Fuelling Italy's Future

How the transition to low-carbon mobility strengthens the economy

Acknowledgements

Analytical team

Jon Stenning, Associate Director,
Cambridge Econometrics

Stijn Van Hummelen, Project Manager,
Cambridge Econometrics

Matteo Caspani, Consultant,
Cambridge Econometrics

Jamie Pirie, Senior Economist,
Cambridge Econometrics

Shane Slater, Director,
Element Energy

Michael Joos, Consultant,
Element Energy

Oliviero Baccelli, Direttore CERTeT,
Università Bocconi

Gabriele Grea, Researcher CERTeT,
Università Bocconi

Raffaele Galdi, Researcher CERTeT,
Università Bocconi

Project Coordination

Pete Harrison, Transport Director,
European Climate Foundation

Veronica Aneris, National Expert, Italy,
Transport & Environment

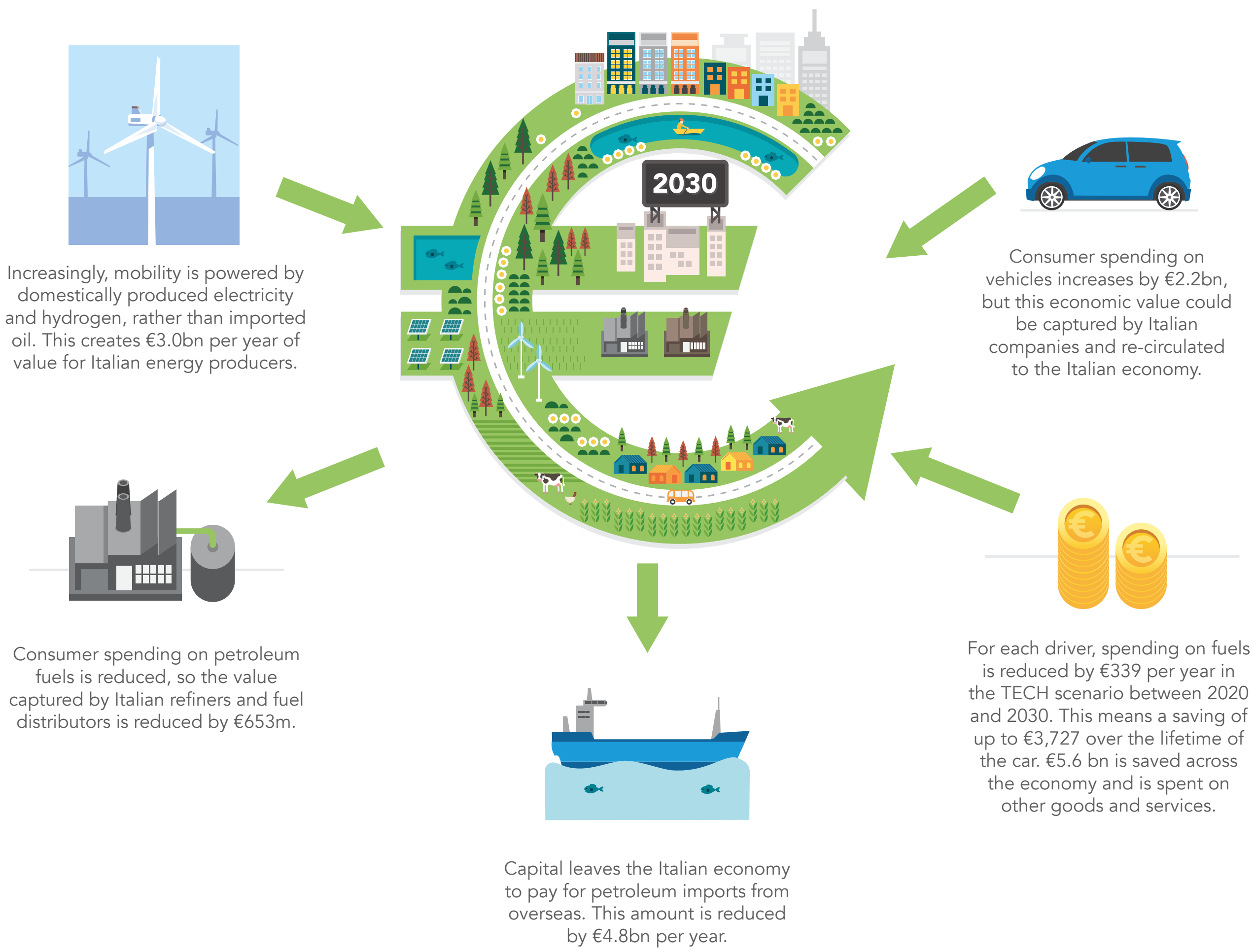
Giuseppe Montesano,
Deputy Director, Enel Foundation

Daniela Di Rosa, Senior Researcher,
Enel Foundation

This report is a summary of the Cambridge Econometrics report "*Fuelling Italy's Future: How the transition to low-carbon mobility strengthens the economy*" which can be downloaded here.

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 is to evaluate the boundaries within which vehicle technologies can contribute to mitigating carbon emissions from cars in Italy. This study has been complemented with an analysis of the impact this transition would have on the electricity grid (Infrastructure Costs & Synergy Between Transport and the Power System) and an analysis on the effects on health (Impacts on Health). Each stakeholder contribute their knowledge and vision of these issue. The information and conclusions in this report represent these contributions, but should not be treated as binding on the companies and organisations involved.

Contents



2030
Increasingly, mobility is powered by domestically produced electricity and hydrogen, rather than imported oil. This creates €3.0bn per year of value for Italian energy producers.
Consumer spending on vehicles increases by €2.2bn, but this economic value could be captured by Italian companies and re-circulated to the Italian economy.
Consumer spending on petroleum fuels is reduced, so the value captured by Italian refiners and fuel distributors is reduced by €653m.
For each driver, spending on fuels is reduced by €339 per year in the TECH scenario between 2020 and 2030. This means a saving of up to €3,727 over the lifetime of the car. €5.6 bn is saved across the economy and is spent on other goods and services.
Capital leaves the Italian economy to pay for petroleum imports from overseas. This amount is reduced by €4.8bn per year.

Executive Summary

This study has been developed in order to investigate the economic, social and environmental impacts related to the transition to low and zero carbon vehicles in Italy.

The challenge of climate change, keeping the average increase in global temperatures well below 2°C according to Paris Agreement, requires rethinking the way we live, produce, consume and how we move people and goods.

Transport is central to this transformation; it is the one source of emissions that keeps increasing year-on-year, as growing demand for transport outpaces any efficiency gains realised. Passenger transport is the most critical segment, responsible for the majority of GHG emissions, and at the same time being amongst the main contributors to the poor air quality in urban areas that currently blights many of Europe's cities.

Italy is lagging behind other European Member States in addressing the negative impacts of its transport system. With one of the oldest passenger car fleets in Europe, amongst the highest number of cars per inhabitants, large numbers of premature deaths due to atmospheric pollution, and high fuel prices, there is a clear need for urgent action in Italy.

Transforming mobility requires a range of solutions, in terms of technology and behavioral change. The three revolutions of mobility "electric, shared and autonomous" offer great potential for reforming mobility systems in a sustainable and efficient way. If considering the three main pillar of sustainable mobility, Avoid, Shift and Improve, this analysis focuses on the Improve pillar, taking a close look on how the most popular transport mode, the passenger car, can become more sustainable.

In carrying out this analysis we have sought to answer key questions such as:

- *Is this transition technologically feasible over a time period where it can help Europe to meet the Paris climate objectives?*
- *What are the greenhouse gas emission, energy savings, air quality and health impacts of the transition?*
- *What are the savings in terms of total energy demand for the passenger vehicle fleet?*
- *What impact will the transition have on the economy?*
- *What will be the impact on producers, consumers, workers, citizens and decision makers?*
- *What is the level of infrastructure and related investment needed to make this transition possible?*
- *How will the national electricity distribution system be impacted?*
- *How much additional electricity will be required to fuel a large fleet of electric vehicles?*

The study outcomes show that the transition to low-carbon mobility can improve the domestic economy, reduce spending on imported fuel, increase national energy security, reduce the exposure of consumers to oil price volatility, strengthen the macroeconomic resilience of the country and improve the health of citizens. Reduced oil imports, and lower costs of mobility, will create jobs and economic growth; greenhouse gas emissions from the passenger car fleet will be substantially cut; local air pollution drastically reduced and related negative externalities avoided.

The final cost of mobility for Italian drivers will decrease due to the transition. In 2030, the annual expenditure on fuel for a small-sized car will be on average €353 cheaper than for a car in 2020, thanks to greater efficiency and the deployment of electric vehicles. Compared to a conventional car (ICE), a battery electric vehicle (BEV) could save the driver of a small car an average of €917 a year on fuel and maintenance costs in 2030, offsetting the higher initial purchasing cost.

In 2030, GDP will be €2,396 million higher than in the reference scenario, mostly driven by the reduction in oil imports. In addition, in the same year about 19,225 net additional jobs will be created.

In the same year, CO_2 emissions from cars will be reduced by 32%, NO_x emissions will be halved and PM emissions will drop by 63% in respect to 2017 levels. These pollutants will all go close to zero in 2050. Thanks to these reduction in NO_x and PM concentrations, it is estimated that in 2030 1,100 premature deaths will be avoided, a significant number of lung cancers, chronic bronchitis and asthma will be prevented, and 1.63 million days of absence from work due to illness will be avoided.

Of course, the transition is not without challenges: although there is an overall increase in employment, jobs will be lost from some sectors, and there will be changes to the government's tax take. It is essential to accompany and manage the transition with well targeted and forward-looking policy interventions, in order to generate quality employment and guarantee social, environmental and economic sustainability.

This study comes to the conclusion that, despite the challenges, the transition towards zero emission vehicles can represent a win-win situation for Italy, that if properly managed could bring social, economic and environmental benefits. The more oil imports are reduced, and replaced with domestically produced renewable energy, the greater these benefits will be.

Italy, with its high potential for the deployment of solar and wind-based electricity capacity, has a unique chance to turn the weakness related to the scarcity of fossil fuel resources into a strength.

Introduction

Historically, the Italian motor vehicle industry has been a major provider of small, efficient, city cars. However, in the last decade, the automotive sector in Italy has experienced a substantial loss of competitiveness.

Although Italy remains one of the largest manufacturers of motor vehicles in Europe, production has halved over the past 20 years, from 1.4 million units in 2000 to 700,000 units in 2016. According to the International Organization of Motor Vehicle Manufacturers (OICA), for every 10 passenger cars registered in Italy, only 4 are manufactured domestically, compared to 17 for every 10 in Germany (reflecting extensive vehicle exports) and 8 in France. Whilst the national cars industry has lost competitiveness, Italy's transportation network has remained focussed on the motor vehicle, with almost 38 million vehicles on the road. The deployment of vehicles reliant upon alternative fuels, of which battery electric and fuel cell represent two potential options, can represent a new opportunity for the industry.

In respect to car innovation and in particular the uptake of low-zero emissions vehicles, Italy is falling behind other EU Member States. The share of pure electric vehicles is among the lowest in Europe, accounting for 0.015% of the total stock, while diesel vehicles still dominate.

However, in the medium term Italy must reduce its GHG emissions from a diffuse range of sectors, including transport. Emissions are required to be 33% below 2005 levels by 2030[1], while by 2050 cars and vans will have to be almost completely decarbonised. This means that, given the average lifetime of a car in Italy, sales of ICEs will have to be phased out somewhere between 2030 and 2040 at the latest.

These reduction targets creates challenges across the motor vehicle value chain. However, they could also represent an opportunity for Italian Original Equipment Manufacturer (OEM) and supply chains to make up some of the lost competitiveness and regain their reputation for developing and producing efficient city cars.

There are signs that progress is being made. The first 6 months of 2018 have been particularly significant: FCA has finally announced plans to stop the production of diesel cars by 2022 and a €9 billion investment in developing PHEV and BEV cars in the coming years; Rome and Milan, the two largest Italian cities, have announced upcoming diesel bans; car sales have started to shift away from diesels (a fall of 6.3% in the first half of 2018, compared to the same period in the previous year), while sales of hybrid and electric vehicles are up (+30.7% in sales in the first half of 2018, compared to the same period in the previous year).

While sales of advanced powertrain vehicles are still very modest in absolute values, these new trends hopefully mark the beginning of a long-term shift in the market towards low-carbon vehicles. In addition, the recently-settled government has clearly stated ambitious goals for the development of electric mobility in Italy.

It looks like a new wind is starting to blow in Italy, that might bring innovation in the automotive Italian sector and put the country on the right path for decarbonisation.

