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The decarbonisation of mobility: the pursuit of an integrated model for future road mobility in the Veneto region

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Introduction

Global society is entering a period of transformation in the mobility sector, the result of a bigger process called fourth industrial revolution.

> The original industrial revolution, it was an energy revolution. I like to think of it as a kind of bookending of a period in human history during which we used fossil fuels, and it worked very well for us for a long time, but now we have to bring that to an end. We have energy technologies that can power our civilisations: solar, wind, biomass.[1]

Sustainable mobility and electric-powered vehicles herald the beginning of a low-carbon era with a lower reliance on fossil fuels. The thesis aims to analyse how the mobility sector is undergoing massive changes, becoming increasingly greener, seamless and shared. As a matter of fact, the mobility of the future will be extremely different from what exists today. The shift towards alternative and renewable fuels combined with a disruptive technological development will shape the future of transportation. World leaders and international institutions, driven by climate-related issues, have pledged to boost this transition and to enable new forms of mobility to being respectful towards the environment. Traditional internal combustion engine vehicles (ICEVs) still dominate the market today, but stricter regulations on emissions, the need for fewer passenger cars and the advent of cutting-edge technologies are trying to curb private car ownership and the use of gasoline-powered vehicles.

The final goal of the thesis is to shape a potential integrated model for future road mobility in a particular area of Italy, the Veneto region. The first three chapters will pave the way for the establishment of an integrated perspective. As a matter of fact, data retrieved from multiple online sources, such as institutional websites or certified reports, give important market insights that support the proposed model of chapter 4.

The thesis is divided into four chapters. The **first chapter** describes the electric vehicle (EV) market at a global, European and Italian level. The EV market is experiencing a rapid growth and electric powertrains are expected to replace most of internal combustion engine vehicles at a fast pace. China is today's largest market in terms of EV stock, but even Europe and the Unites States are growing rapidly. At a

[1] Oreskes N., *The Fourth Industrial Revolution: what it means, how to respond*, available from www.weforum.org [Accessed: 17 October 2019]

European level, Nordic countries like Norway and Sweden are at the top of the world's most advanced EV markets in terms of annual sales. Overall, Europe's top 4 EV markets are Norway, Germany, the UK and France, considering total units sold in 2017. The same chapter highlights that hybrid mobility will play a «bridging» role in the transition towards fully electrified vehicles. Moreover, the chapter describes the role of international institutions and the impact of conventional vehicles on the environment. The International Transport Forum (ITF) depicts an alarming scenario that identifies the transport sector as the main responsible for most of CO_2 emissions worldwide. Compared to other transportations, passenger cars have the highest impact. Italy is behind other EU countries in terms of EV market penetration and related infrastructures. For example, Germany had almost 23,000 recharging points at the end of 2018, whereas Italy hardly outnumbered 2,000 points. The chapter outlines solutions to help the Italian EV market to evolve into something more competitive and productive and compares the total cost of ownership (TCO) of a battery electric vehicle (BEV) with that of an ICEV. The final part introduces other electric vehicle categories that could reduce private car use in favour of alternative and more eco-friendly transportations, such as buses, car-sharing services or two-wheeled vehicles (motorbikes, scooters, bicycles).

The **second chapter** defines the electric vehicle ecosystem, an array of players that must work together in order to create value and make the EV a mainstream product. It also deals with the electric vehicle demand, recognising customers' main hurdles to turn electric and proposing solutions to help them to adopt the innovation. Feasible solutions include alternative energy sources, standardisation of the battery pack and sharing models. Alternative fuels like hydrogen could extend the vehicle range and limit the charging time, whereas standard battery pack would cut the price of batteries, thus reducing the purchasing price of the electric vehicle, one of customers' main barriers. The shift towards sharing models can eliminate the costs of ownership and turn to mobility as a service or on-demand mobility, gradually abandoning the product-ownership model.

The **third chapter** focuses on hydrogen as a possible alternative fuel to run next-gen vehicles. The resulting fuel cell electric vehicles (FCEVs) can use hydrogen to generate electricity and pursue zero-emissions mobility. The International Energy Agency (IEA) forecasts that FCEVs in the three main markets (USA, EU4 (France, Italy, Germany and the UK) and Japan) will reach 400,000 units sold by 2025. The share of FCEVs on total car sales will account for 30% of the whole automotive market by 2050. The need for a higher production of hydrogen is leading several companies to invest in renewable energy sources (RES) to generate hydrogen with no carbon footprint, for example harnessing sun power and using electrolysis. With reference to H_2 for road mobility, a marketing campaign, carried out during my internship experience, has been included in the thesis to demonstrate that this technology is efficient and feasible, even though large-scale applications will be more likely in a medium- to long-term perspective. The campaign aims at promoting hydrogen as the only option for local public transports in the Veneto region. It also underlines the importance of creating a carbon-free hydrogen production cycle, thanks to photovoltaic plants and electrolysers.

The **fourth chapter** is the core of the thesis, as it analyses current mobility in the Veneto region and aims to propose an integrated model for future road mobility in the same area, with a major focus on the Province of Padua and the Metropolitan City of Venice. An integrated perspective means that cities will navigate different models of mobility in the future, combining shared mobility, autonomous driving and alternative fuel vehicles with public transport services, two-wheeled electric vehicles and walking and cycling. The advent of electrification, the increasing urbanisation rate and high-tech innovations will reshape today's mobility, reducing private car ownership, tackling carbon footprint and combining a variety of movement possibilities, thus creating integrated models. These models also try to limit fragmented trips thanks to a higher connectivity. The integrated model is based on three main goals to be pursued in the reference area:

- Reduce private cars,
- Boost alternative fuel vehicles,
- Foster mobility as a service and overcome fragmented trips.

The study then shows solutions to fulfil the above goals and introduces time intervals that foresee the time when a particular trend or innovation will occur. At the end of the same chapter, the thesis depicts the benefits and costs to citizens deriving from this new model. As individual travellers will be the drivers of this transition, they can obtain several benefits by adopting integrated perspectives, though they know this model can entail some costs either.

CHAPTER 1 – Analysis of the electric vehicle market

1.1 The electric vehicle market worldwide

The electric vehicle market has developed very fast in recent years and is experiencing a rapid growth worldwide. With electric vehicles (EVs) the analysis generally refers to the car industry, whereas other EV categories will be introduced at the end of the chapter. To begin with, policy makers and the automotive industry have to work together and find valuable solutions to foster the deployment of electric vehicles (EVs). In 2009, a multi-governmental group founded the Electric Vehicle Initiative (EVI), a policy to boost and accelerate the development of EVs worldwide. Current members of the EVI are: China, Finland, France, Germany, India, Japan, Mexico, the Netherlands, Norway, Sweden, the United Kingdom and the United States. The countries listed above are the largest and most rapidly developing EV markets on a global scale and thanks to accurate policies are supporting EVs adoption. Due to the alarming effects of internal combustion engine (ICE) cars on the environment, some EVI countries are also planning to ban the sale of ICE cars by 2025 (Norway) or by 2040 (the United Kingdom). Others instead are working to introduce circulation restrictions to certain areas for the same ICE cars. Overall, the majority of governments are adopting measures to reduce greenhouse gas (GHG) emissions and radically change the transport sector. As a consequence, the largest automakers are scaling back the production of ICEVs and increasing electrified powertrains. Before showing the current value of the EV market and forecasting its future performances, it is useful to introduce what kind of electric vehicles the analysis is going to consider. Electric vehicles can be fully or partly powered by electricity and can include (MIT, 2008:1-4):

- **BEVs**: battery electric vehicles (entirely powered on electric energy)
- **HEVs**: hybrid electric vehicles (they rely on two energy sources: electric energy and internal combustion)
- **PHEVs**: plug-in hybrid electric vehicles (they work the same way of HEVs, but unlike HEVs their battery can be recharged by plugging-in from wall electricity.)

- **ZEVs**: zero-emissions vehicles
- **FCEVs**: Fuel cell electric vehicles are electric vehicles that use internally stored hydrogen and a fuel cell stack to produce the electricity required for traction. This can be considered the most innovative model applied to mobility and it will be examined in the third chapter.

