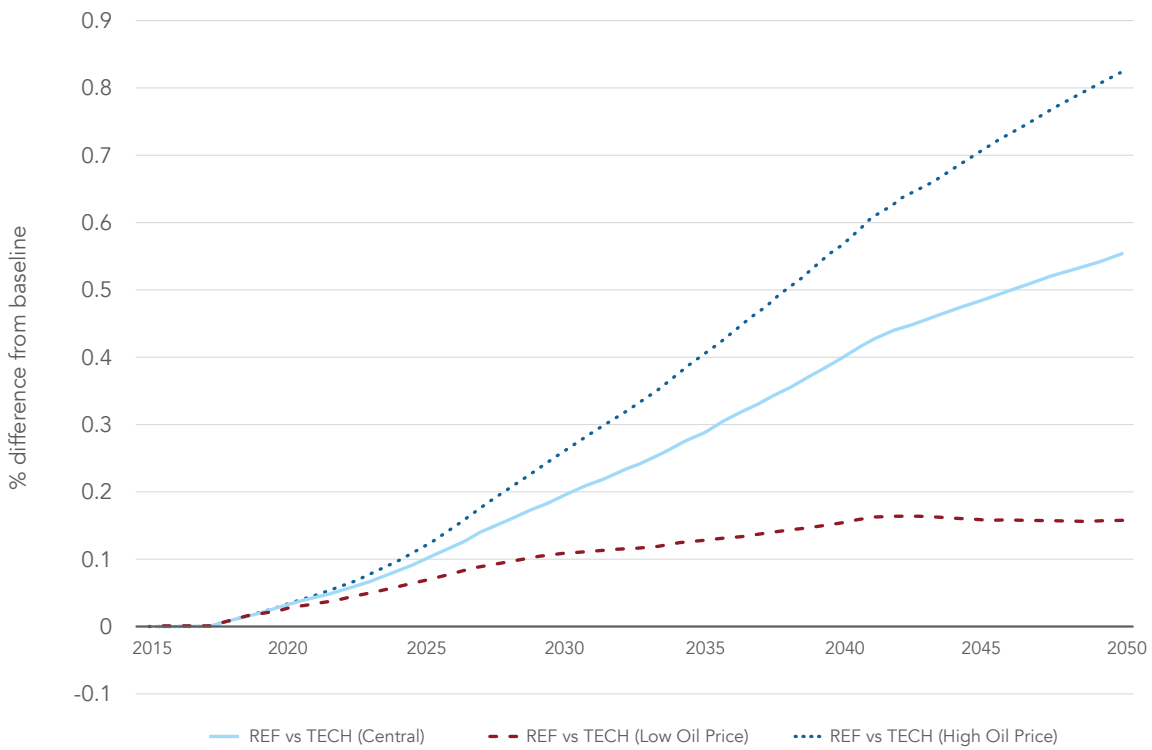


Figure 16. The GDP impact of the transition to low-carbon vehicles in Europe under a range of future oil price projections.

technologies, and it thus seems plausible that these companies will compete effectively in the deployment of the next wave of technologies, for example 48V mild-hybrid systems. This supports the assumption in this study that Europe's share of the market for technologies to improve the efficiency of diesel and gasoline engines, including hybridisation, remains unchanged in the period examined.

By contrast, one cannot automatically make the same assumption about Europe's share of the market for some of the entirely new technologies that will be needed during this transition. While European companies are well established in the production of electric motors, and several are involved at the cutting edge of fuel-cell development, there are questions about the future location of production. For lithium-ion battery cells in particular, Asian companies currently dominate the market.

The battery value chain can be disaggregated into various steps, the most important being cell production; assembling cells into battery packs; and assembling packs into modules and then integrating them into the vehicles. European companies are already well placed to capture the value of these last two steps. However, cell production currently comprises around 60% of the overall value in a vehicle battery[9], and it is this area that is currently dominated by Asian producers.