Methodology

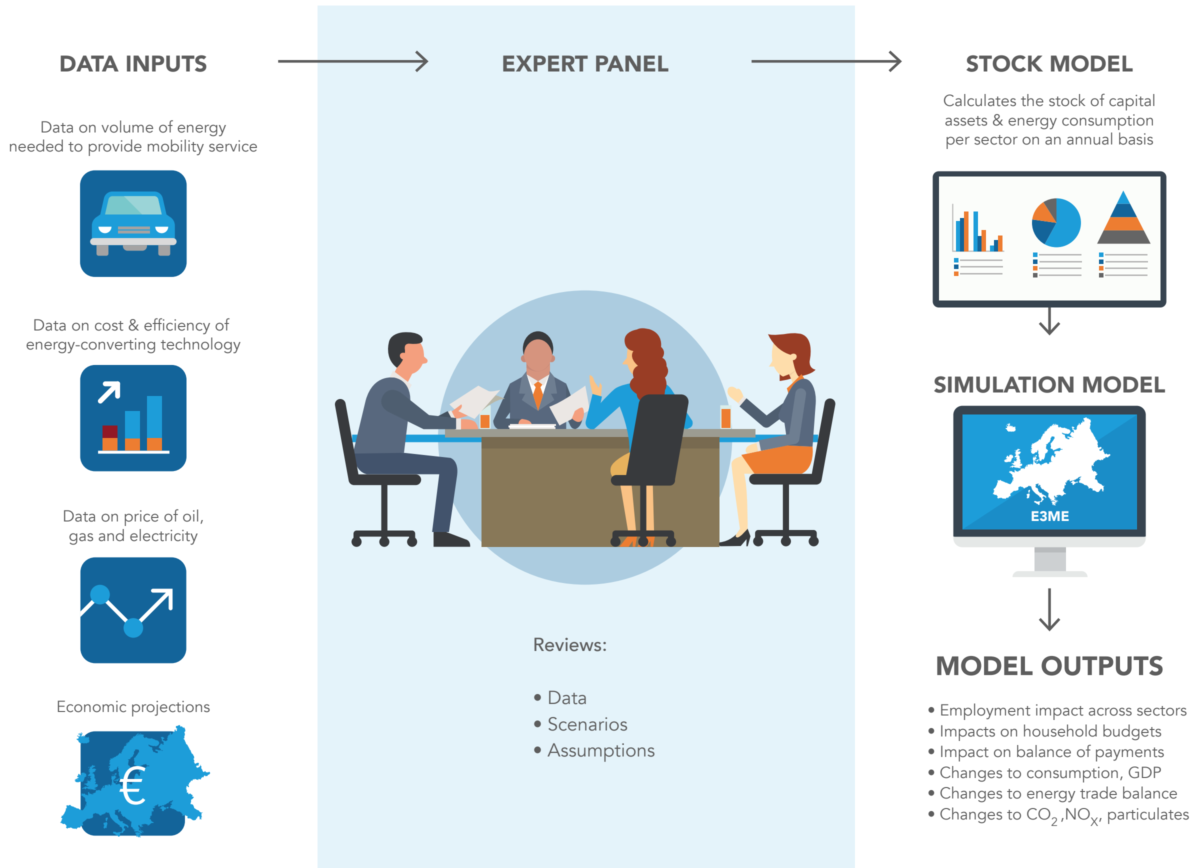


Figure 1. An overview of the modelling approach.

The modelling approach used in this project is described in detail in the technical report[2], and is summarised in Figure 1.

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.

The panel met five times during the first half of 2018, advising on the most relevant input data on mobility, vehicles, energy, infrastructure and economy.

The agreed dataset was then fed into a stock model, which determined changes to Italy's overall vehicle fleet and energy consumption per sector on an annual basis under each of the scenarios. Finally, the outputs from the stock model were fed into the macro-economic model E3ME[3].

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 has delivered outputs in terms of changes to household budgets, the energy trade balance, consumption, GDP, employment, CO_2 at the tailpipe and implied emission from electricity production, NO_x and particulates.

Building on the results of the estimation of future emissions (PM and NO_x) provided by the E3ME, the impact on health associated with the low carbon scenarios analysed has been estimated through a range of different indicators. Specific functions have been adapted for the main relevant health impacts, and represented in terms of monetary value according to current sanitary costs and to the willingness to pay principle.

Different scenarios were agreed, which are described below. Each scenario has a different combination of technologies and reflects a plausible vision of the future passenger car market in Italy.

• *Scenario Reference (REF)*: no change in the sales mix of new vehicles, just some improvements in the fuel-efficiency of the vehicle stock because new cars replace older less efficient cars. This is an instrumental scenario that is used as a reference to make comparisons.

• *Scenario Current Policy Initiatives (CPI)*: improvements to the efficiency of the internal combustion engine and a modest increase in the sales of Hybrid, Plug in Hybrid (PHEV) and battery electric (BEV) vehicles to meet the 95 gCO_2/km EU vehicle efficiency target for 2021 and achieve a reduction of 15% in 2025 and a reduction of 30% in 2030 respect to 2021 values in line with the EC proposal for post-2020 CO_2 standards[4];

• *Scenario TECH*: gradual transition towards hybrid, plug-in hybrids and battery electric vehicles until 2030, as well as fuel-efficient technologies (e.g. light-weighting) in all new vehicles. After 2030 PHEVs are gradually phased out and replaced by more advanced powertrains such as BEVs and fuel cell electric vehicles (FCEVs). This is the central scenario: it implies a less ambitious uptake of PHEVs and BEVs than foreseen in the recently approved National Energy Strategy[5] (SEN).

• *Scenario TECH RAPID*: faster transition to a vehicle stock dominated by plug-in hybrids, battery electric vehicles and FCEVs in 2030, compared to the previous TECH scenario. After 2030, the market will be dominated by BEVs, although there will also be an important share of PHEVs and FCEVs. In this scenario there is a faster technological evolution.

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 and related economic, social and environmental impacts. Such changes can reasonably be driven by standards and economic instruments at least until the total cost of new technologies reaches parity with existing technologies.

The study also doesn't consider other possible changes in mobility, such as for example the impact of autonomous vehicles, public transport or new shared mobility initiatives. Car ownership (the number of vehicles per 100 inhabitants) is kept stable over time to assess the impact of shifts between technologies in the fleet. Nonetheless, changes in the use and ownership of vehicles could bring significant co-benefits in the transition.

Most of the environmental, energy and economic indicators presented in this short version of the report are shown as regard to the TECH central scenario. Indicators for all others scenarios can be found in the detailed technical report.

Consumer Impacts

A transition towards low emission mobility will require all actors to do their part in order to make the transition possible. It is well recognised that consumers don't always accurately consider all the relevant factors when buying cars. The transition to low emission mobility entails a shift towards vehicles with (typically) a higher purchase price, but lower running costs, as compared to a conventional ICE vehicle. A successful transition will require recognition of the changing profile of mobility, and consumers to consider the total cost of owning a car (TCO).

The analysis shows that the average cost of running a car in Italy will go down over time in all low-carbon scenarios, compared with the current situation. The development and introduction of technologies to reduce fuel consumption will increase the initial purchase costs of new cars, but this will be offset by a reduction in fuel costs, with significant savings made over the average lifetime of a car.

The TCO has been analysed over the first 4 years of the car and over its total useful lifetime[6]. Results show that already in 2020, owning a small sized plug-in hybrid is less expensive than owning an equivalently sized conventional petrol car, and the lifetime savings amount to €346. When looking at the TCO in 2030, the lifetime savings increase to €1,837.

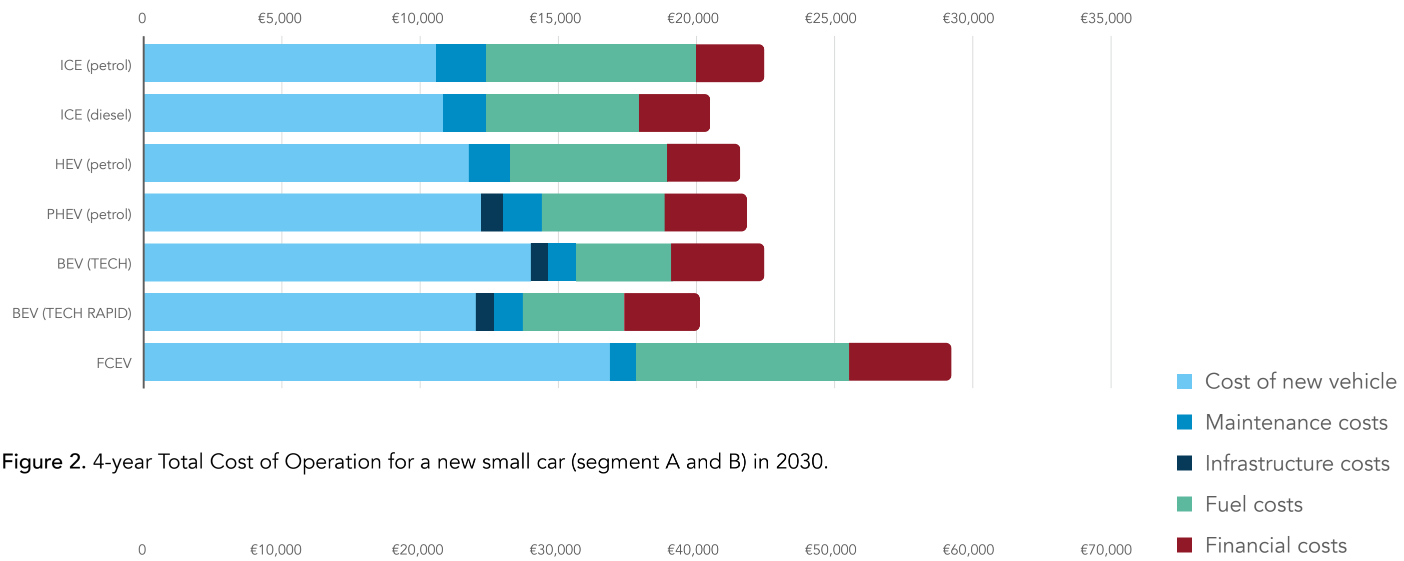


Figure 2. 4-year Total Cost of Operation for a new small car (segment A and B) in 2030.

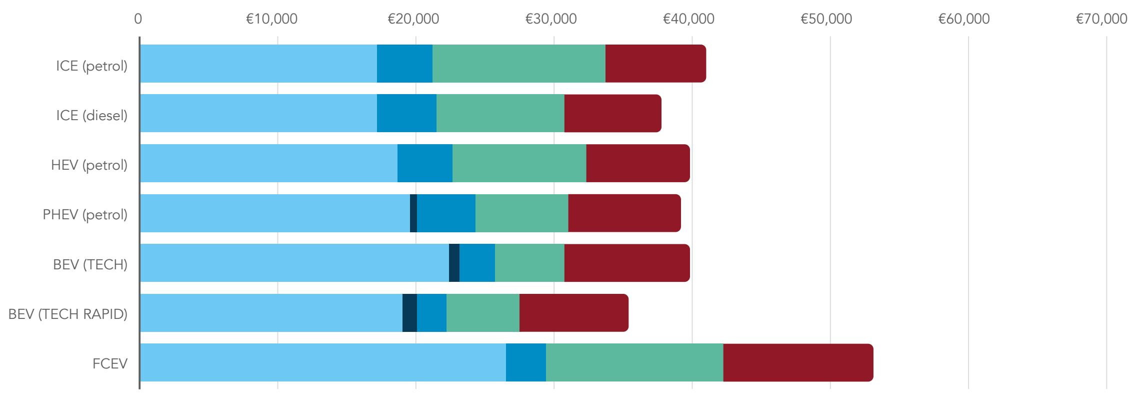


Figure 3. Lifetime Total Cost of Operation for a new small car (segment A and B) in 2030.

In the TECH scenario, in 2030, the lifetime TCO of a small sized BEV will be lower than that of a conventional petrol car. This is due to lower fuel and maintenance costs for BEVs compared to ICEs and to reductions in the purchase price of BEVs as a result of lower battery prices.

In the TECH scenario, the yearly average fuel bill for a motorist of a small car in Italy will go down from €1,643 in 2020 to €1,304 in 2030 thanks to greater efficiency and the deployment of electric vehicles. This corresponds to a €339 reduction in annual expenditure on fuel.

There is a certain degree of uncertainty over the factors that determine the total costs of ownership, such as future fuel costs, maintenance costs, financing cost and depreciation. Fuel prices at the pump are difficult to predict (linked to the price for a barrel of crude oil) and for this reason the total cost of ownership for three different fuel price scenarios have been analysed: a central case and two additional scenarios in which all fuel costs were 25% higher and 25% lower, to understand the differential impact on consumers.

As can be noted from Fig. 5, variation in fuel prices has a lower impact on the cost of ownership for drivers of PHEVs, BEVs and FCEVs than those driving ICEs, reflecting the smaller role that fuel costs have in the TCO. As the same analysis was performed for all fuels, they are not directly comparable across powertrains. For example, if electricity prices decrease, it doesn't necessarily mean that petrol prices also decrease, and vice versa.

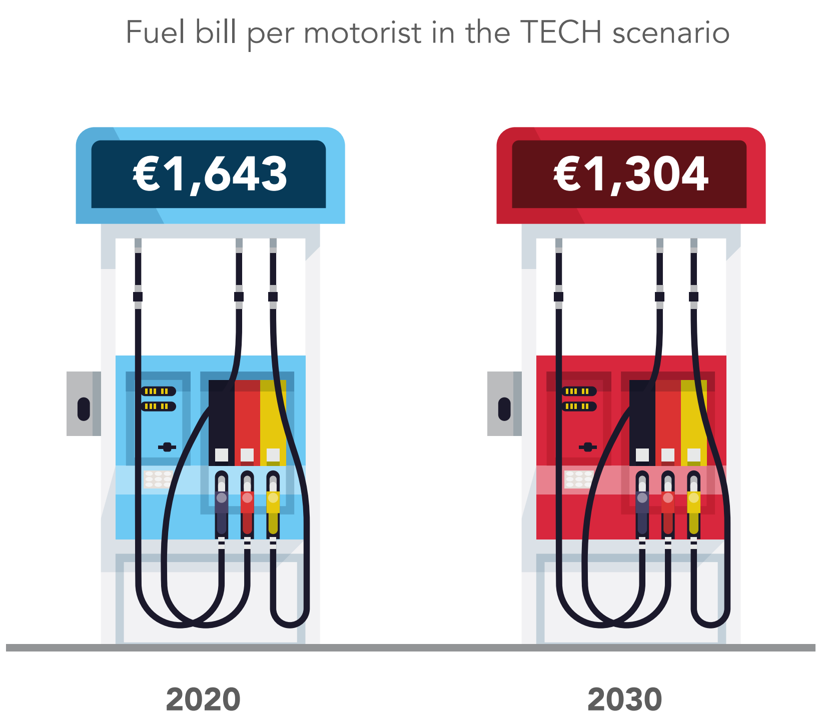


Figure 4. Yearly average fuel bill per motorist of a small car in Italy in 2020 and 2030 in the TECH scenario (as an average across the various vehicle technologies used in Italian cars).