According to the Global EV Outlook 2018 carried out by the International Energy Agency (IEA), electric cars achieved more than 1 million units sold in 2017 (+54% compared to 2016). Globally, from January to December 2017, EV sales (BEVs and PHEVs) achieved almost 1.2 million units, with a peak in December 2017 when sales outnumbered 170,000 units. In terms of sales share, Nordic countries place themselves at the top of the world's most advanced markets of electric vehicles, with Norway that holds the leadership followed by Iceland and Sweden. In Norway, 39% of the whole car sales are electric while Sweden is far behind with only 6%. China is however the world leader in terms of global sales, with around 580,000 units sold in 2017, registering a +72% compared to the previous year. Europe ranked second with almost 290,000 vehicles sold, overcoming the USA that performed 200,000 EVs sold in the same period (E-Mobility Report 2018, 2018:7). The global electric car stock has also been growing significantly since 2013. With less than half a million units in 2013, the stock has rapidly increased surpassing 3 million units in 2017. China has the largest stock, 40% of the whole, while Europe and the United States have similar numbers. Around two-thirds of electric cars sold in 2017 were BEVs, with a higher uptake in China, France and the Netherlands, whereas PHEVs outnumbered BEVs in Japan, Sweden and the UK (Global EV Outlook 2018, 2018:9).

1.1.1 Future scenarios

Bloomberg New Energy Finance provides data on possible future scenarios of the EV market. Forecasts show that EVs production in 2030 will be cheaper than ICE cars, and global sales of EVs will achieve almost 560 million units by 2040 (Bloomberg, Electric Vehicle Outlook, 2018:3). China will be the leading promoter of this transition, whereas Europe will rank second, followed by the US. The largest deployment of EVs will be enabled by the reducing costs of the lithium-ion battery pack. As a result, EVs will probably become competitive when the price of lithium-ion battery will fall consistently; today it costs $200/kWh approximately, but it is expected to fall to $70/kWh in 2030 (Electric Vehicle Outlook, 2018:3).

J.P. Morgan's report *Driving Into 2025: The Future Of Electric Vehicles* carried out in 2018 analyses how the car market will look like by 2025. The American giant estimates that 30% of all vehicle sales will be EVs and HEVs by 2025, with plug-in electric vehicle (PEV) registrations increasing close to 8.4 million vehicles, whereas the hybrid electric vehicle (HEV) sector will swell to more than 25 million units sold in the same period. With reference to the plug-in sector, BEVs will register a massive increase compared to PHEVs. Moreover, pure ICE cars will fall to 70% of total market share in 2025 and to 40% in 2030, registering a dramatic 30% downfall between 2025 and 2030. China is far ahead other nations and is expected to account for 59% of global EV sales by 2020. One of the main drivers of China's fast deployment of EVs is the rapidly falling cost of the batteries.

1.1.2 The battery sector

With reference to the battery sector, the analysis gives a brief overview of the main concerns and opportunities regarding the EV batteries and the main manufacturers worldwide. Current manufacturing capacity of lithium-ion batteries will rise dramatically, as well as the demand for the components of the same battery. The leading market is China that will account for 73% of the global production capacity by 2021, according to Bloomberg. Asian manufacturers currently lead the battery sector, with Panasonic owning 40% of global lithium-ion battery market share. In order to cut the EV purchase costs and make them more affordable, battery pack prices should drop to at least $100/kWh. According to the Global EV Outlook 2018, technological innovation will enable batteries to be cheaper for automakers, but cost reductions will be seen only by 2030, mainly due to 3 main factors:

FACTORS THAT ARE LIKELY TO REDUCE BATTERY COSTS BY 2030
Battery production volumes will increase thanks to economies of scale
Battery chemistries will evolve providing a higher energy density and relying less on cobalt
Larger Battery sizes tend to have lower specific costs

Table 1: Factors that are likely to reduce battery costs by 2030 (source: OECD/IEA: *Global EV Outlook 2018*)

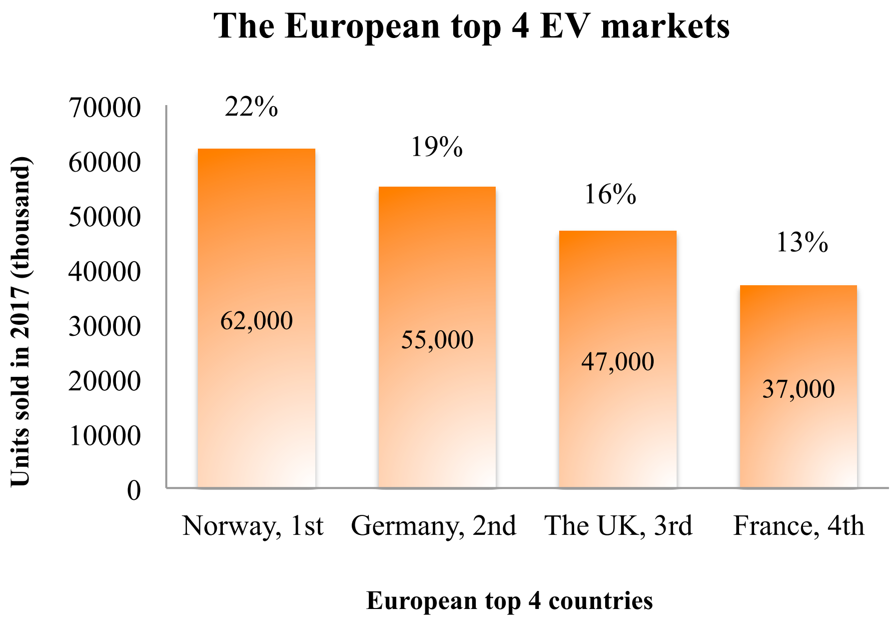
The rising demand for batteries is also expanding new markets. For example, the demand for lithium is globally increasing and is expected to exceed 20% by 2025. The same is true for nickel that is an important component of the battery, as it determines the energy density (the amount of energy stored in a battery pack). Nickel will be predominant in the battery sector, making it the second-largest market in terms of nickel consumption. However, it is not nickel the most expensive material but cobalt. Cobalt costs three times as much as nickel. Consequently, battery manufacturers need to find alternative solutions to cobalt in order to achieve cost reductions in the battery pack production.

1.2 The electric vehicle market in Europe

With reference to Europe, in 2018 EV sales registered an increase of 33% compared to 2017, with more than 400,000 units sold, making Europe the second largest EV market after China. This data both include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).[2] Moreover, due to stricter regulations on ICE emissions, the European demand and supply is shifting towards BEVs only, gradually abandoning PHEVs, which however have been crucial for the transition towards fully electrified powertrains. In 2016, plug-in vehicle sales were 50% BEVs and 50% PHEV approximately. The trend has now changed: at the end of 2018, BEV sales accounted for 56% of the whole plug-in sector. The four leading countries in the EV market in Europe account for 70% of the whole EV sales. Italy still plays a marginal role in the

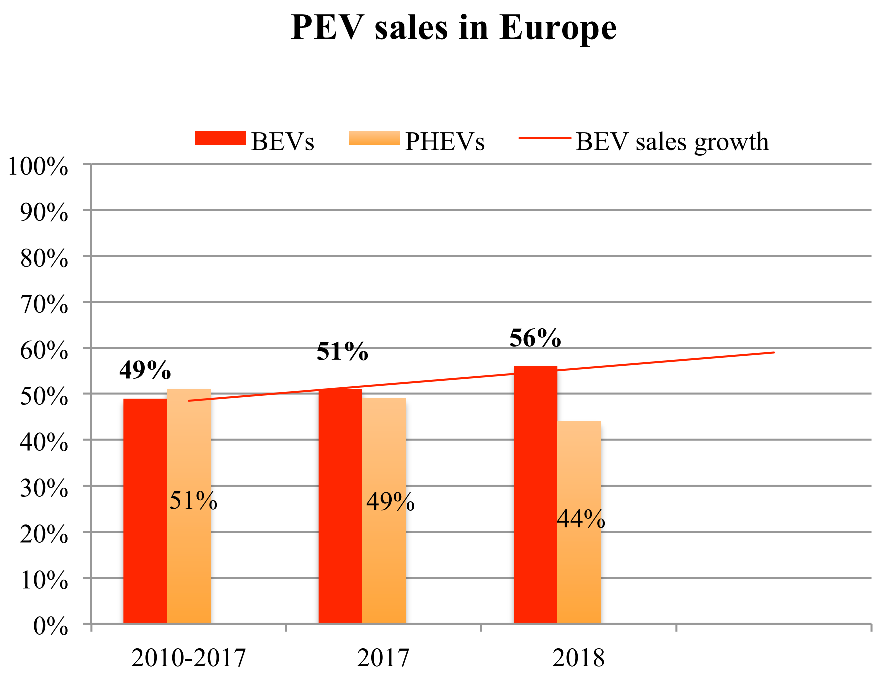
[2] Irle, R., *Europe EV Sales for 2018*, available from: www.ev-volumes.com [Accessed: 2 April 2019]

European ranking, accounting only for 2%. The chart below (graph 1) displays the European top 4 EV markets in terms of units sold at the end of the 2017.