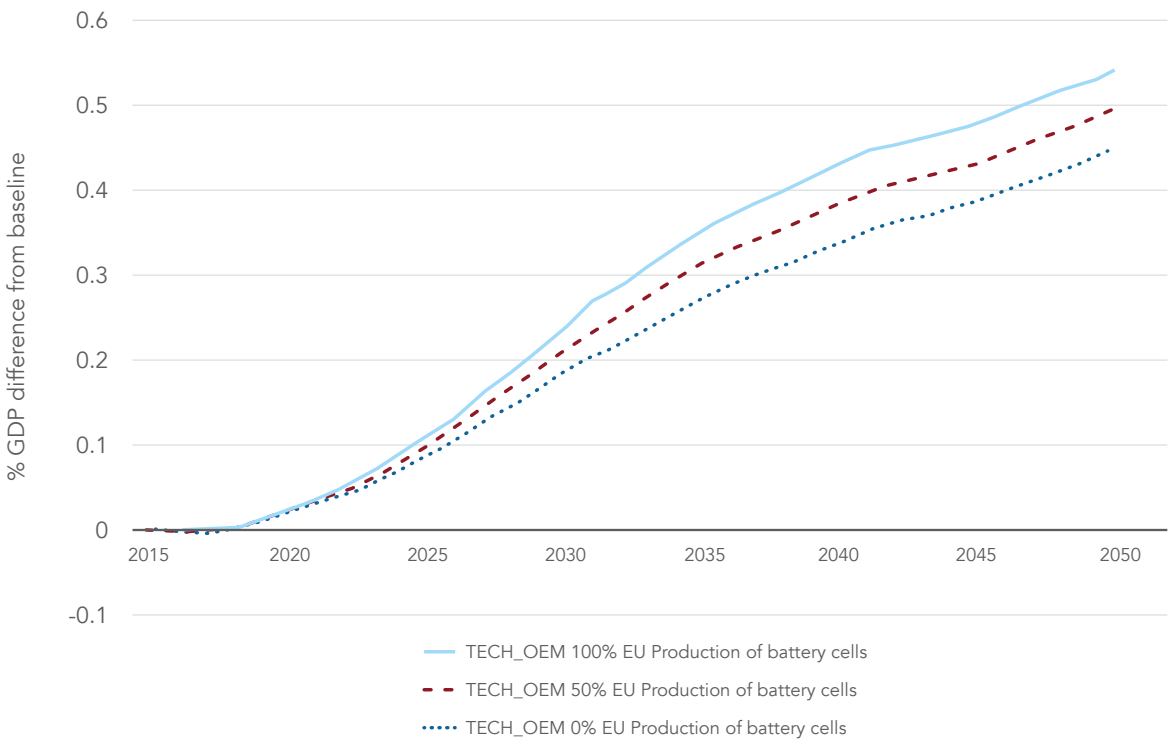


Figure 17. The GDP impact of the transition to low-carbon vehicles in Europe under a range of assumptions about the location of battery cell manufacturing.

But What if...?

The likelihood of battery cell production occurring in Europe in future depends on factors such as future labour costs and skillsets, energy costs, corporate tax rates, borrowing costs etc. When it comes to current battery cell chemistries, incumbent cell producers in Asia have the advantage because they can expand existing production sites relatively cheaply. Opportunities for production in Europe will start to emerge when a switch is made to new battery chemistries, if a supportive policy environment can be put in place[10].

At this point, existing manufacturing sites can become more of a burden for incumbent players than an asset, and new market entrants with the right product might gain the competitive advantage. Already, some initiatives have been taken to lay the foundations for battery cell manufacturing in Europe. Below are a few examples:

- Bosch has acquired Seeo, a US battery start-up offering solid-sate technology, with a view to bringing such technology to the market by 2020[11]

- Daimler has committed €500 million to developing lithium-ion battery production at a site in Kamenz, Germany[12]

- LG Chem plans to build a battery factory in Poland to be completed in 2018 to produce up to 230,000 BEV batteries per year[13]

- Samsung is analysing if a Samsung TV factory in Hungary could be converted into a battery factory[14]

- Northvolt has selected a site in Sweden for the planned construction of Europe's biggest battery factory as it continues to raise finance[15].

This supports the assumption in our central case that in the period until 2050, automotive battery cells will be manufactured within Europe, following the long-held practice of manufacturing components close to the point of assembly to minimise logistics costs. However, we also explored scenario variants where battery cells are either wholly or 50% imported. Increased import content does lead to a lower GDP gain than if cells are manufactured domestically, but the GDP results remain positive regardless of the assumption made (Figure 17).

Conclusions

This project has explored the economic impact of the transition to low-carbon vehicles, while using a mid-range set of cost assumptions and acknowledging the inherent uncertainties. It has found that the transition from petroleum-based energy sources to renewably sourced energy will strengthen Europe's economy, with mild increases to both net GDP and net employment. However, there will be significant transition challenges along the way. Electricity grids will need to be modernized as part of sector coupling, and a determined multi-sectoral effort is needed to deploy sufficient charging infrastructure. Efforts must be made to ensure workers who are currently producing legacy technologies are retrained for quality jobs in producing the technologies of the future.

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