Regarding FCEVs, the cost of owning this type of vehicle is substantially higher than that of other powertrains in 2020. FCEVs remain the most expensive powertrains to own in 2030. However, the cost of owning an FCEV gradually moves towards that of other powertrains over time, plus the gap between the TCO of FCEVs and that of other powertrains is slightly lower for medium and large cars than for small cars (shown in figure 2 and 3). FCEVs could also bring other non-monetizable benefits, such as short refuelling times (less than 5 minutes) and long driving range (currently already above 800 km).

Other costs not included in the model, such as exemptions from registration taxes and circulation or parking costs in large cities for low and zero-emission vehicles, would increase the differential in the TCO in favor of low and zero-emission vehicles.

In conclusion, in the central scenario, the analysis shows that a transition to low and zero-emission vehicles is not only plausible, but even more it will very likely result in financial benefits for the average car owner (vehicle ownership and use will become more affordable between 2020 and 2030). Provided that public policies are in line with these new circumstances, the consumers will have greater disposable income to spend on other goods and services, which further enhances the economy.

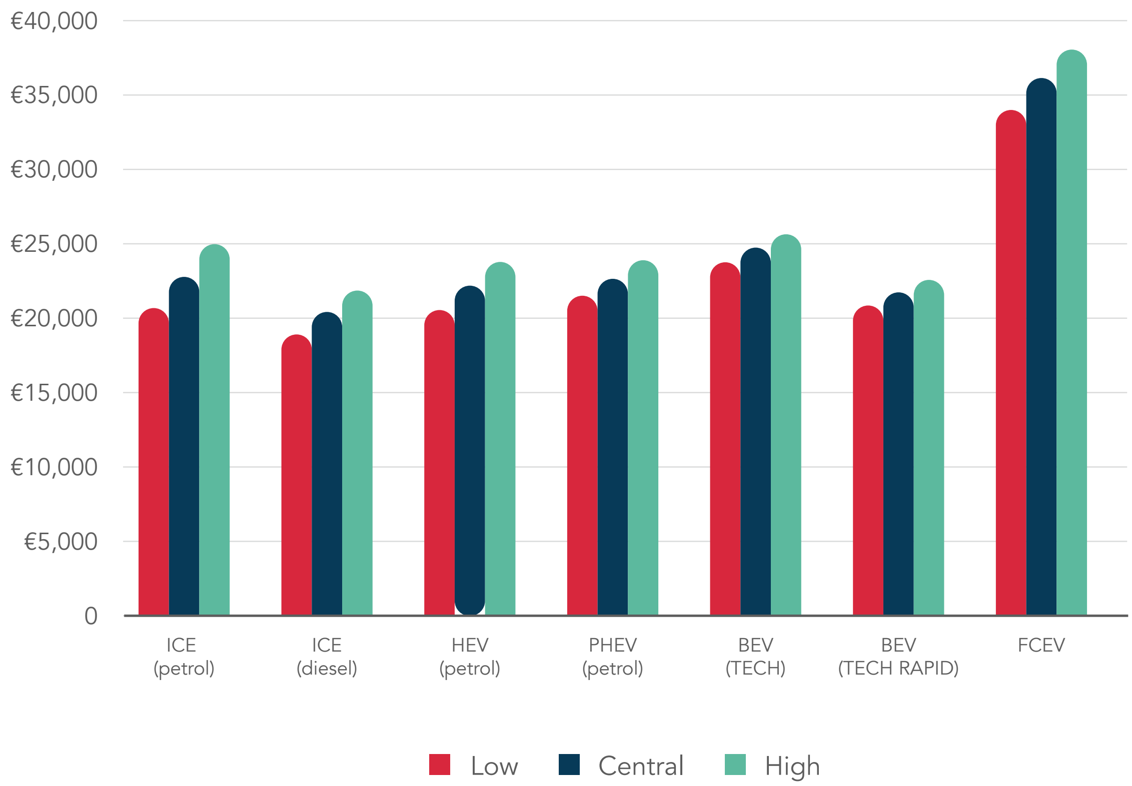


Figure 5. 4-year TCO for a new small car in 2020 according to different scenarios for future fuel prices.

Impact on the Climate

To prevent more than 2°C of warming, EU emissions must be reduced to at least 80% below 1990 levels by 2050. This means that the transport sector will have to be almost completely decarbonised by 2050, and the deployment of zero-emission cars provides an excellent opportunity to help the sector meet that objective.

Greenhouse gas emissions from cars are directly associated with the dominant powertrain type in the fleet and the way in which electricity is produced for electric vehicles. In the central TECH scenario the fleet goes from being dominated by internal combustion vehicles to one in which about the 40% of the new vehicles in 2030 will be plug-in hybrids and battery electric vehicles. After 2030, PHEVs are gradually phased out and replaced by more advanced powertrains (BEVs and FCEVs). Soon after 2035, cars with only an internal combustion engine will no longer be sold. However, due to slow fleet turnover, the fleet in Italy will still contain ICEs in 2050, as can be seen in Fig. 6.

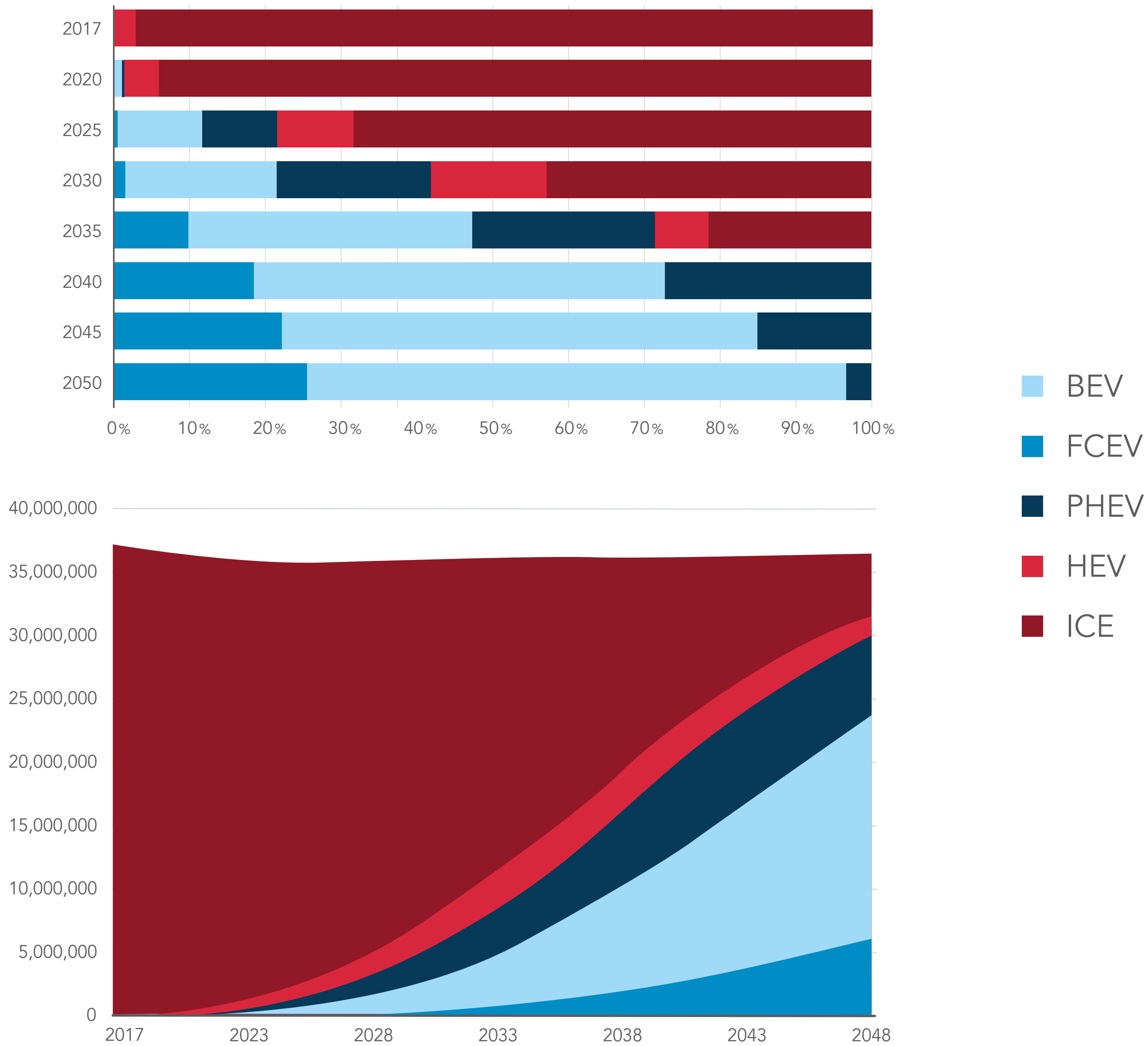


Figure 6. Proportion of vehicle sales and vehicle fleet resulting in the TECH scenario.

In the central TECH scenario, the total direct CO_2 emissions of passenger cars are reduced from 53 Mt in 2017 to 36 Mt in 2030 and to 4 Mt in 2050 (Fig. 7).

Regarding the GHG emissions associated to the production of the electricity required to charge PHEVs and BEVs and produce hydrogen by electrolysis for FCEVs (i.e. implied emissions), it should be noted that these will be capped under the European Emission Trading System. The expert group for this study has nonetheless expressed the importance of adding the implied emissions to the analysis, in order to provide a sense of the climate impact of the generation of energy for electric traction.

For the future carbon intensities associated with the Italian electricity mix, the conservative projections of the PRIMES Reference Scenario 2016 were used. In PRIMES, the growth of electricity generation from renewables in the Italian grid is modest, with just 49% of generation from renewable energy sources (RES) in 2050. In reality, Italian energy policy has been and is more progressive than this. The recently approved SEN assumes that the share of RES in the Italian energy production mix will be 55% in 2030. Ongoing discussions at political level suggest that this target may be raised even further.

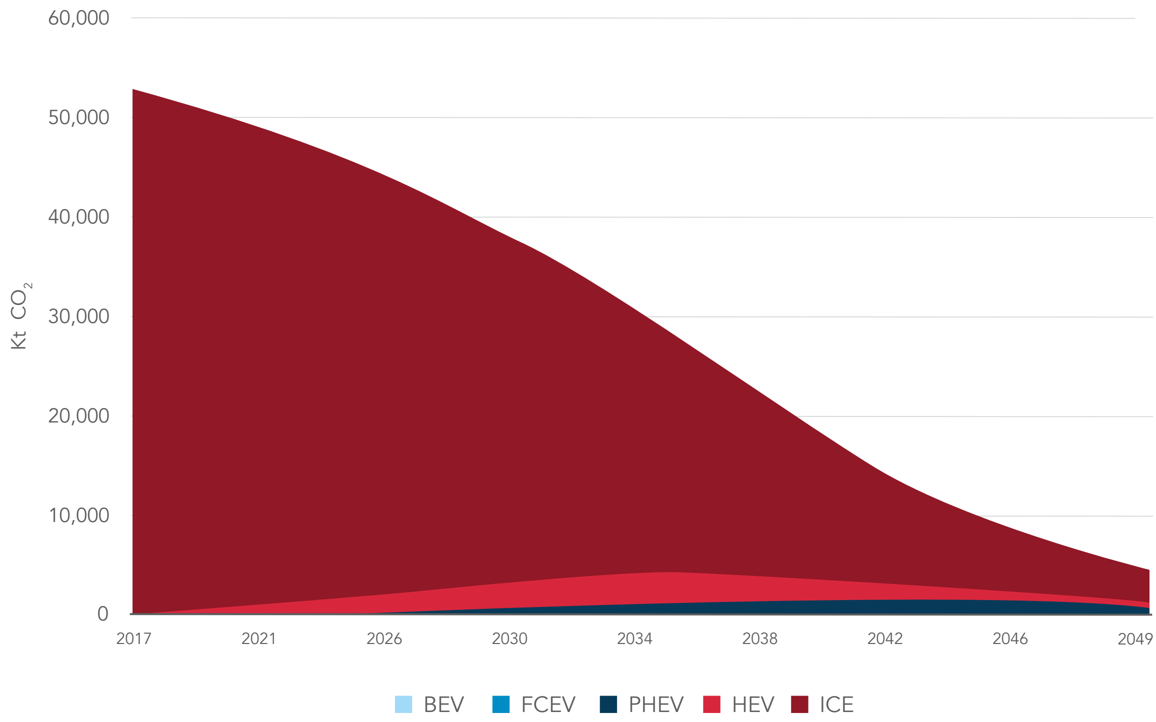


Figure 7. Tailpipe CO_2 emissions from passenger cars in the TECH scenario over the period to 2050.

This analysis shows that the implied emissions from the production of electricity for 2.2 million PHEVs, 2.3 million BEVs and 212 thousand FCEVs in the TECH scenario are modest, accounting for only 2 Mt of CO_2 in 2030. The implied emissions are even smaller if we consider an energy mix with a greater share of renewables like the one proposed by the SEN for 2030. In this case, the implied emissions are reduced to only 1 Mt of CO_2, equal to 3% of the total exhaust emissions of the passenger car fleet in 2030.