Graph 1: Units sold in 2017 in the European top 4 EV markets (source: E-Mobility Report 2018)

According to the European Alternative Fuels Observatory (EAFO), there were 882,000 EVs registered in Europe between 2010 and 2017. Numbers show good sale performances of PHEVs compared to BEVs, since 446,000 of the total amount were PHEVs, while 436,000 were BEVs (Tsakalidis, Thiel, 2018:8). This trend might be explained by two main reasons: first, there is a lack of sufficient battery recharging infrastructures in most European countries and second, fully electrified vehicles are still too expensive in today's EV market.



Graph 2: PEV sales in Europe 2010-2018 (source: EAFO)

Graph 2 shows that in 8 years' time (2010-2017), the market reached almost a 50:50 situation of BEVs and PHEVs sold in Europe. However, this trend has changed in recent years, registering a gradual increase in sales of BEVs between 2017 and 2018.[3] According to multiple sources, this gap between the two vehicle categories will widen even more in favour of BEVs, revealing a future with less PHEVs and a higher amount of fully electrified powertrains. As a consequence, automakers are designing and producing fully electrified vehicles to meet the new market demand that will gradually abandon gasoline-powered cars.

A study conducted by the EAFO reveals that PHEVs will be the initial pathway to follow in order to lead mobility towards zero-emissions vehicles (ZEVs). The future scenario, forecasted by the same European agency, is called *PHEVs Bridging* and implies that PHEVs will contribute to the decarbonisation of the mobility by 2035. After 2030, PHEVs will be largely substituted by ZEV sales, in particular BEVs. Calculations and forecasts have been made by assuming that technological innovations will considerably cut costs.

[3] Irle, R., *Europe EV Sales for 2018*, available from: www.ev-volumes.com [Accessed: 2 April 2019].

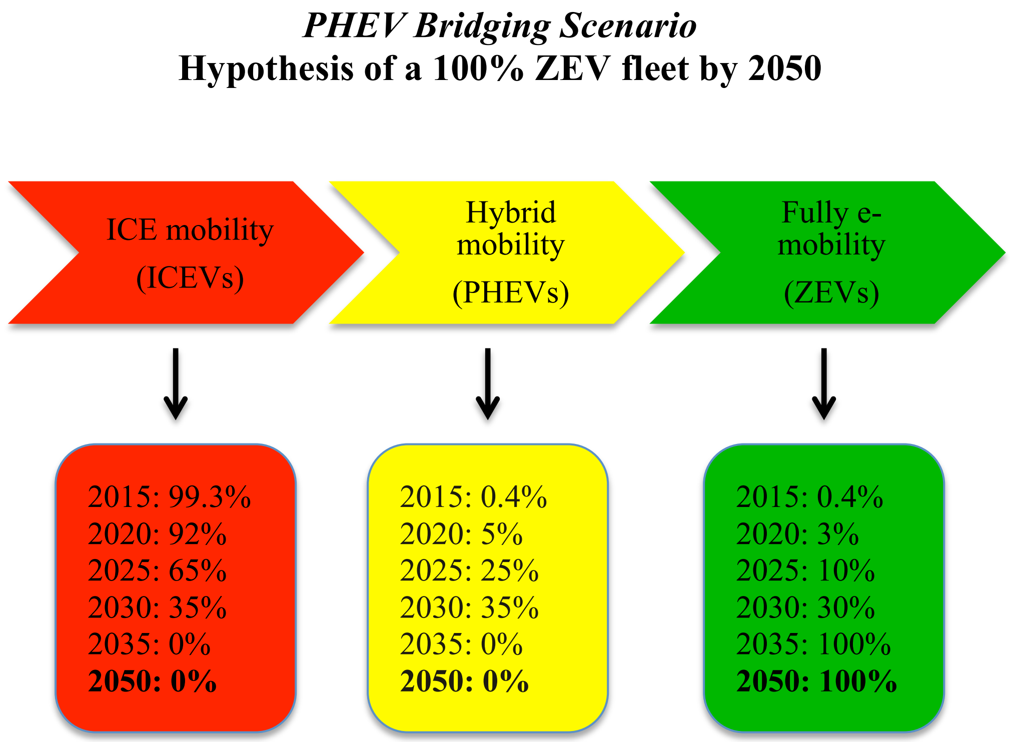


Figure 1: Hypothesis of a 100% ZEV fleet by 2050 (Source: EAFO)

Figure 1 shows that hybrid vehicles (PHEVs or HEVs) will be a temporary compromise for the transition towards a fully electrified mobility and zero-emissions vehicles (ZEVs). European Union's goals to achieve 100% ZEVs by 2050 is unlikely to happen, but the early adoption and sale of hybrid car fleet will contribute to increasing acceptance among consumers and boosting countries and institutions to invest in infrastructures and recharging stations. Additionally, the scenario assumes that ICEVs will abandon European roads after 2035, predicting a utopian world with no fossil-fuel cars in only 20 years. This result could be achieved in some countries like Norway, but this is generally harder to obtain in a vast majority of European countries, including Italy.

Apart from passenger car category, the electric light commercial vehicles (eLCVs) have also shown an increasing presence in the e-mobility market. These vehicles are mainly used for small distances trips and play a key role in commercial fleets and logistics. Considering their daily usage and fossil fuel consumption, they register massive GHG emissions and high expenditure on fuels. Therefore, owning an eLCVs for short-range commercial trips is sustainable, affordable and brings benefits: drivers do not need to recharge the battery so often during a day, electricity cuts the high costs of fossil fuels and the impact on the environment is lower. France is the European leading country in term of eLCVs registrations (almost 30,000) between 2010 and 2017, scoring four times as much as Germany that ranks second, whereas Italy places itself at the sixth place, with less than 3,000 registrations throughout the same period.

Overall, the report published by the European Union highlights that in the passenger car category PHEVs outnumbered BEVs in the larger car size segments, while BEVs have better performances in the small car size segments. Nowadays, carmakers still rely on ICEV market but future more severe limitations on ICEV circulation will lead automotive companies to the electrification of most road vehicles. Investments in technology, lower costs of batteries, policies, infrastructures and care for the environment will be the main factors of a more sustainable future and an epochal change in the mobility market.

1.2.1 The recharging infrastructures

The availability of EV recharging infrastructures is also a crucial requirement for a faster development of the e-mobility market. Across Europe, the leading country in terms of number of recharging stations are the Netherlands, with more than 30,000 units, while Italy places itself only at the tenth place (Tsakalidis, Thiel, 2018:14). At a European level, there are no clear targets for countries related to PEVs charging stations. Therefore, all decisions are mostly taken at a regional level. As a result, the lack of a EU's coordination is slowing down the rapid uptake of electric vehicles, though chargers have increased in recent years, with most of them being normal-power charging. Before introducing some of the benefits related to electric charging infrastructures, there is a distinction between a charging station and a charging point. A charging station can be equipped with more than a cord for plugging-in. Each cord or connector is commonly called charging point. So, a station with a single connector is a charging point as well, whereas a station with two or more connectors has two or more charging points. Unlike ICEV drivers, who need to go to a petrol station to refuel the car, EV drivers can benefit from different types of charging stations in different locations: normal-power charging (<22kW), high-power charging (>22kW), residential charging, public and urban charging and commercial charging. Home chargers are typically the least performing charging stations in terms of power output, resulting in smaller acquisition costs but several hours to fully recharge (Spöttle et al., 2018).