After 2030, as more PHEVs, BEVs and FCEVs enter the vehicle fleet, implied emissions will evolve relative to the future grid mix; the more electricity is generated using renewables, the lower the implied emissions will be. But even when taking into account emissions from electricity production and a very modest growth of renewables in the national electricity production mix, EVs will be considerably less environmentally damaging than traditional cars.

In the TECH scenario, in 2050, total tailpipe plus implied CO_2 emissions of the entire fleet will be 84% lower than the emission level in 2017. With more progressive national energy policies, aimed at tapping into the big potential in developing wind and solar energy in Italy, an even better result could be achieved.

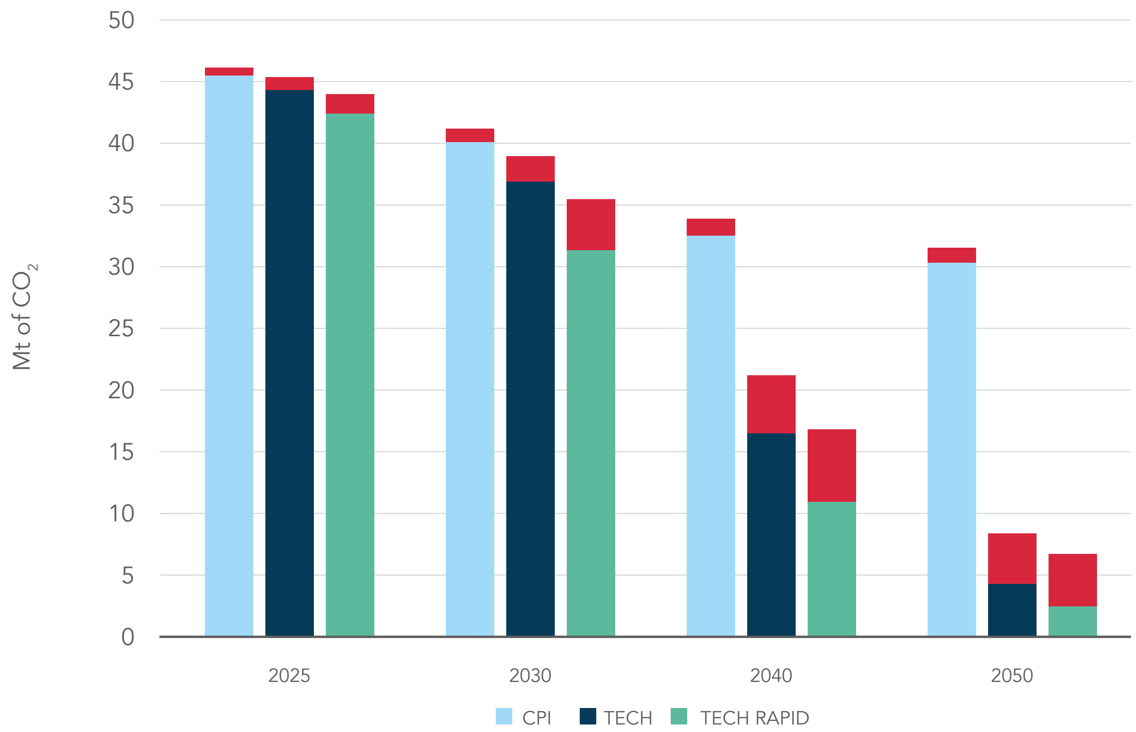


Figure 8. Tailpipe and implied (in red) CO_2 emissions from the fleet across scenarios.

Impacts on Air Quality

One of the major challenges the Italian government faces in the coming years is improving the air quality in its urban centres. Italy's principal cities suffer air pollution, of which one of the main drivers is emissions from an ICE-dominated vehicle fleet. Recently Italy, together with other EU Member States, was referred to the EU Court of Justice for failing to meet agreed limits for NO_x and PM emissions. In 2016, 28 towns in Italy persistently failed to meet air quality standards.

This continuing poor air quality negatively affects human health in Italy and other EU Member States. With over 1,500 premature deaths per 1 million inhabitants per year due to air pollution[7], Italy is the poorest-performing EU Member State.

According to ISPRA, the Italian road transport system is the main national source of $NO_{x,}$ with diesel vehicles the dominant source of NO_x transport emissions (92%). The increased penetration of diesel cars in Italy, going from 10% of the stock in 1995 to 55% in 2015, has exacerbated this issue. The loopholes in the testing cycle for vehicle regulation compliance and the dieselgate scandal have revealed the complexities of accurately monitoring emissions of ICEs, as well as the technological limitations to drastically reduce emissions from ICEs of NO_x, PM and CO_2 at the same time.

Addressing local air emissions requires drastic and often unpopular measures to be put in place by local administrators, from the creation of zero emission zones to diesel and petrol car bans in cities. When designing policy addressing passenger transport, it is of crucial importance to ensure that the new technologies entering the vehicle fleet have emissions that are as low as possible. BEVs, PHEVs (normally driven in electric mode in urban areas) and FCEVs, while offering an opportunity to drastically reduce CO_2 emissions, also hold the potential to address the issue of low air quality linked to passenger mobility.

In the low carbon scenarios analysed, tailpipe NO_x and PM_{10} emissions decrease substantially. In the TECH scenario, in 2025 NO_x emissions will already be reduced by 50% compared to 2017 levels, and PM_{10} emissions will drop by 63%, moving close to zero in 2050. This is due to the higher penetration of advanced powertrains and to the renewal of the fleet with more efficient ICEs.

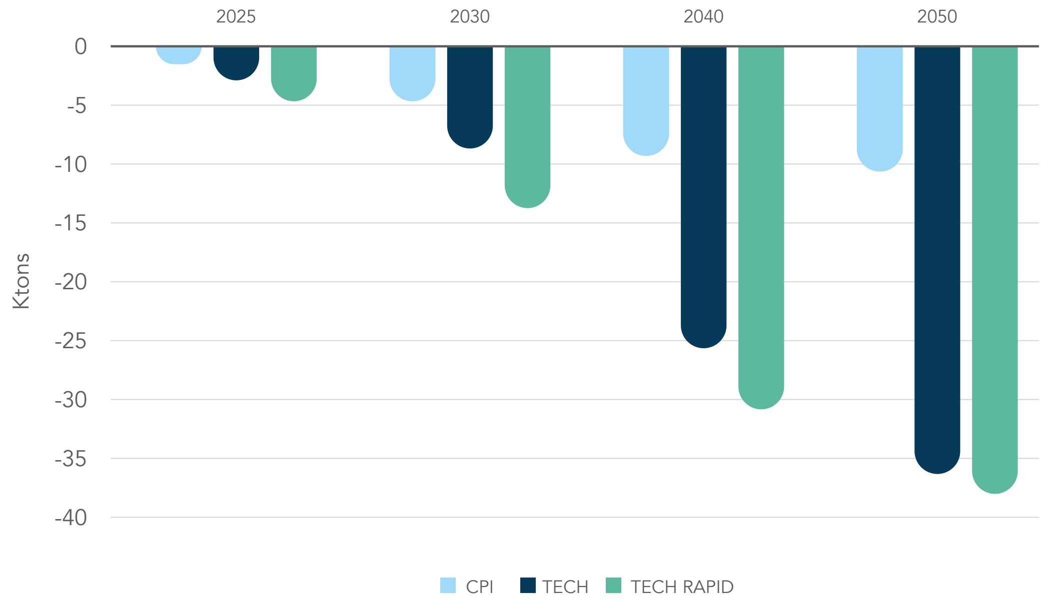


Figure 9. NO_x emission reduction from the fleet across scenarios compared to REF scenario.

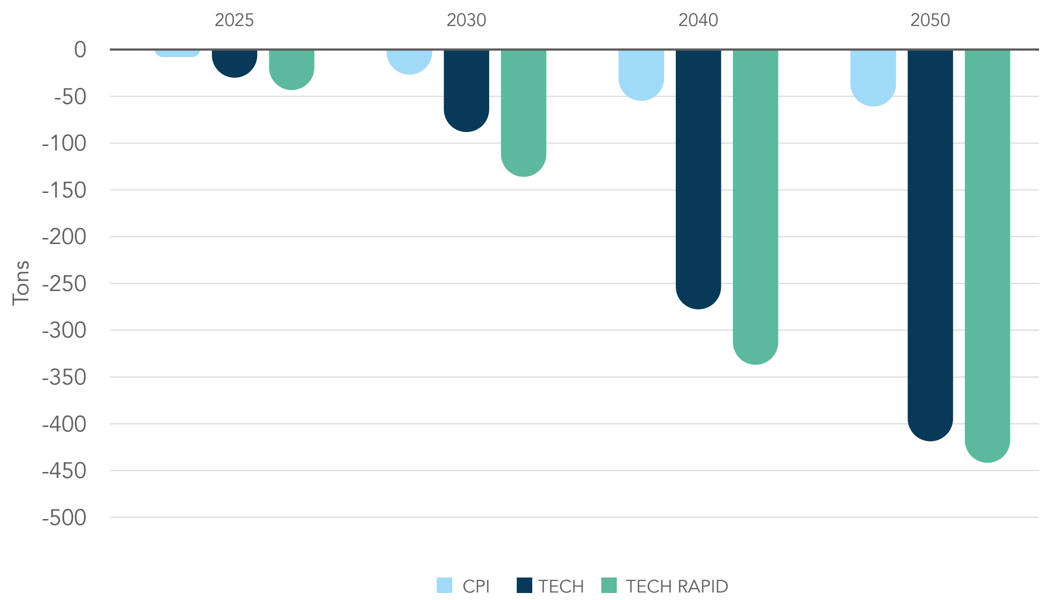


Figure 10. PM_{10} emission reduction from the fleet across scenarios compared to REF scenario.

Impacts on Health

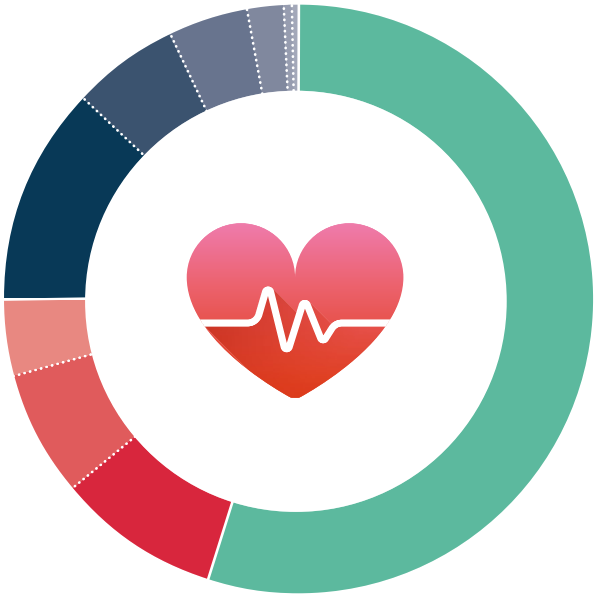


Figure 11. Savings generated by the TECH scenario by kind of impact and events (2017-2050).

NO_x emissions commonly lead to increased rates of diseases such as asthma and, in some cases, bronchitis or even pulmonary oedema. Nitrogen monoxide (NO) is a cause of pulmonary oedema and harms the blood due to the formation of methemoglobin. In addition, nitrogen dioxide (NO_2) irritates the eyes, the mucus membranes and lungs and exacerbates respiratory diseases such as asthma, allergies, irritations and bronchitis. It also forms fine particulate matter ($PM_{2.5}$) as it reacts with the atmosphere.

The contribution of low-zero emissions vehicles in improving air quality results in positive impacts on human health, and these can be quantified, both in terms of the reduction of effects and in terms of an associated monetary value. Focusing on the reduction in tailpipe emissions of primary and secondary (from NO_x) $PM_{2.5}$, from cars only, results are classified in terms of health, productivity and life savings connected to the reduction in cases of associated diseases.

Comparing the economic benefits from a reduced health impact in the TECH scenario along the considered timeframe, life savings represent 55% of total impact. In absolute terms, the total cumulative number of life years gained thanks to the reduction of pollution due to tailpipe emissions in 2050 is 114,644. Given an average life expectancy of 83.5 years, this is equivalent to almost 1,400 lives.

The second largest category of savings is related to the reduction in disease rates, in particular to lung cancer, asthma and chronic bronchitis. Around 2,000 cases of lung cancer are prevented (equivalent to 12% of all monetary savings), 12,600 cases of chronic bronchitis are also estimated to be prevented (6% of savings) and 8.8 million cases of lower respiratory symptoms among adults (4.3%) and 852 thousands among children (0.4%) are removed (9%).

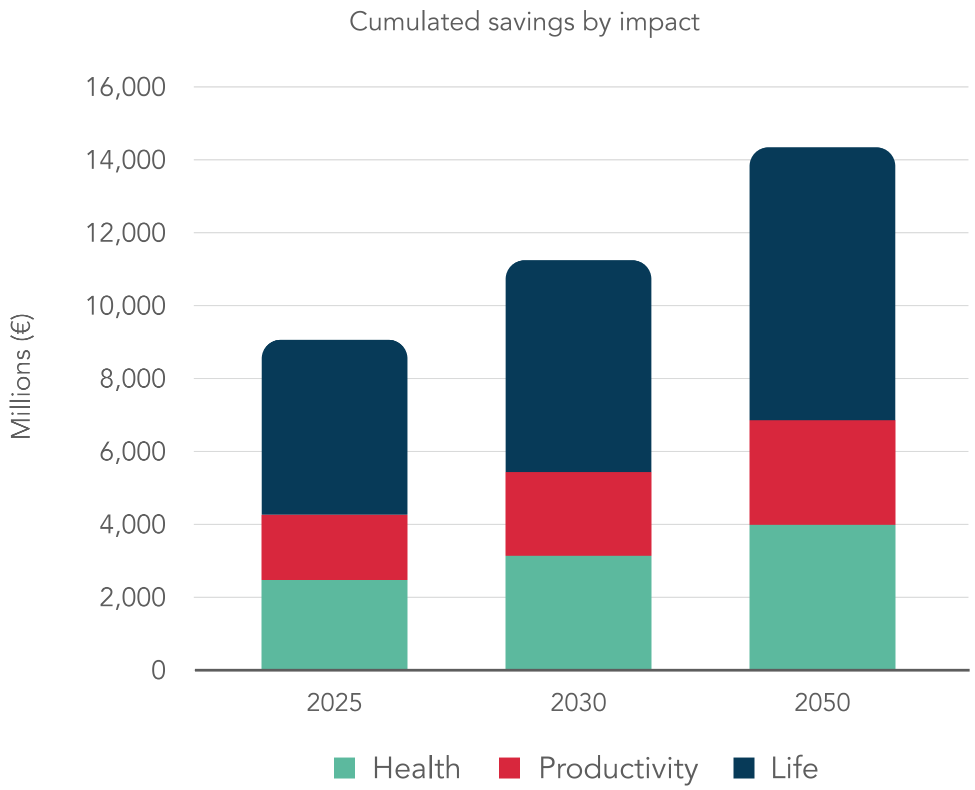


Figure 12. Cumulated saving generated by the TECH scenario by kind of impact.