1.3 The role of international institutions

International institutions are promoting initiatives that aim at achieving a future with lower GHG emissions and therefore a cleaner and healthier world to live in. The United Nations (UN) has established the sustainable development goals (SDGs) that are meant to achieve a more sustainable future for all nations. The 17 goals are part of the *2030 Agenda for Sustainable Development*, adopted in 2015.[4] Some of the SDGs are strictly related to the transport sector and, in this scenario, the EV larger adoption will surely contribute to achieving some of the sustainable development goals. The analysis now focuses on how the EV market can meet UN's targets and what kind of benefits can the same market bring to the following SDGs:

Image 1: Sustainable development goals (No 11, 12, 13) of the 2030 UN Agenda (source: the UN)

The automotive sector has a huge impact on these three goals. The majority of world's metropolis are congested and polluted by road traffic and GHG emissions that make them unhealthy and noisy places to live in. Shifting towards the e-mobility can help improving the life of people, but still it will not solve the problem completely. Not only should people replace ICEVs with EVs, but they should also change their

[4] *The Sustainable Development Agenda*, available from: www.un.org. [Accessed: 2 April 2019]

mentality, relying more on public transports and bicycles in order to make cities safer and more sustainable. With reference to the electrification of public buses, China is investing a lot of financial resources in the implementation of the public transport services. Electric buses in China are having a rapid market penetration. In terms of stock, e-buses achieved nearly 370,000 units by the end of 2017 globally (Global EV Outlook 2018, 2018:10). Moreover, e-buses are thought and designed to run a full day without recharging the battery and this is a great advantage. The hardest challenge is to create an efficient system for the e-bus circulation. Buses should have their own lanes otherwise they would get stuck in traffic and would give people no clear benefits in terms of time saving and reliability. In this context, Italy is far behind other nations.

The deployment of EVs can also have positive effects on people's daily habits: driving electric can lead people to a more responsible consumption that can reduce waste. For example, a person with an electric car will be keener to install solar panels in their house and rely on renewable sources, since they can recharge the car battery by using the energy stored by the panels. In the production context, technological innovation plays a crucial role. The use of the latest technologies applied to EVs production can lead to a lower reliance on fossil fuels and reduce air pollution. According to the World Health Organisation (WHO), "the transport sector is the fastest growing contributor to climate emissions".[5] The most harmful pollutants are long-lived CO_2 emissions and short-lived black carbon generated by diesel cars. After carbon dioxide, black carbon is the second highest contributor to global warming and it is also associated with several diseases related to air pollution. The relation between the EV market and the climate change will be further analysed in this chapter, as it is one the main drivers of the transition towards the e-mobility.

The European Union has also set new rules to limit CO_2 emissions. From next year onwards, European targets aims to average GHG emissions for cars to 95g per kilometre. In 2018, it averaged close to 120.5g per kilometre. These new tougher regulations impelled carmaker giant Fiat Chrysler Automobiles (FCA) to sign a multi-million deal with the American-based Tesla in order to avoid EU severe emissions fines. As first reported by the *Financial Times*,

[5] *Health and sustainable development*, available from: www.who.int [Accessed: 4 April 2019]

> Fiat Chrysler Automobiles has agreed to pay Tesla hundreds of millions of euros so the electric carmaker's vehicles are counted in its fleet in order to avoid large fines for breaking tough new EU emissions rules.[6]

This financial deal is due to FCA's current underdevelopment in terms of hybrid or electric vehicles available in the market, making the EU targets unachievable without the agreement with external manufacturers like Tesla. Similar commercial agreements are allowed by European rules (it is allowed to form the so-called open pools), however this is the first time that two competitors agreed to do so. Additionally, FCA is going to scale back the production of its most polluting ICE vehicles, even though it will continue to sell diesel-powered cars with lower level of CO_2 emissions, according to FCA's chief executive Mike Manley. European permission to sign "emissions pools" has enabled Tesla to earn one billion dollars in the last three years by selling emissions credits to other manufacturers in the United States.[7] These monetary operations are helping Tesla to finance its electric fleet and all other projects that Elon Musk's company has launched recently.

International goals need the collaboration of local governments in order to be fulfilled. For example, a lot of European countries are trying to ease consumers' buying process by giving them some incentives for purchasing their new electric cars. In some countries, electric cars are exempt from ownership tax or road tax. In Italy, e-vehicles do not have to pay the annual circulation tax for the first five years. The same incentive is applied in Germany with a larger period of exemption (ten years). Norway, with its campaign *Polluter Pays*, is discouraging consumers to buy ICE traditional vehicles, applying higher circulation taxes for traditional cars with a high rate of GHG emissions. All these fiscal incentives and disincentives are trying to soften the initial high cost of the electric car that often stops consumers to buy it (E-Mobility Report 2018, 2018:12-13). Today's cars are too expensive for a mass-market penetration. Evidence from the same report reveals that there is almost a €10,000 differential between a gasoline car and its electric equivalent. In this context, countries and automakers should insist on the fact that owning an EV is a long-term investment that will considerably cut consumers' annual expenditure.

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[6] McGee, P., Campbell, P., (April 2019), *Fiat Chrysler pools fleet with Tesla to avoid EU emissions fines*, Financial Times, available from: www.ft.com [Accessed: 10 April 2019]

[7] BBC (April 2019), *Fiat to pool with Tesla to avoid EU fines*, available from: www.bbc.com [Accessed: 10 April 2019]

1.4 Impact on the environment and health

One of the most challenging issues facing the planet today is the pollution generated by the transport sector. It must be said that electric vehicles are expected to replace internal combustion engine (ICE) cars in the coming decades, because of the high polluting impact of ICE cars on the environment. Governments and institutions commitment to adopt effective policies is therefore a key factor to push consumers to buy an electric car, to give automakers some incentives and to scale up the EV production. Below is the Article 2, clause (c) of the *Paris Agreement*, signed and published by the United Nations in 2015:

> This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development (Paris Agreement, 2015).

This is the first ever global climate deal that aims to limit global warming below 2°C, trying to average it close to 1.5°C. “Human activities are responsible to have caused approximately 1°C of global warming above pre-industrial levels” (IPCC, 2018:6). The gap between 1.5°C and 2°C of global warming seems irrelevant, but it’s actually really significant because it can bring to species extinction and a considerable increase in the sea level. The Intergovernmental Panel on Climate Change (IPCC) published a report on global warming and climate-related risks. It highlighted that, reaching 1.5°C of global warming “in the context of sustainable development, implies system transitions that can be enabled by an increase of adaptation and mitigation investments, policy instruments, the acceleration of technological innovation and behaviour changes” (IPCC, 2018:23). One of the main barriers to a radical sustainable change is human beings’ bad attitude and scarce commitment towards climate-related issues. A broader public acceptability is one of the pathways to pursue in order to achieve a faster development of the e-mobility and therefore a lower impact on the environment.

According to the International Transport Forum (ITF), today’s action to limit CO_2 emissions is not enough to fulfil the requirements of the *Paris Agreement*. **The transport sector is responsible for most of CO_2 emissions (23%)** and today still depends on oil-based fuels for 92% of its energy demand. The same Forum highlights that, in a future scenario, carbon dioxide (CO_2) emissions will increase by 60% by 2050.[8] Although the decarbonisation of transports will be deployed, it will not be sufficient, because transportation volume will double or even triple within the same period. Therefore, it will be very important to stimulate people to change their daily habits and change their sensibility towards road mobility. Hence, countries and policy makers will have to optimize public transport services, foster train or bus mobility and promote sustainable attitudes, such as cycling and walking. This means that the mobility needs not only a decarbonisation, but also a new system based on newer infrastructures, for example safe and efficient cycle lanes, and incentives to push people to benefit from public transport mobility. The US Environmental Protection Agency (EPA) revealed that in the US the transportation sector accounted for the largest amount of GHG emissions, scoring 28% in 2016. This sector scored the same as the industry sector, while electricity sector ranked third with 22% of the total emissions.

At a European level, the 7th Environment Action Programme (EAP) identified various objectives to be pursued by 2020:

- "Turn the Union into a resource efficient, green and competitive low-carbon economy",
- "Safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing".[9]

Both objectives are strictly related to the electrification of the mobility. The same European Union highlights that the transport sector contributed 27% of total EU-28 greenhouse gas emission in 2016, with a 3% increase compared to the previous year. The European Environment Agency (EEA) estimated that in 2017 emissions would grow even more significantly, increasing by 1.5%. Moreover, road transport accounted for 72.1% of the whole transport sector, which includes: road transport, maritime, aviation, railways and other transportation. Passenger cars have the highest impact on

[8] *Decarbonising Transport Initiative*, available from: www.itf-oecd.org [Accessed: 5 April 2019]
[9] *Environment Action Programme to 2020*, available from: ec.europa.eu [Accessed: 5 April 2019]

the environment in terms of GHG emission, compared to other road transportations, with 43.7% of the total emissions.

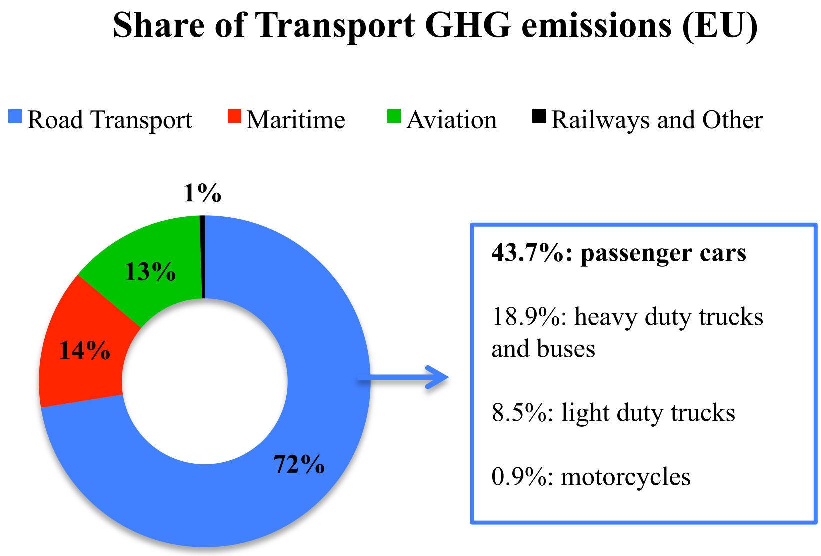


Chart 1: Share of Transport GHG emissions (EU) (Source: EEA)

The IPCC fifth Assessment Report identifies the main options to achieve transport mitigation and reductions of CO_2 in the transport sector:[10]

I. Reduce overall transport demand growth (shift to more efficient models);
II. Reduce the amount of energy needed for propelling a vehicle (increase fuel efficiency);
III. Reduce the carbon intensity of transport fuels (fuel shift).

Globally, option 2 and 3 are the most likely scenarios. First, the report highlights that road transport could contribute to climate change mitigation by shifting to electric vehicles, gradually abandoning internal combustion engine vehicles. "Battery-electric

[10] Creutzig F., Jochem P., Edelenbosch O.Y., Mattauch L., van Vuuren D.P., McCollum D., Minx J. (2015), *Transport: A roadblock to climate change mitigation? – Urban mobility solutions foster climate mitigation*, AAAS, available from: www.sciencemag.org.

mobility, for instance, might take off faster than expected owing to substantial declines in battery prices, which would make battery-electric travel less expensive than conventional fossil fuel–based mobility" (Creutzig et al., 2015:912). Second, infrastructure development, policies and behavioural interventions can also lead to a more sustainable future, fewer harmful emissions and a low-carbon transport era. Moreover, investments in infrastructures can result in positive financial outcomes, because they would produce cost savings for low-carbon transport at around 20 trillion dollars by 2050 globally. For example, investments in bicycle lanes and pedestrian zones are affordable and would positively contribute to mitigation policies, as car usage would partly decrease. However, option 1 includes more investments in public transportation and infrastructures in order to lower the stock of cars worldwide, as well as their distance travelled. Option 1 would also contribute to implementing target 11 (sustainable cities and communities) of the SDGs promoted by the UN Agenda, because it would lead to a faster urban development, including bus lanes to enhance rapid transit, bicycle highways and overall a more efficient public transportation system. Other urban policies can also produce social benefits by reducing road noise, air pollution, traffic congestion, and smog-related diseases.

As clearly stated in this paragraph, CO_2 emissions have a tremendous impact on climate change and all other climate-related issues. However, traditional ICEVs emit other harmful and polluting substances that directly affect the health human beings. For example, petrol-based cars release a huge amount of carbon monoxide (CO), a substance that enters the air and remains in the atmosphere for months. The inhalation of high levels of this gas can cause lung or heart diseases. Diesel cars have low CO emissions, whereas electric vehicles have no CO emissions. On the contrary, diesel cars release high quantity of nitrogen oxides (NO_x). Nitrogen oxides are a mixture of nitrogen oxide (NO) and nitrogen dioxide (NO_2). These substances can damage respiratory functions and harm people's lung. EVs do not have NO_x emissions.

List of the most challenging issues of today's EV market:

- REDUCE CO_2 EMISSIONS AND REPLACE ICE CARS: CO_2 reductions ential a cleaner deal both with the environment and people's health. The planet needs to tackle global warming and smog-related diseases that commonly affect people. Among all transport categories, road transport contributes to the most GHG emissions and therefore this phenomenon must be reduced in the the coming decades. It is not only the EV mobility, but also investments in public transports and infrastructures that can cut CO_2 emissions. Automakers are launching EV models, gradually scaling down ICE car production. This trend will continue to increase because of the many disadvantages of ICE cars, mostly dealing with the safeguard of the ecosystem.

- IMPLEMENT RECHARGING STATION SYSTEMS AND CUT BATTERY PACK COSTS: an efficient network of recharging stations is a key factor to foster a rapid deployment of EVs. The future increase in the stock of electric cars will require a wider system of public recharging stations. The EV market will also benefit from battery pack decreasing costs. Due to the high prices of its raw materials, a battery pack is still very expensive today and is the main factor of the e-vehicle high prices. However, forecasts say that costs will radically fall in the coming decades, boosting the EVs adoption. Today the average cost is $200/kWh approximately, but it is expected to fall to $70/kWh by 2030. Technological innovation will play a leading role in attaining both huge cost reductions and the transition towards a fully electrified mobility.

- PROMOTE E-PUBLIC TRANSPORT AND INVEST IN INFRASTRUCTURES: the optimisation of public transport services and infrastructures can foster train or bus mobility and promote sustainable attitudes, such as cycling and walking. The electrification of buses is a good way to meet international targets on sustainable cities and climate change, as evidence from China confirmed. Furthermore, investments in bus and bicycle lanes can lead people to avoid travelling by car and join a more sustainable mobility.

- CHANGE PEOPLE'S BEHAVIOUR AND HABITS: the biggest revolution starts from people. A larger public acceptability can drive the EV market to a faster development in all countries. Data confirm that the uptake of the electric vehicles is more frequent in those countries where governmental policies give people incentives and benefits to own an EV. Nordic countries rank first in this context. Hence, the biggest challenge is to understand how to address people and how to convince them to change their daily habits in order to shift to a more sustainable mobility.

- MEET INTERNATIONAL INSTITUTIONS GOALS: the United Nations' SDGs have set common targets in order to make our planet a more sustainable place to live in. European countries are trying to limit ICEVs circulations with traffic restrictions, higher taxes or granting tax exemption for the EV ownership. International institutions and local governments should inform people that owning an electric vehicle is a long-term investment that will cut future expenditure and tackle the most threatening challenges of our planet.

1.5 The electric vehicle market in Italy

EV sales in Italy crossed the threshold of 4,800 units in 2017, widening the total stock of EVs to almost 13,000 units, with 7,500 of them being BEVs. In the first semester of 2018, Italy performed very well in terms of new EV registrations: BEVs and PHEVs scored + 90% compared to 2017, with BEVs increasing by 124% compared to the previous year (E-Mobility Report 2018, 2018:41-43). Diesel and gasoline car registrations decreased, but they still lead the automotive industry in terms of total sales. The American information and technology company, Bloomberg, said Italy is "Europe's most sluggish market for electric cars"[11], dooming the nation to an uncertain future in terms of electric transition. However, the same source revealed that the Italian government is planning to invest around 10 billion dollars in incentives to reach 1 million EVs by 2022. Considering today's EV market penetration in Italy, the plan is far too promising. With reference to the B2B market, firms are increasing their investments in electric corporate fleets, as evidence from Enel X confirms. The Italian energy company giant, with its programme *Fleet Electrification Management* has been offering

[11] Ebhardt T., Albanese C. (2018), *Italy wants to put a million electric cars on the road. Price: $10 billion,* available from: www.bloomberg.com [Accessed: 6 April 2019]

a dedicated opportunity to companies that would like to turn their fleet into electric. Moreover, Enel signed an agreement with PwC Advisory to test the possibility of turning most commercial fleets into electric. The plan entails pilot programmes that aims to evaluate the service and see how far it can go. The partnership combines the competences and visions of both players in order to convince firms that shifting towards electric vehicles can bring several advantages: e-fleets cut harmful emissions and have therefore a positive impact on the social responsibility and sustainability of a company. They also reduce the refuelling costs. A survey carried out by the same PwC shows that electric commercial fleets will increase to half a million by 2025, compared to today's 15 thousand units.[12] This is a good step to evolve the e-mobility in Italy and influence private consumers to invest in electrified vehicles instead of the traditional ICE cars.