In terms of productivity, the air quality improvement caused by the reduction of tailpipe emissions of cars will result in 2.1 million fewer work loss days (WLDs), together with a reduction of Minor Restricted Activity Days (MRADs) by 5.8 million, and 9 million fewer Restricted Activity Days (MRADs).

The total monetary value of the improvements is estimated to be €8.5 billion in 2025, increasing to €10.5 billion in 2030 and up to €13.5 billion in 2050.

The total cumulated savings in terms of the medical costs estimated alone sum up to €3.2 billion, while the economic value attributed to the life years saved is estimated around €7.4 billion.

In the TECH scenario, the additional net benefits peak in 2040, when net savings are estimated to be around €96 million. This reflects the trend of emissions in the scenario, decreasing rapidly until 2040 due to the yearly decrease of ICE vehicles sales, slowing down when diesels are no longer sold.

By 2050, the cumulative impacts in the TECH scenario are nearly €2 billion, compared to less than €400 million in the CPI scenario.

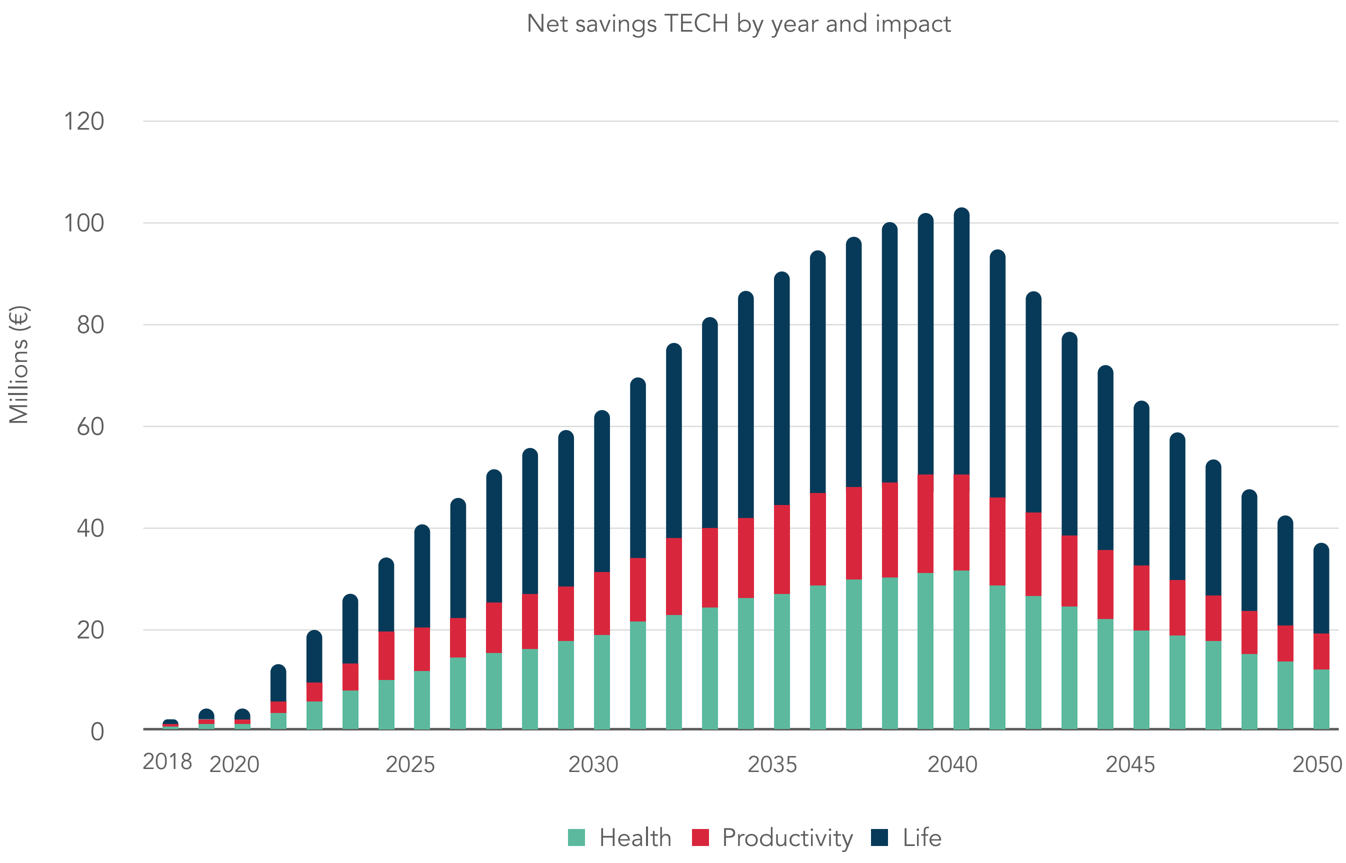


Figure 13. Net savings generated by the TECH vs REF scenario by kind of impact (2017-2050).

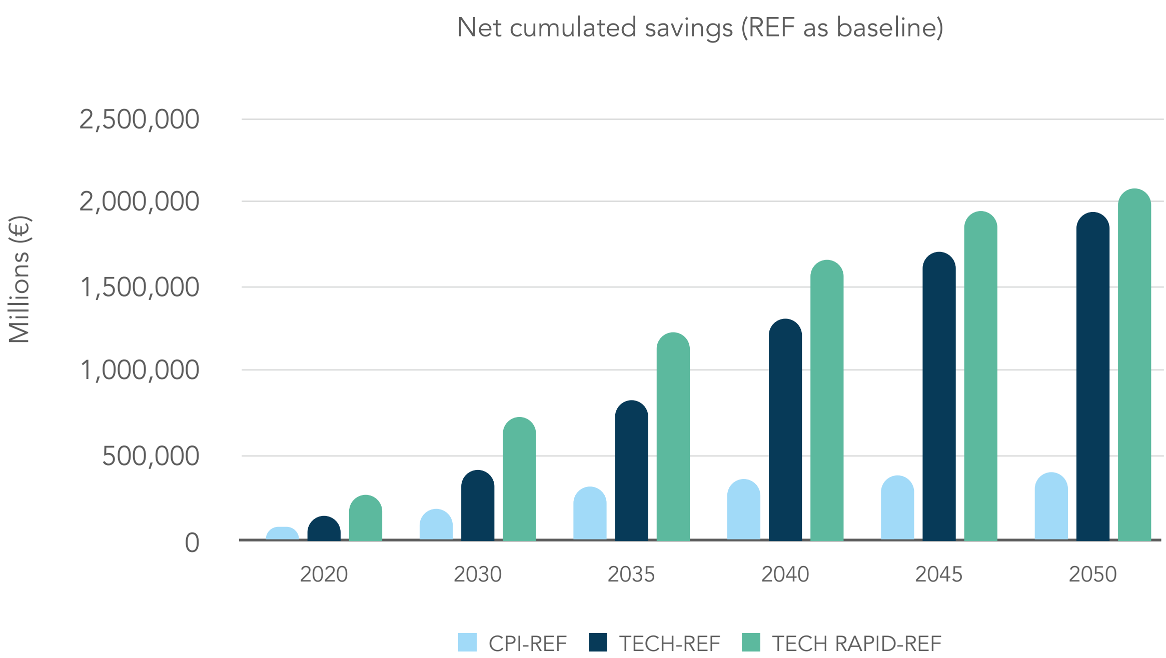


Figure 14. Net cumulated saving generated by the CPI/TECH/TECH RAPID vs REF scenario.

Impacts on the Economy

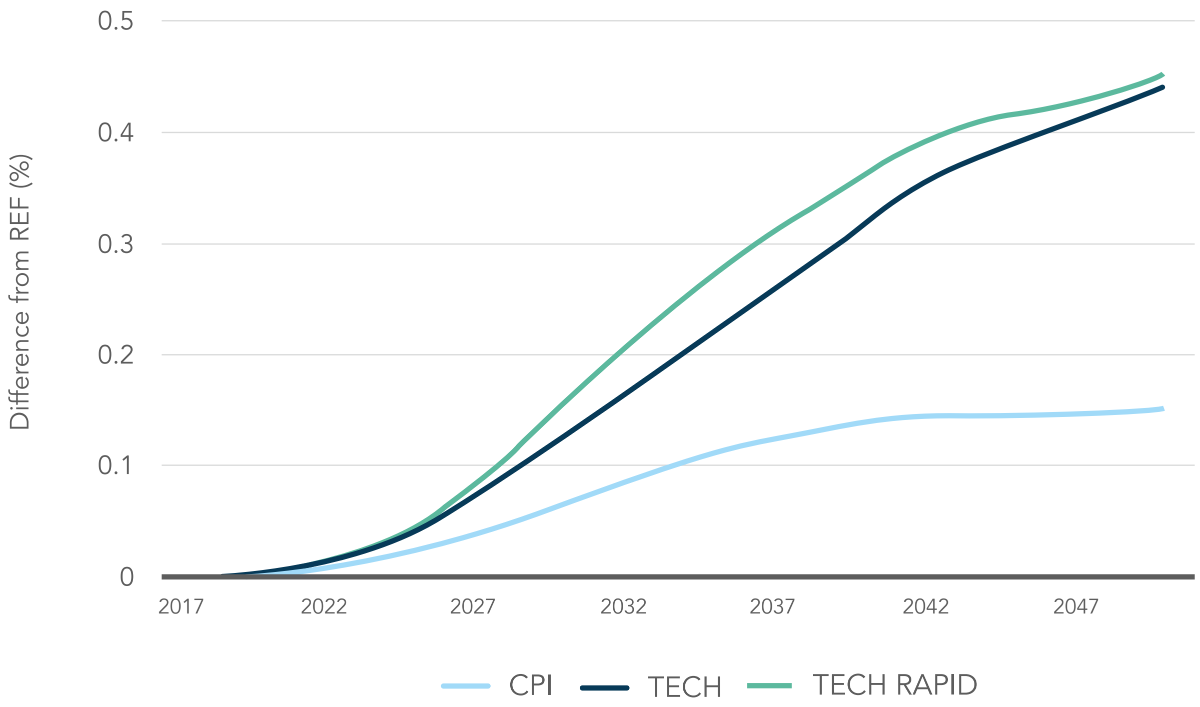


Figure 15. Impact on GDP of each of the core scenarios relative to the REF scenario.

The transition towards low and zero emissions vehicles has the potential to profoundly transform the wider economy, bringing beneficial effects for society. The main driver of this transformation will be the shift from imported petrol and diesel to domestically produced renewable electricity and hydrogen as the primary fuels for mobility, as well as the reduction of final energy demand of passenger vehicle fleet thanks to higher average efficiency of the vehicle stock. Moving from a fossil fuel-based transport system to one in which domestically produced electricity and hydrogen are the main fuels will reduce leakage from the domestic economy, and shift economic activity towards other sectors which create more jobs within Italy.

In this analysis the impacts on GDP, employment and total tax revenues in Italy have been calculated using the macroeconomic model E3ME. The results show that, even assuming a continuation of Italy's relatively weak economy that has been a feature of recent years, the transition to low carbon passenger cars will have positive effects on output and employment. By 2050, in both the TECH and TECH RAPID scenarios, GDP will be higher than in the REF case. GDP will be 0.4% higher in the TECH scenario in 2050, with consistently higher output from 2020 onwards, while there will be 52,146 additional jobs created in Italy by 2050 in this scenario. However, at a sectoral level there are winners and losers from the transition.

Today imported oil is central to the Italian transport system; according to the Unione Petrolifera, in 2017 Italy imported 15.9 million tonnes of refined petroleum products. However, the petroleum industry employs relatively few people; historical data shows that 1 million euro of value added in the petroleum sector in Italy created only 3.5 jobs in Italy in 2017, while the electricity and hydrogen sectors are almost 5 times more labour intensive (Fig. 16). In other words, when we fill up the tank of our cars with fossil fuels we contribute only a little to the domestic economy, primarily creating jobs in countries outside the EU.

Employment in the motor vehicle sector increases in the short term, as more complex ICEs are manufactured (reflecting the addition of fuel efficient technologies), along with dual powertrain hybrid vehicles. However as production shifts to BEVs, which are simpler to manufacture, employment in this sector falls slightly. There is increased employment in electrical equipment, which benefits from increased demand as a key part of the supply chain for electric vehicles. In addition, there is a substantial boost to employment in the service sector, reflecting the benefits of reducing consumer expenditure on fuel; this money is instead spent on other items, including consumer services.