New EV registrations also result in lower GHG emissions. According to the E-Mobility Report 2018, each BEV can cut 1.3 tons of CO_2 emission per year, 2.7 times more than a traditional vehicle. However, today's number of EVs in Italy is still insufficient to pursue the international targets and limit the negative impact of ICE cars on the environment. The same report carried out a national survey on the current situation of the e-mobility in Italy assessing the status of electric vehicles and related infrastructures based on three parameters:

- Technology level
- Market penetration
- Regulations and policies

The **technology level parameter** is considered the least critical one by the Italian public opinion. Consumers believe that Italy has to face two big challenges in order to turn the transport sector into a fully electrified market in the next decades:

- First, the battery pack capacity requires improvements, as the e-cars need to widen their range. Not only the capacity but also the battery prices must fall significantly.

[12] *Enel X e PwC promuovono la mobilità elettrica aziendale*, available from: corporate.enel.it [Accessed: 27 May 2019]

- Second, the recharging infrastructures must ensure a faster charge, be more accessible and evolve into newer technological solutions, like induction recharging systems.

The **EV market penetration** shows that Italy has a good e-vehicle supply, in terms of EV models available in the market, but the demand does not involve many users, making the EV market a niche market. Moreover, the low diffusion of public high-power charging stations slows down a larger deployment of e-vehicles in Italy. With reference to the **regulations and policies**, Italian people consider it the most critical parameter. There is a lack of a government's centralised policy and incentives are mostly given at a regional level. Local policies are banning the circulation of the most polluting ICE vehicles, raising a strong criticism among the public opinion. Italy seems to be several steps backwards, if compared with the top 4 European EV markets in terms of national policies and interventions. On the contrary, other European countries like France and Norway are adopting policies to ban the sale of diesel vehicles within the next decades, making these nations the main drivers towards a radical revolution of the transport sector.

Other measurements made by the same survey analysed the current situation and future trends of the four road electric transport categories, which include: passenger cars, buses, motorcycles and light commercial vehicles (LCVs). Based on the same three parameters, Table 2 forecasts the possible evolution of the EV market in Italy in the coming years, using a scale from 0 to 4. The *Now* section rates the e-mobility status in Italy at the end of 2017, whereas the *Trend* section estimates the likely future situation of the EV market in Italy over the next five years (E-Mobility Report 2018, 2018:83). The scoring scale (0-4) includes:

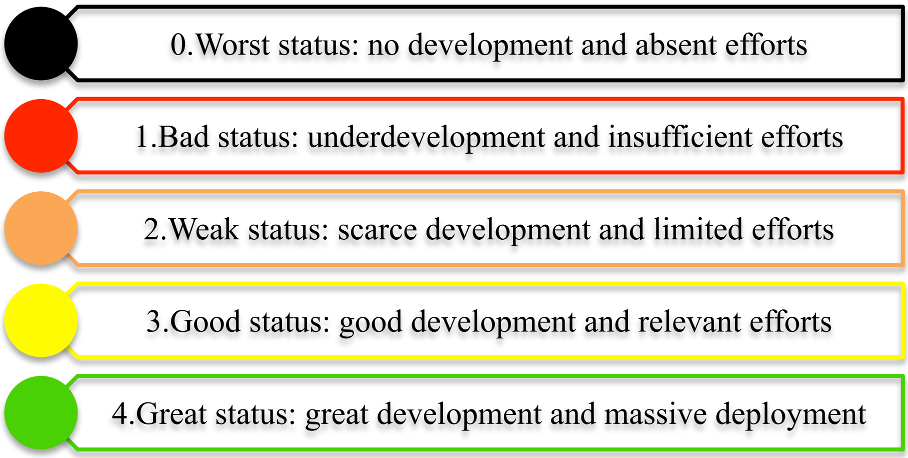


Figure 2: The scoring scale for road EVs in Italy (Source: E-Mobility Report 2018)

EV type	**Technology level**		**Market penetration**		**Regulations and policies**		**TOT**	
	Now	Trend	Now	Trend	Now	Trend	Now	Trend
Car	2.5	**3**	1	**4**	1	2.5	4.5/12	**9,5**/12
Motorcycle	2.5	**3**	1.5	3	0	2	4/12	8/12
Bus	2	**3**	0.5	1.5	1	2	3.5/12	6.5/12
LCV	1.5	**3**	1	2	0.5	2.5	3/12	7.5/12

Table 2: Overall scoring of road EVs in Italy (source: E-Mobility Report 2018)

Comments and considerations (analysis of Table 2 outcomes):

- The **technology level** has the highest increasing rate, with future trends scoring 3 for all road transport categories. It means that the price of lithium-ion battery pack is expected to fall and the network of recharging infrastructures will constantly increase. However, forecasts show that the EV market in Italy will not experience huge technological innovations over the next five years, meaning that Italy still has a relevant growth potential.

- With reference to the **market penetration**, future trends show that the demand of e-cars will grow sharply and flourish over the next few years. It does not mean that the Italian automotive market will abandon traditional cars, but it will register a higher increasing rate of new EV registrations due to stricter limitations and regulations on ICEVs circulation and sale.
- Overall, future trends confirm that Italy's transport sector will shift towards the electrified mobility with a widespread adoption of passenger car first, which seems to be the most promising category, according to all three parameters. Technological innovations will help this transition the most, whereas **regulations and policies** will be the biggest obstacle for a faster uptake of EVs in Italy, as this parameter has an average score for future trends limited to 2.25 points.

1.5.1 The recharging infrastructures in Italy

Electric current to charge EVs comes in two forms: AC (alternating current) and DC (direct current). AC charging is the most common method for electric vehicles with a plug. When using AC supply, a converter located inside the car converts the power into DC and then moves it into the battery. Normally, AC charging speed is lower than DC and also less expensive. On the contrary, a DC installation has higher costs, resulting in more expensive tariffs for recharging. Despite its high costs, DC ensures a faster recharge and therefore it is very useful when people have long-distance journeys, because it enables them to recharge the battery in a short time. Consequently, DC stations are more frequently installed in highways rather than urban roads.[13] EV producers should also explain to potential customers what kind of charging connectors they would use to charge their car batteries. Traditional fuel filling is much easier because it requires one type of pump that works the same way for both petrol and diesel cars. On the contrary, BEVs or PHEVs use different plugs and connectors to transfer electricity inside the car. Below follow the most common types of chargers worldwide:

[13] *AC charging vs DC charging*, available from: newmotion.com [Accessed: 6 April 2019]

Image 2: Connector types (source: BEAMA)

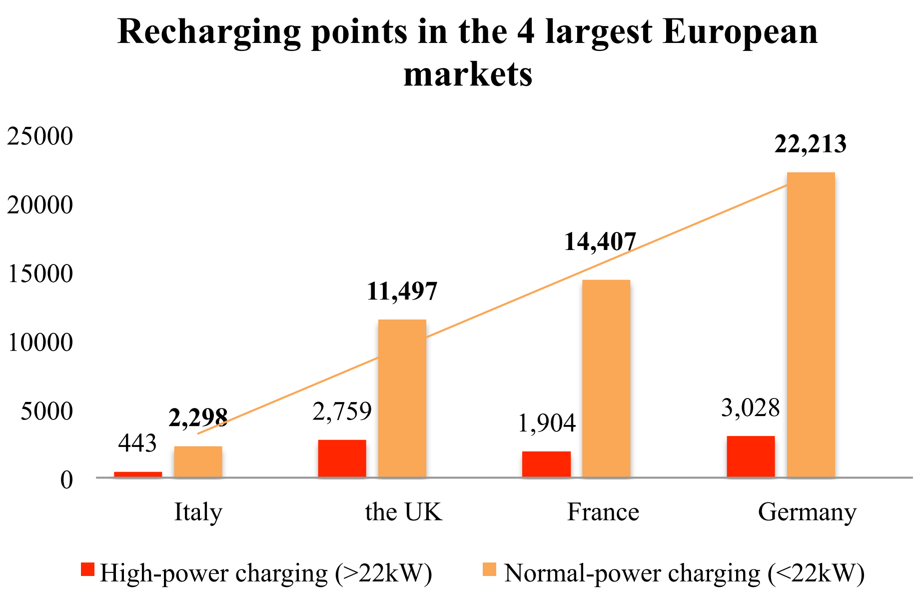
TYPE 1 - AC	-Single-phase plug -Max. charge speed: 7.4kW -North American and Japanese standard.
TYPE 2 - AC	-Single- and three-phase plug -Max. charge speed: 16.1kW (single-phase); 43.7kW (three-phase) -European standard. -The most common connector used by automakers in Europe.
CHAdeMO - DC	-Max. charge speed: 100kW -The most common standard for fast DC charging in the world. -EVs equipped with this standard usually have two connectors: 1) CHAdeMO for fast DC charging 2) Connector for AC charging (normally Type 1). -Developed by Japanese manufactures, it has been used by renowned EV automakers so far: Nissan, Mitsubishi, Peugeot, Citroën.
CCS (Combined Charging System) - DC; AC	-Max. charge speed: 170kW -CCS standard has one connector that allows both DC and AC charging. -CCS was developed by German and American carmakers and has been lately adopted by BMW and Volkswagen as well as the Asian maker Hyundai. CCS will be the main standard for incoming electric vehicles.

Table 3: Description of connector types (Source: multiple sources, read below)

The data of table 3 have been retrieved from multiple sources including a report on electric vehicle infrastructure (PDF version) carried out by BEAMA, the UK association for manufacturers working in the electrotechnical industry and a report on the e-mobility (PDF version) carried out by E_mob 2018, Italy's National Conference on the electric mobility.

Table 3 summarises the most important features of the EV connector types. Overall, the main charger of the future will be the CCS, as the market will slowly abandon type 1. The success of the CCS is mainly due to its extremely fast charging, which enables the car to be fully recharged in maximum one-hour time.

With reference to Italy, AC charging stations outnumber DC across the Italian territory. According to the E-Mobility Report 2018, **Italy had 2,750 public charging points at the end of 2017**, with 16% of them being high-power (>22kWh). Geographically, the North owns 48% of all charging points, followed by the Centre (40%). With a mere 12% of total charging points, the South and the Islands place themselves at the bottom, revealing a wide gap compared to the north-centre regions. Moreover, only 10% of the 2,750 recharging infrastructures are DC, most of them located in the North (63%), while the percentage in the South falls below 10%. The Italian situation is even worst when we compare it with other European countries:



Graph 3: Recharging points in the 4 largest European markets (source: E-Mobility Report 2018)

Graph 3 shows a huge gap between Italy and other European countries. Since recharging points are crucial to expand the EV market, Italy must improve its network largely, in order to compete with countries like France and Germany. It is also true that in these countries, the amount of EV registrations is far higher than the Italian numbers, but this does not justify the current Italian carelessness on this critical issue. What is more is that one of the main concerns of consumers is the fear to remain out of batteries while driving. As a matter of fact, providing people with a better system of electricity chargers would be a good method to make them aware that Italy actually cares the transition and that is investing funds to foster the e-mobility. Hence, potential consumers would also be keener on buying an electric car and shifting towards a more sustainable mobility, as they could rely on a larger system of recharging infrastructures. It is not only a matter of quantity. Infrastructures must also be located strategically across the country. The identification of the most suitable locations to place a charging station requires accurate preliminary studies, because it is very important that the most crowded and visited areas have the highest rate of charging points availability. The same report has identified three main areas where chargers might be installed:

- Point of Interest (POI): shopping malls, cinemas, supermarket, etc.
- Urban roads and car parks
- Motorways, minor and major out-of-town roads

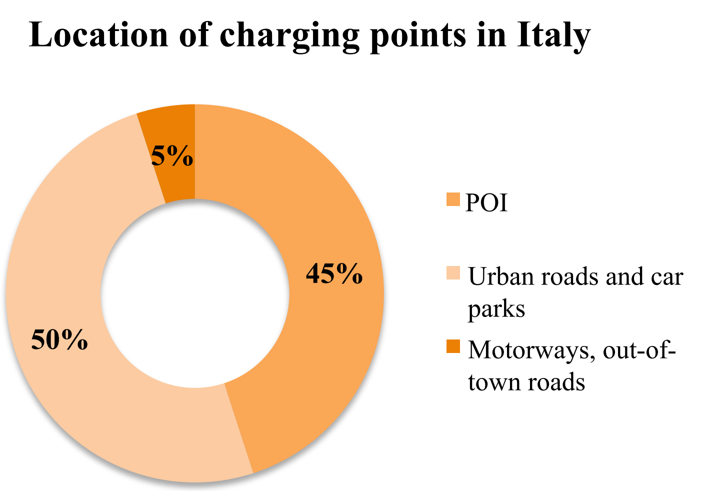


Chart 2: Location of charging points in Italy (source: E-Mobility Report 2018)

As chart 2 shows, the alarming data is the **5% of charging stations along the Italian motorways**. It means that the Italian motorways are not sufficiently equipped to provide people with the minimum requirement of charging infrastructures. Motorways in Italy are most of the time congested and used to cover long distances. Since the current range of the electric car is limited, it would be a main prerogative of the government to invest financial resources in installing chargers along the country's motorways, in order to give more drivers the possibility to charge the car while having long-range journeys. The implementation of highway services could play a role in convincing potential consumers to buy an EV, as it would eliminate or at least ease drivers' range anxiety. As a matter of fact, the Italian National Plan for the EV recharging infrastructures (PNire) is planning to increase the number of high-power charging stations by 2020, installing around 2,000–6,000 units. Moreover, the Italian largest energy company, Enel, has planned to allocate an estimated EUR100–300 million for the installation of high-power charging stations by 2022. Rapid high-power chargers (50-150 kW) will be installed in motorways and out-of-town roads to ensure a faster recharging. The target is to reach 14,000 charging stations within the next 4 years.[14] These targets are also supported by the Italian law. The legislative Decree 257/2016 transposes the *Directive 2014/94/EU* and sets minimum requirements for the implementation of infrastructures for alternative fuels, including charging points for electric vehicles.[15] The same Decree states that urban and suburban areas as well as high-density population cities must be equipped with an adequate number of recharging infrastructures by 2021.

The e-mobility provider (EMP) sells the charging service to the final customer. The EMP is therefore responsible for defining the pricing of the service. In Italy there are three pricing strategies (E-Mobility Report 2018, 2018:117):

- Energy-based tariff (€/kWh)
- Time-based tariff (€/minute)
- Free charging

Free charging is generally offered at the Point of Interest. Strategically, it aims at attracting consumers to commercial areas where they can spend money doing shopping or paying for various services. Hence, a shopping mall with a free charging service is

[14] *E-Mobility Revolution: Enel presenta il piano di infrastrutture di ricarica in tutta Italia*, available from: corporate.enel.it [Accessed: 6 April 2019]
[15] Ministry of Economic Development (April 2017), *Annual report on energy efficiency – Results achieved and targets for 2020*, ENEA, p.27

more attractive for people driving an EV, as they can charge the car while doing shopping. Moreover, it would result in a higher rate of potential visitors or customers for the mall itself, generating added value compared to other competitors. Overall, people generally prefer energy-based tariffs (€/kWh) rather than paying for the minutes they benefit from the service (time-based tariffs), because the time of charge can vary. For example, when the state of charge is 80%, the charger gets slower and takes more time to fully recharge the car. This results in a smaller amount of energy released by the charger and therefore it costs more for the user.

Moreover, the E_mob 2018, Italy's National Conference on the electric mobility, compares the fuel consumption and its cost during the lifetime of an ICEV with the electricity consumption and its cost during the lifetime of a BEV and Hybrid (PHEV). Calculations have been made with the following parameters:

- Total distance covered: 260,000 km
- ICEV efficiency: 15km/l
- PHEV efficiency: 30km/l
- BEV efficiency: 7km/kWh
- Petrol cost: 1.9 €/l
- Electricity cost (domestic charging): 0.25 €/kWh

	Litre	**€**
ICE	17,400	33,000
PHEV	**8,700**	**16,500**
BEV	**0**	**9,300**

Table 4: Comparison of ICEV, PHEV and BEV in terms of consumption and cost of refilling during the car lifetime. (Source: E_mob 2018)

As Table 4 shows, BEVs can considerably reduce drivers' expenditure in terms of battery charging, thanks to the lower prices of electricity compared to fossil fuels. In its 260,000 km lifetime, a BEV can save money up to €23,700. This is a huge economic advantage for electric vehicle owners. The plug-in hybrid vehicle brings significant economic advantages compared to the traditional car. The hybrid also has a lower purchase price than the full electric one and ensures a longer range. It is a compromise among the two single propulsion models.