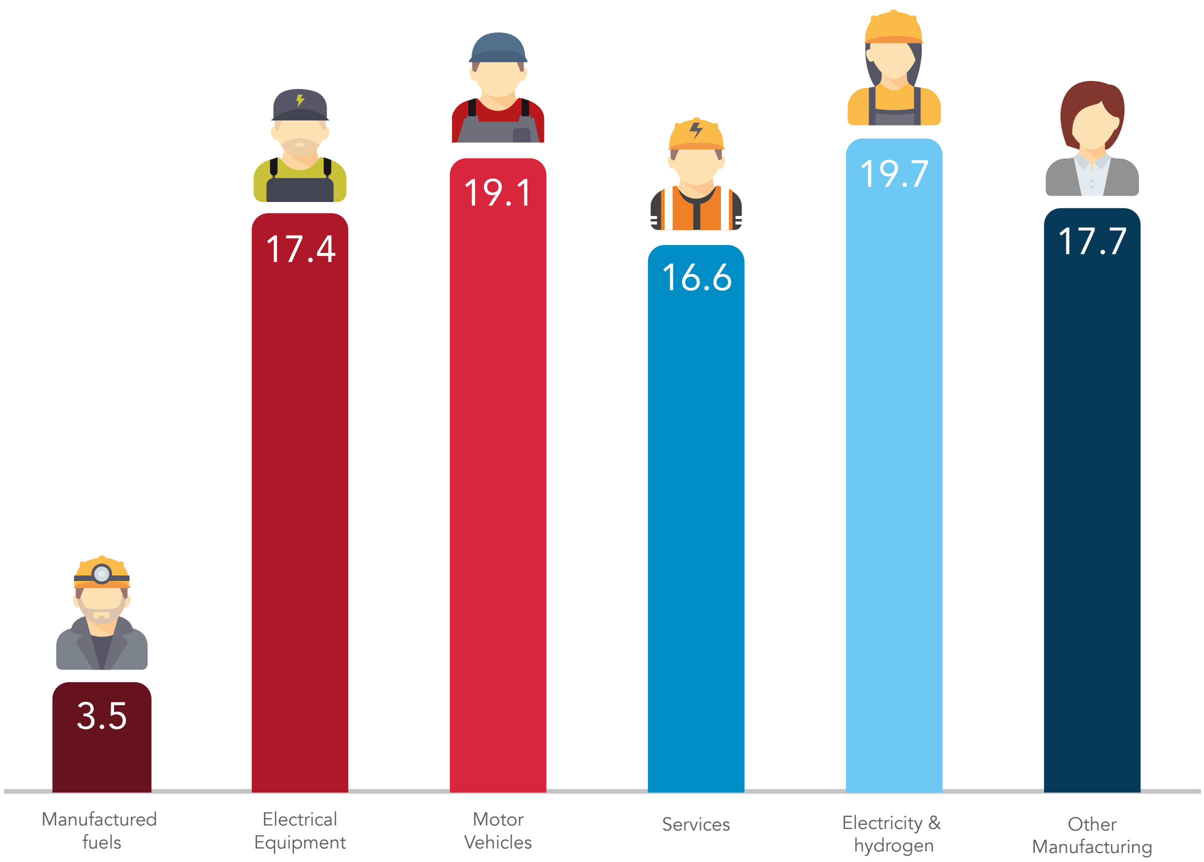


Figure 16. Employment intensities (jobs per €1m value added) of different sectors of the Italian economy in 2017.

Overall, the transition has a net positive impact on employment (19,225 additional jobs in 2030), and will create opportunities for the adaptation and transformation of workers and regions that are particularly affected by the long-term decline in the manufacturing of ICEs. There is clearly a role for public policy in delivering assistance to those workers that lose their jobs in the transition, to allow them to take up jobs created elsewhere in the economy.

The macroeconomic benefits are relatively small in Italy, when compared to similar studies in other EU Member States. This reflects the current economy in Italy, and an Italian automotive industry that has lost some competitiveness relative to its competitors within the EU. However, the transition to new technologies and powertrains can present opportunities to improve the competitiveness of the industry; focussing on new supply chains and the changing demands of the wider European motor vehicles industry. In particular, if Italian OEMs can again reach the forefront of European development of small and efficient urban vehicles, then there is the potential to regain domestic market share that has been eroded over the past decade. This could also have additional benefits for GDP and employment in Italy.

Another important aspect addressed in the analysis is the reduction in government income that such a transition might bring about, due to reduced revenues from fuel taxes. While all scenarios show a decrease in fuel duty revenues, relative to the REF scenario, this represents only a small portion of the overall tax base of the government, less than 3%. The analysis estimates that government revenues in the TECH scenario will decrease by about €4 billion compared to the REF scenario in 2030. This gap will partially be offset by higher income, VAT and social security revenues that will be generated by the additional activity in the Italian economy.

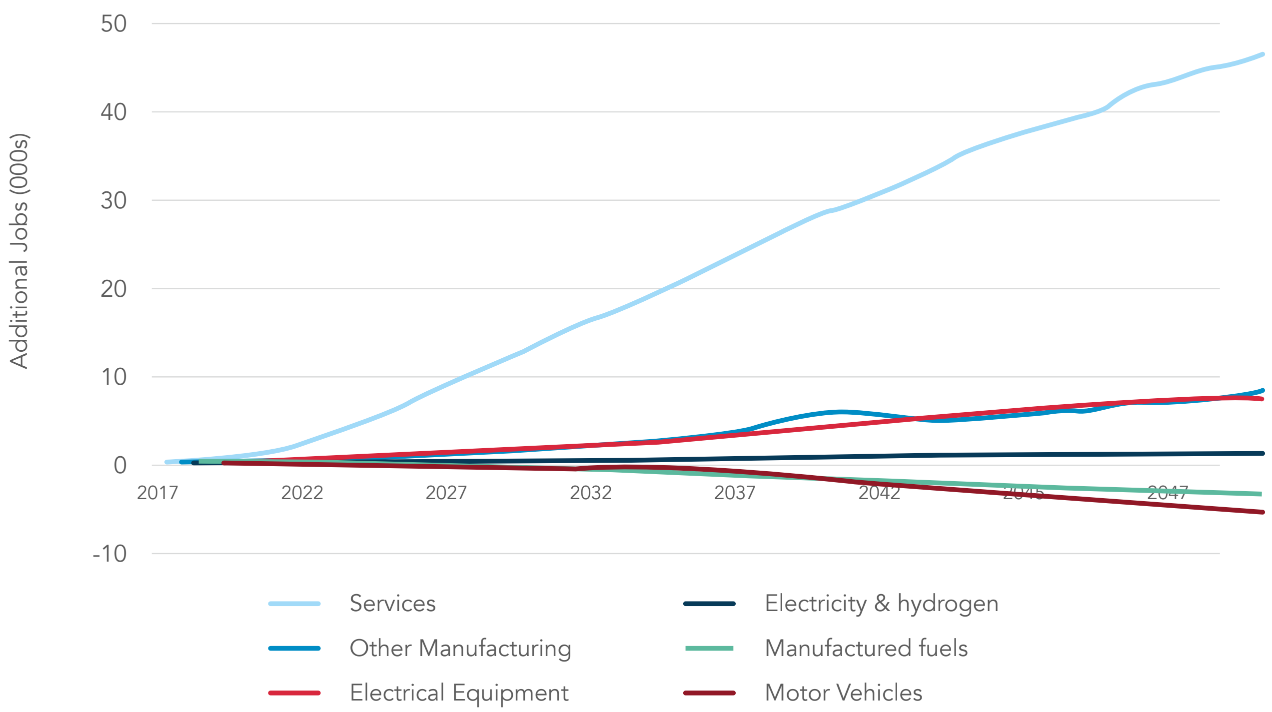


Figure 17. Additional jobs in key sectors of the economy[8], including vehicle manufacturing, their supply chains, energy and service sectors of the economy in the central TECH scenario compared to the REF scenario out to 2050.

The remaining gap could be addressed through other tax changes, including those targeted specifically at passenger car drivers (in order to mitigate the other undesirable characteristics of driving, such as congestion) via road charging and congestion tariffs.

Finally, there are implications for energy security from the transition. Italy is highly dependent on imported energy for transport. As well as having geopolitical implications, it also means that large portions of the Italian economy and consumers are vulnerable to oil price volatility.

The analysis carried out has shown that a major shift in the nature of energy demand for transport, both in terms of the nature and quantity of energy supplied, can be achieved. In the central TECH scenario, the energy consumption of the Italian car fleet in 2050 could be reduced by 72%, thanks to a switch to more efficient vehicles and powertrains. In 2050, only 35% of the total demand will be for fossil fuels, with the remaining demand being met through electricity and hydrogen, providing a potential market for Italian solar and wind energy.

In the TECH scenario, by 2030, the lower demand for petrol and diesel from passenger cars leads to a cumulative reduction in imported refined petroleum of 183 million barrels of oil equivalent compared to the REF scenario, increasing to 1,755 million barrel of oil equivalent in 2050 (see Fig. 20). This equates to cumulative savings of about €21 billion by 2030 and €377 billion by 2050, providing a boost to the Italian trade balance.

In conclusion, the more oil imports are reduced, the greater the benefits for the country. A win-win situation, in which Italy will have the opportunity to minimise its exposure to oil price volatility and maximise the market for domestically produced renewable energy.

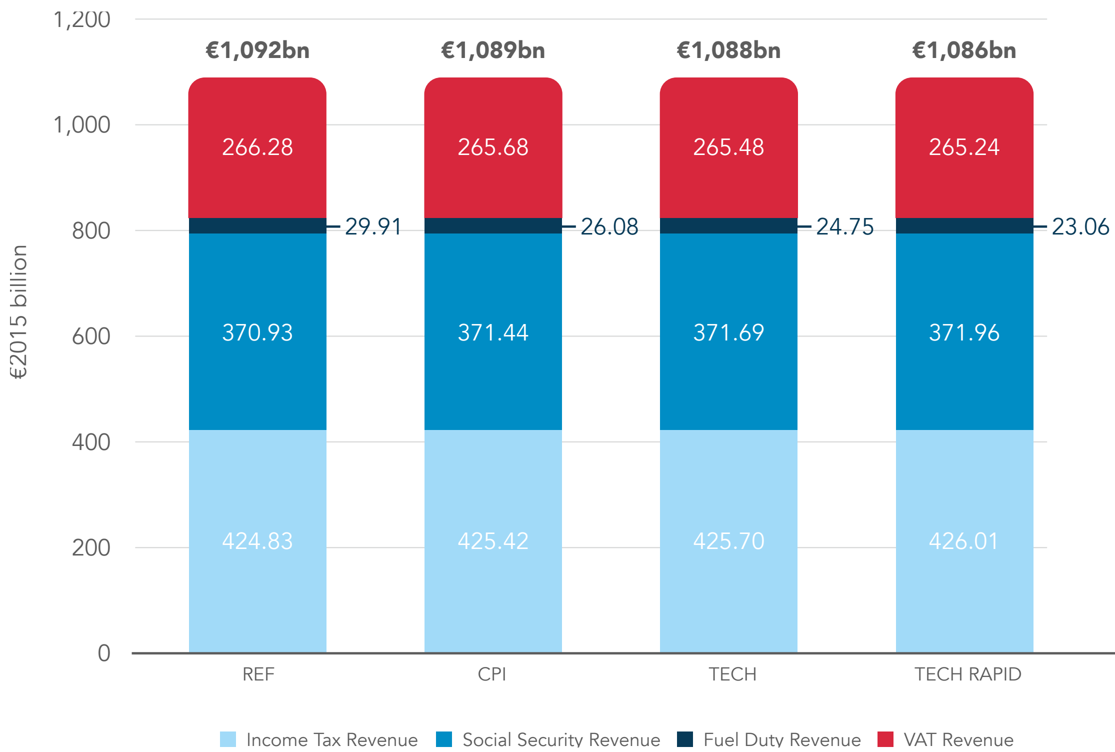


Figure 18. Annual government tax revenues in 2030 in the REF, CPI, TECH and TECH RAPID scenarios.

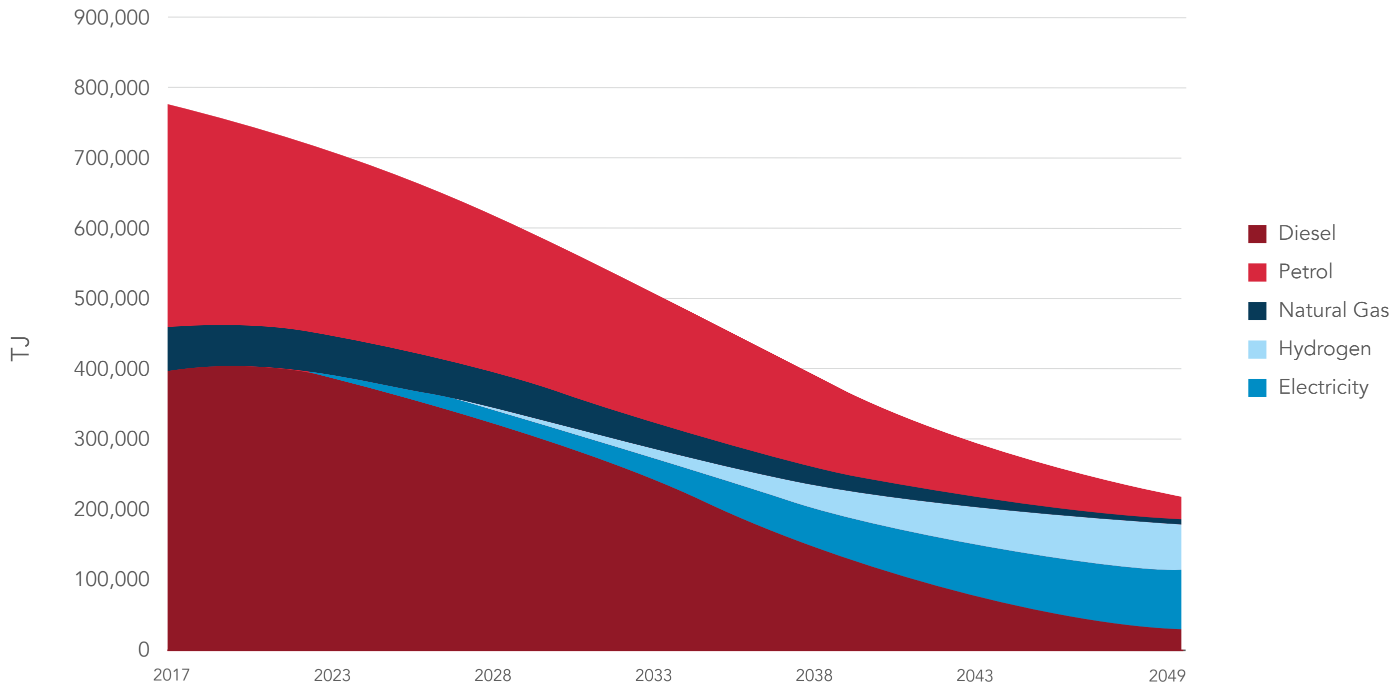


Figure 19. Energy consumption by passenger cars in the TECH scenario over the period to 2050.

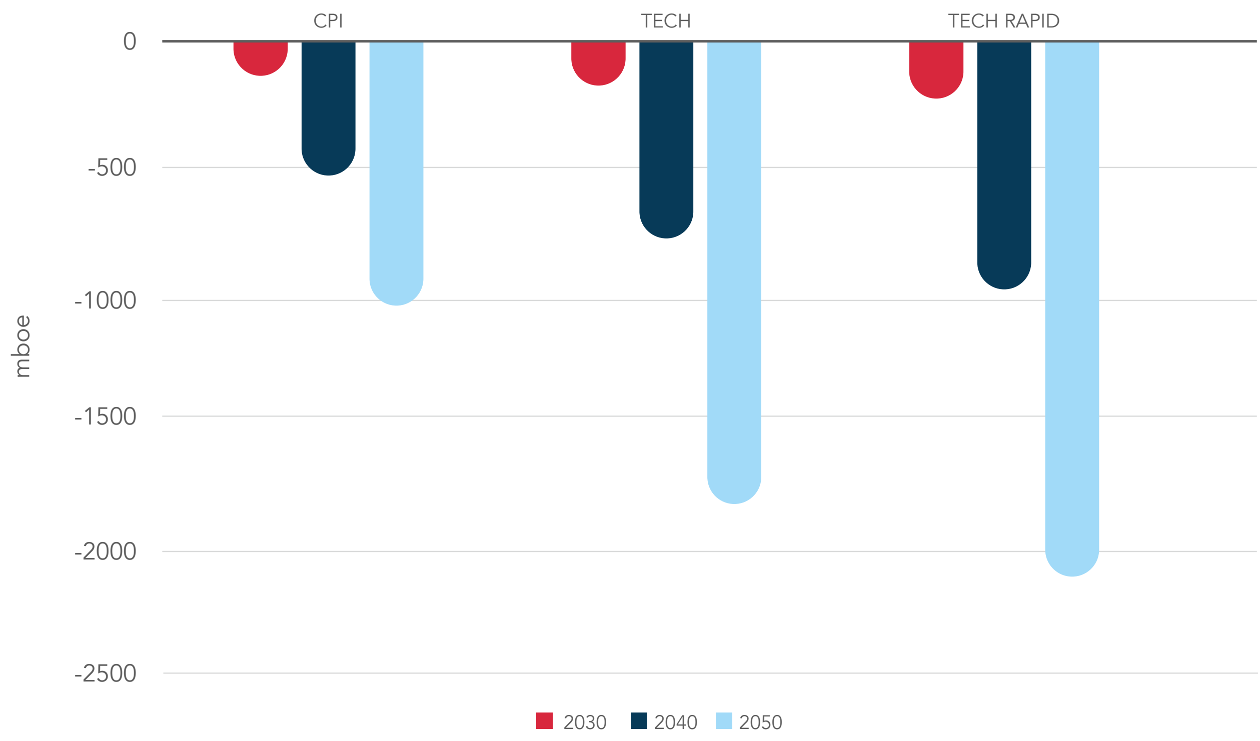


Figure 20. Cumulative refined petroleum imports savings in mboe.

Infrastructure

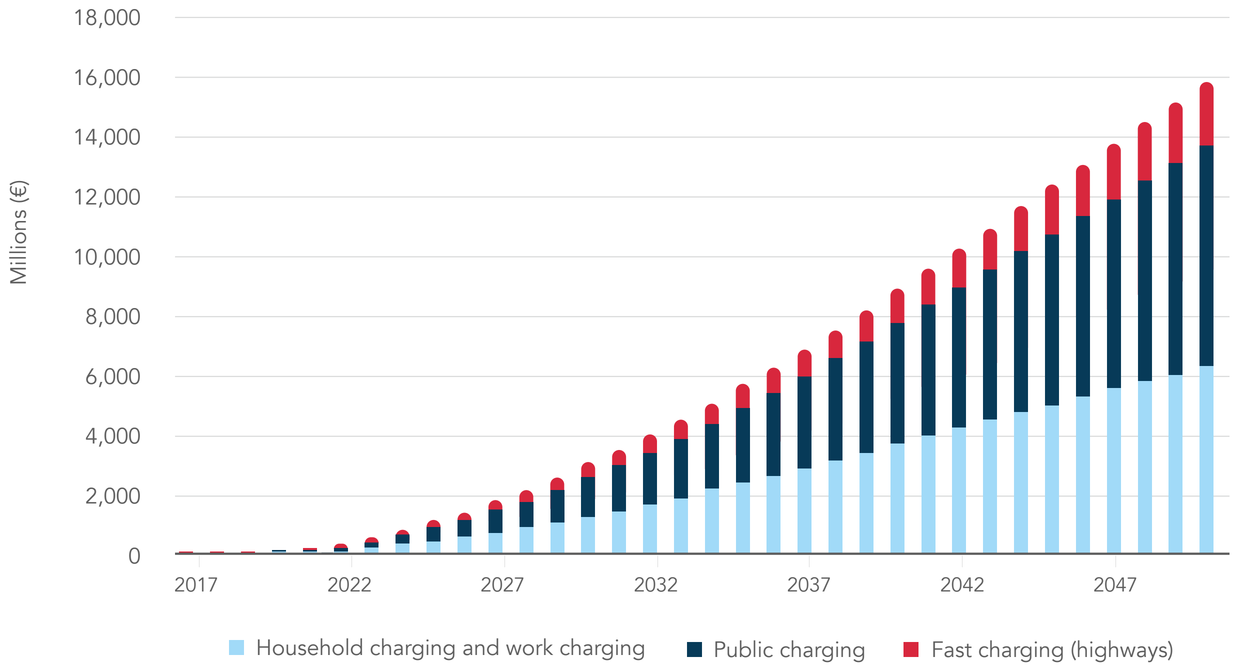


Figure 21. Cumulative investment in EV charging infrastructure in the TECH scenario over the period to 2050.

Sufficient accessible charging infrastructure is a key enabler for the accelerated uptake of low-carbon mobility. Whilst the early market is likely to be dominated by wealthier consumers, with access to off-street parking and therefore the ability to charge their vehicle at home, the wider population need access to a mix of charging options, including publicly accessible locations. This includes fast charging along highways for trips beyond the range of a single battery charge, and publicly available charging in other locations, largely in urban areas. In addition, the deployment of FCEVs would require hydrogen refueling stations (HRS).

In 2015 there were only 1740 electric charging points across the whole of Italy, 1670 for standard charging and 70 for fast charging along motorways. This is far fewer than deployed in other EU countries like France and Germany, although proportional to the modest number of electric vehicles in circulation in Italy at the time. As the number of EVs increases, it is essential that sufficient recharging/refuelling infrastructure is installed to meet the needs of the fleet.

This study has analysed the infrastructure needed to support the EV fleet in the different scenarios. In each case, the total investment required over time to deliver this infrastructure has been calculated.

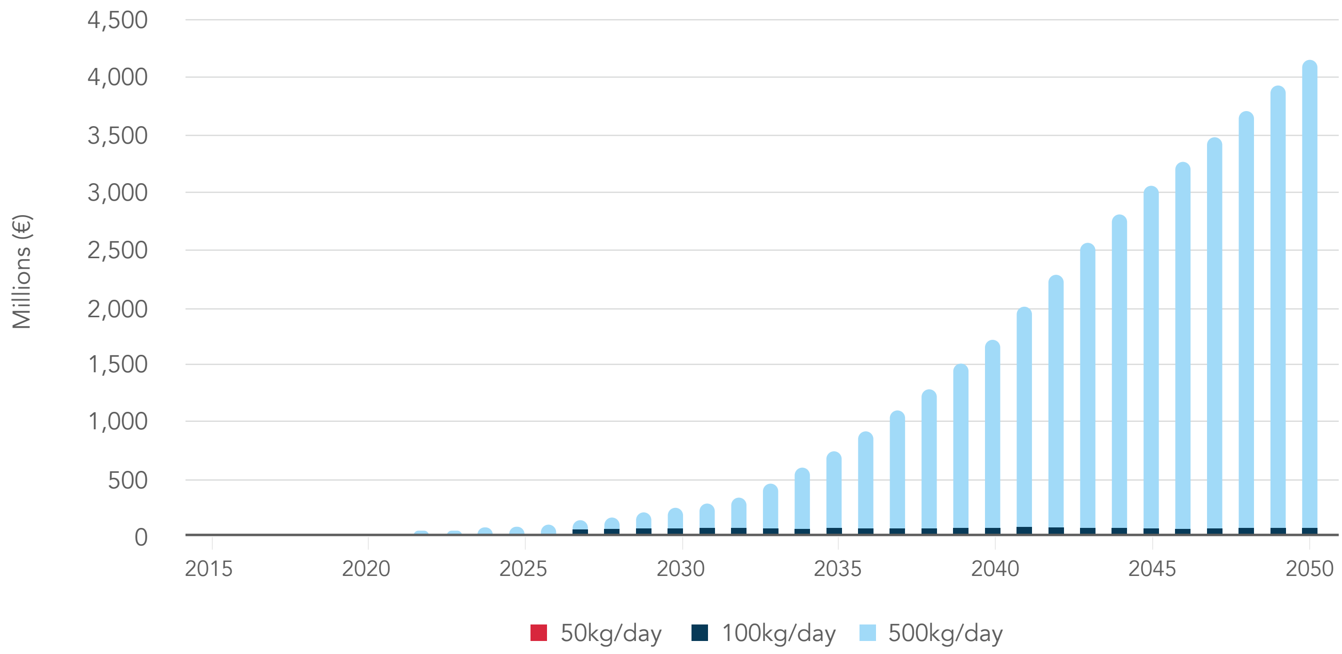


Figure 22. Total cumulative investment in H2 refuelling infrastructure in the TECH scenario over the period to 2050.

In the central scenario analysed, the level of infrastructure planned for plug-in hybrids and battery electric vehicles is broadly consistent with the National Plan for Recharging Infrastructure (PNIRE[9]), which envisages between 4,500 and 13,000 'slow' charging points and between 2,000 and 6,000 rapid charging stations (all available for public use) in 2020.

Moreover, the central scenario is also broadly consistent with the Scenario MobilitàH2IT[10], Italian implementation of the DAFI Directive 2014/94/EU for hydrogen mobility[11], which foresees 10 car HRS in 2020, 350 in 2030, 3,000 in 2040 and 5,600 in 2050.

It is estimated that €3 billion will be required for investments in charging infrastructure for electric vehicles in the period to 2030: of this, €1.8 billion is required to provide publicly available charging infrastructure (slow public chargers and rapid chargers on motorways).

Due to the slow penetration of FCEVs into the fleet up to 2030, the total investment required to support the hydrogen refueling infrastructure in the TECH scenario is €236 million up to 2030. The investment requirements are more substantial in the period between 2030 and 2040. During this period, a further €1.5 billion of investment in refueling hydrogen infrastructures will be required.

Synergies between transport and the electricity grid

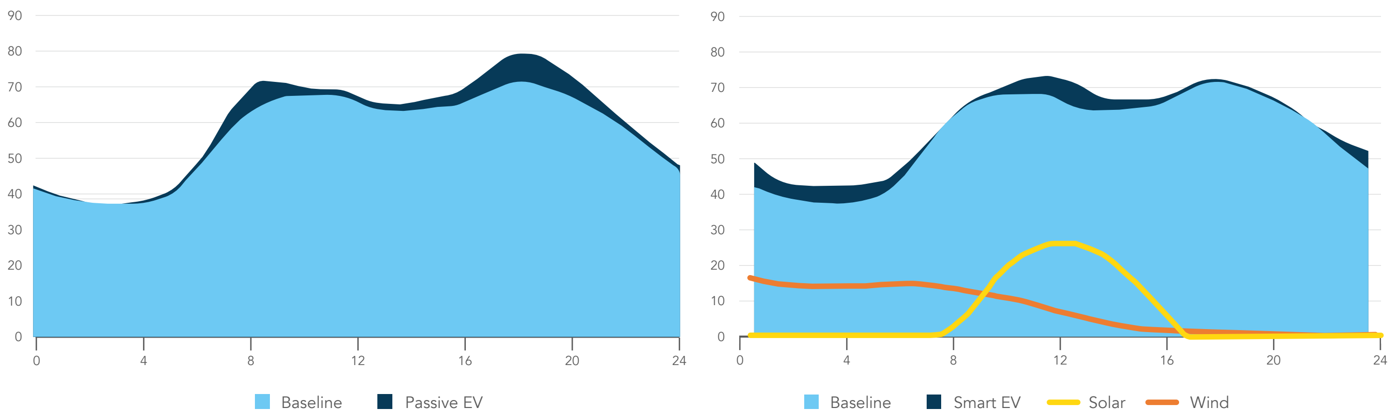


Figure 23. Graphs show calculated passive and smart charging profile for day charging for the day of peak demand (in December).

In addition to the macroeconomic analysis, we have assessed the impact that electric vehicles will have on the national electricity system, from generation through to distribution, and explored potential synergies between the transport and power system.

In terms of increasing annual electricity demand, the impact of EV charging would be relatively modest, adding only 6% to total electricity demand in 2050. As this increase in energy demand is relatively small, it has limited impact on annual energy balances - these are the focus of the E3ME model. However the pattern and timing of this demand have a much larger impact, for example on peak electricity demand and corresponding generation and network capacities.

To deploy EV charging without incurring unnecessary electricity system costs, more attention will be required in the management of peak loads. Three distinct potential charging options have been assessed: "passive" (unmanaged), "smart" (managed) and "active" (Vehicle to Grid, V2G).

In a passive charging scenario, most of the electric vehicles in the parc would begin charging as soon as they are plugged in when they arrive at home in the evening after work, and in the morning (when drivers arrive at work). Most EVs in use today begin charging as soon as they are plugged in - this tends to increase peak loads on the network. Following widespread EV adoption, this would require significant distribution network investments and additional electricity generation capacity (peaking plants) to deal with new peaks in demand. Peaking plants are less efficient than baseload plant and so "peaking" energy is more expensive and more carbon intensive to generate. We calculate that passive charging could incur additional system costs of €160 - 730 million per year (2030 and 2050 figures). These costs relate to distribution network reinforcement, additional peaking plants, and additional fuel used in these peaking plants.

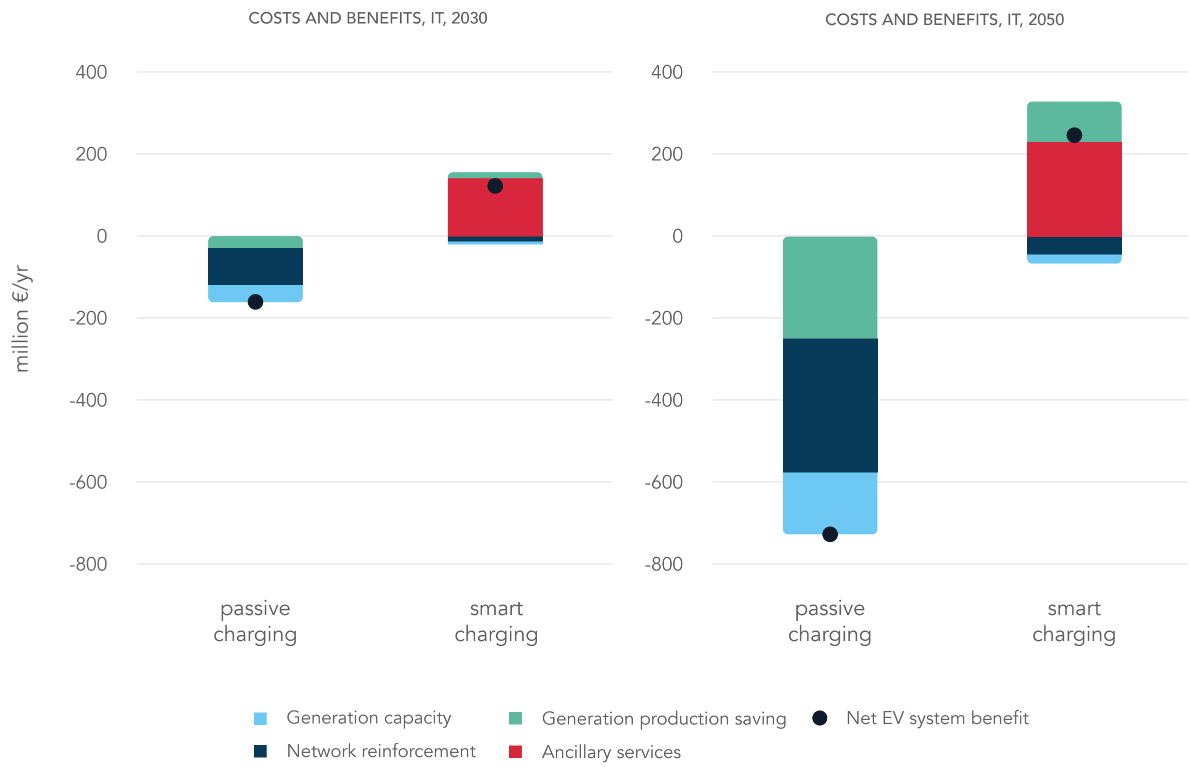


Figure 24. Comparison of electricity-system net cost or benefit for passive versus smart charging, for 2030 (left) and 2050 (right).

In a managed, *smart charging* approach, EV peak demand is shifted into periods of high renewables output, while avoiding increasing loads on the network. In this way electric vehicles can increase the use of renewable electricity generated from wind and solar sources that could otherwise be lost (curtailed). Also, smart charging can displace charging periods away from times of peak demand, largely avoiding upgrades in the distribution network.

Smart charging could generate significant synergies between the transport and power system, reducing costs incurred by passive charging systems and providing benefits to the grid instead. This analysis calculates that, in the TECH scenario, the deployment of smart charging would lead to benefits of approximately €140 million per year in 2030 relative to the baseline cost, rising to €260 million per year in 2050, while passive charging leads to additional net costs of €160 million per year in 2030, rising to €730 million per year in 2050. The net benefits - relative to a passive charging scenario - are even greater.

Savings from smart charging arise throughout the system: it largely avoids the need to invest in the distribution network, and increase in peak demand is very small, so there is limited impact on peaking plants and fossil fuel burn. In addition to these avoided costs, smart charging could generate revenues from providing ancillary services (required to balance/stabilise the electricity grid), and also usefully absorb some excess renewable energy which otherwise would need to be curtailed.

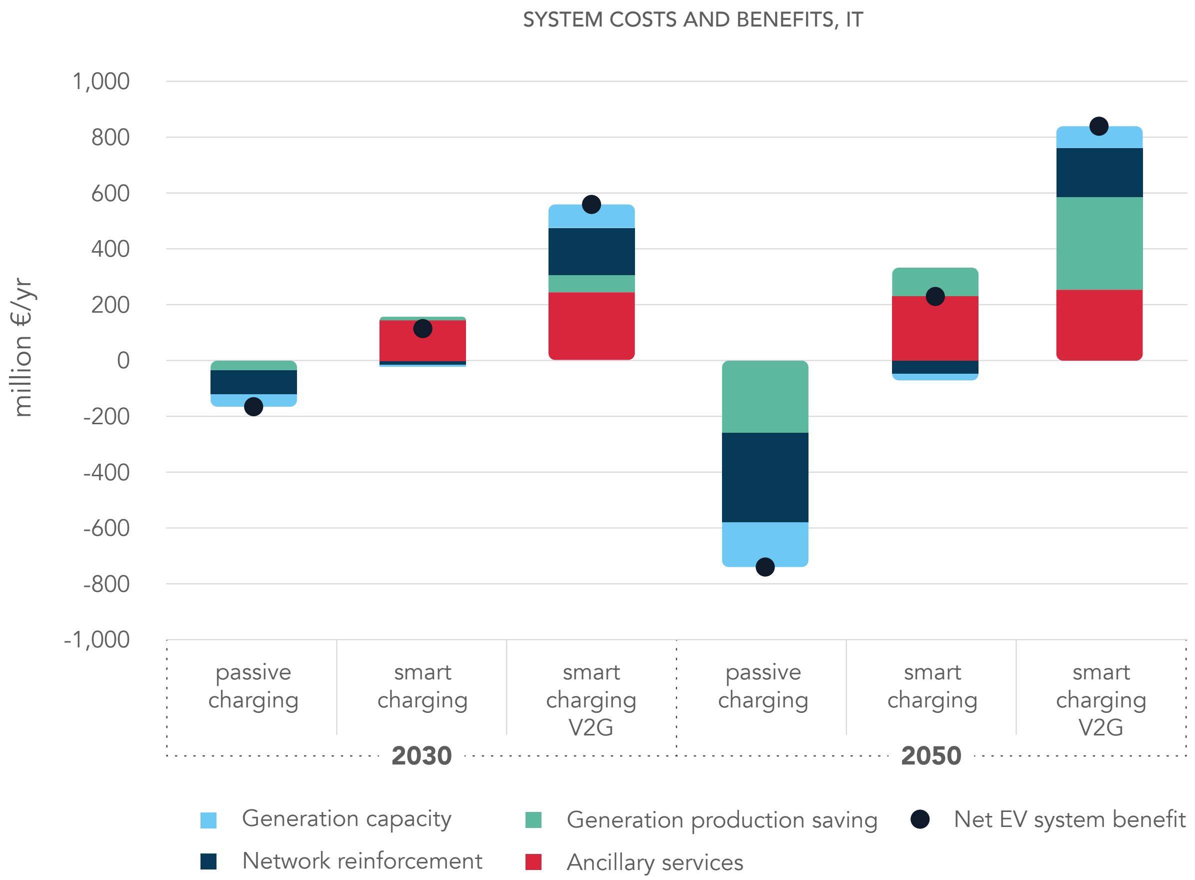


Figure 25. Comparison of electricity-system net cost or benefit for passive versus smart charging, for 2030 (left) and 2050 (right).

In an *active charging system*, using V2G technology, vehicles act as decentralised, grid responsive batteries, where electrons are allowed to flow back into the grid. In principle this can help further reduce RES curtailment, make maximum use of available baseload and reduce the use of high-cost peaking plants. With V2G deployment, the EV fleet could provide a benefit to the electricity system of €840 million per year in 2050. However V2G operation does increase the flow of energy through the vehicles (relative to their use solely as a transport asset), and this could adversely impact on the life of the battery. It also requires more investment in charging infrastructure, relative to smart charging.

It should be pointed out that the calculations above are done based upon an evolution of the Italian electricity production mix to 2050 taken from the European Commission's 2016 PRIMES reference scenario. This presents a conservative view of the potential future development, with modest growth in renewables. If renewables play a larger role in the future electricity mix then the potential benefits from smart and V2G charging could be considerably larger.

The analysis also explored synergies between Fuel Cell EVs and the electricity grid. Such synergies could be realised if hydrogen is generated by electrolysis. Electrolysers supplying hydrogen to FCEVs could provide a significant amount of balancing services in Italy as they can adjust their electricity consumption according to the needs of the grid. This in turn would improve the economics for FCEV owners, if a proportion of the revenues from these services are passed on to them. The total revenues from providing such services could grow to €140m per year in 2050 given the uptake of FCEVs in the TECH scenario. Similarly to the benefits of EVs, these revenues could be significantly higher with a higher share of renewable electricity generation than in the PRIMES scenario, along with further flexibility benefits that electrolysers could provide.

Notes

1 EU Member States have binding annual greenhouse gas emission targets for 2021-2030 for those sectors of the economy that fall outside the scope of the EU Emissions Trading System (EU ETS). These sectors, including transport, buildings, agriculture, non-ETS industry and waste, account for almost 60% of total domestic EU emissions. For Italy, the binding targets is set at -33% CO_2 emissions by 2030;

2 Fuelling Italy's Future: How the transition to low-carbon mobility strengthens the economy.

3 E3ME is a computer-based econometric model of the world's economy and energy systems and the environment, used in Europe and beyond for policy analysis. For further details, please see *www.camecon.com;*

4 Proposal for a directive of the European Parliament and of the Council amending Directive 2009/33/EU on the promotion of clean and energy-efficient road transport vehicle, COM (2017) 653 final 2017/0291 (COD);

5 National Energy Strategy, 2017

6 Total useful lifetime has been estimated using the average age of cars currently circulating on the Italian road network. This value corresponds to approximately 11 years;

7 Sustainable Development Foundation, 2017 La sfida della qualità dell'aria nelle città italiane;

8 The **Motor Vehicles** sector pertains to all traditional motor vehicles production, covering every component of the vehicle; the **Electrical Equipment** sector covers the manufacture of batteries, electric motors and fibre optics, lighting and electrical appliances; **Other Manufacturing** includes all other manufacturing other than electrical equipment and motor vehicles, such as food, textiles, paper, chemicals, pharmaceuticals, rubber and plastics, basic and fabricated metals and other machinery and equipment; **Manufactured fuels** covers the refinery and production of refined petroleum products; **Electricity & hydrogen** entails the electricity and hydrogen production and distribution sectors; **Services** encompasses a broad range of sectors such as retailing excluding motor vehicles, accommodation, publishing and telecommunications, legal and consulting services, real estate, advertising, residential care, arts and sports;

9 PNIRE - National Plan for Recharging Infrastructure

10 Viesi, D., Crema, L. and Testi, M., 2017, The Italian hydrogen mobility scenario implementing the European directive on alternative fuels infrastructure (DAFI 2014/94/EU), International Journal of Hydrogen Energy, 42(44), pp.27354-27373;

11 D. lgs. 257/2016 (Italian Republic), Implementation of the directive 2014/94/EU on the deployment of alternative fuel infrastructure; 2016;

Contact

European Climate Foundation
Rue de la Science 23, 1040 Brussels
T +32 2 894 9302
M +32 478 34 00 51
www.europeanclimate.org

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