1.6 TCO: comparison of an ICEV and a BEV

When people decide to buy an electric vehicle, they do not consider the high purchasing price as a long-term investment. It is therefore important to understand the extent of the ROI and what financial benefits the e-car can ensure them over the medium-to-long period. The E-Mobility Report 2018 carried out a study that compared the TCO (total costs of ownership) of an ICE car and a BEV, a financial estimate that calculates the cost of a vehicle during its lifetime cycle.

The subject of the study was an electric vehicle with an affordable purchasing price in its category that was designed to hit the mass market (for example the Nissan Leaf). This vehicle was compared to a traditional propulsion vehicle with similar characteristics but a lower price.

In the first case, calculations were carried out assuming that the vehicle ran limited annual distances (11,000 km). In the second case (TCO with extended mileage), the scenario forecasted an annual distance up to 20,000 km. Calculations of the costs for recharging and refuelling were measured based on today's average. The aim is to understand how many years it would take to make the investment in an electric vehicle (BEV) financially advantageous, compared to a traditional vehicle. Several variables can obviously influence these estimates, such as the floating cost for fuelling, maintenance costs and the average annual mileage. The analysis is divided into two case studies.

Features		
Price	€34,300	€23,000
Annual distance covered	11,000km	11,000km
Consumption	13.3$kWh/100km$	6.3$l/100km$
Cost for refuelling	€0.2/kWh	€1.6/l
Fee (bollo)	€0 $first$ 5 $years$ €45 $from$ 6th $year$	€180/$year$
Annual third-party motor insurance (RCA)	€350	€500
Annual maintenance	€150	€500

Table 5: Features of the two vehicles – Case study 1 (Source: E-Mobility Report 2018)

1.6.1 Case study 1: TCO with and without incentive

The calculation of case study 1 includes two sub-cases: with and without government incentive (€6,000).

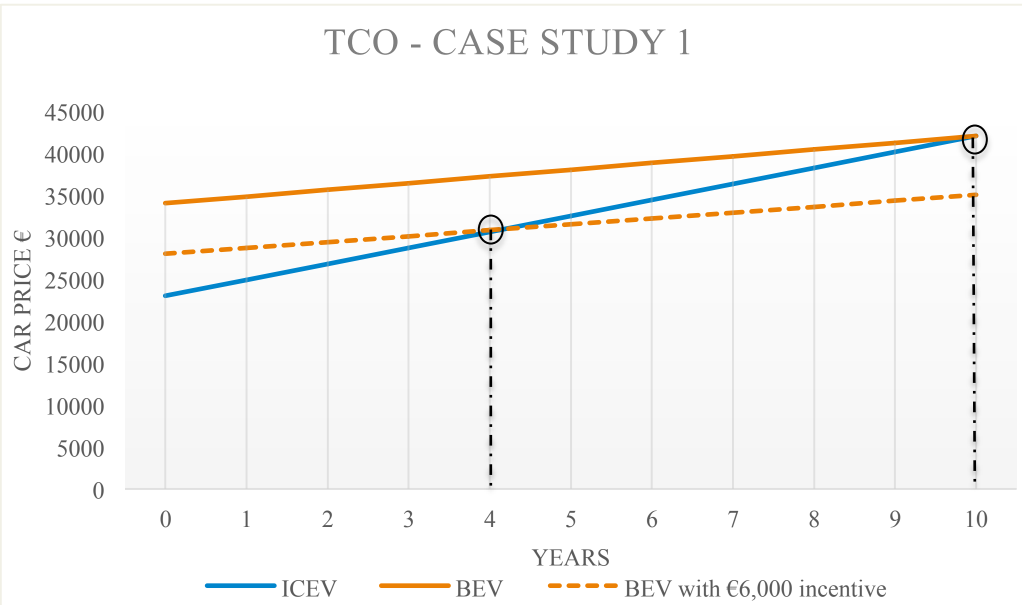


Diagram 1: TCO with and without government incentive (Source: E-Mobility Report 2018)

In the starting hypothesis, the lower annual cost of the electric car balances the initial investment only within 10 years, making the two solutions comparable by looking at the entire time interval. In Italy, the average life of a car is almost 11 years, higher than in the rest of Europe. Hence, it makes it difficult to justify the purchase of an electric vehicle, at least with reference to a financial point of view.

The second hypothesis introduces the government incentive (€6,000) that reduces the initial purchasing cost of the electric vehicle. The orange dotted line crosses the blue line after only 4 years' time, meaning that the electric vehicle takes 4 years to equalise the costs of a fuel-powered vehicle. As a consequence, after 4 years the ICE car starts to be more expensive, as the blue line steps up compared to the orange dotted one. The differential after additional 6 years' time (from 4 to 10) results in €6,000 savings in favour of the BEV. Economically, this hypothesis corresponds to a reduction of the initial purchasing price of the BEV. E-cars can become more affordable in terms of initial investment providing that the automotive industry heads towards economies of scale in the production of batteries, which are an extremely costly asset. Estimates suggest that electric vehicles could be fully competitive with ICE vehicles by 2023-2024.

1.6.2 Case study 2: TCO with extended mileage

This scenario entails a more extended use of the car, with a substantial increase in the annual mileage: from 11,000 km to 20,000 km.

Features		
Price	€34,300	€23,000
Annual distance covered*	**20,000km**	**20,000km**
Consumption*	**15.8kWh/100km**	**5,4l/100km**
Cost for refuelling*	**€0.25/kWh**	€1.6/*l*
Fee (bollo)	€0 *first* 5 *years* €45 *from* 6*th year*	€180/*year*
Annual third-party motor insurance (RCA)	€350	€500
Annual maintenance*	**€400**	**€900**

Table 6: Features of the two vehicles with extended mileage – case study 2 *differences with Table 5.
(Source: E-Mobility Report 2018)

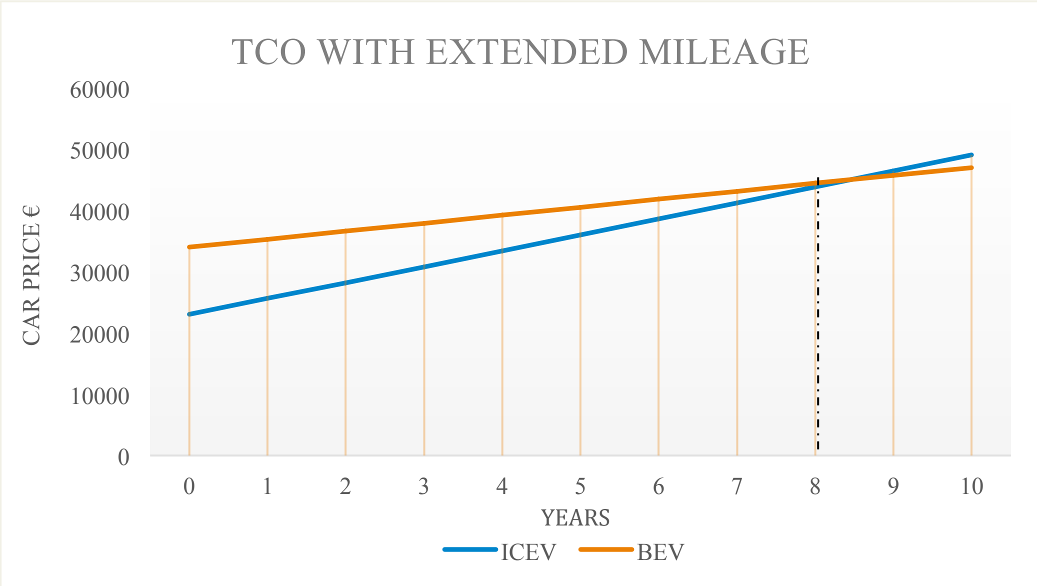


Diagram 2: TCO with extended mileage (Source: E-Mobility Report 2018)

Despite the increase in the average cost for recharging, a consumer driving electric can equalise the costs of an ICE car after about 8 years, thanks to an extended use of the vehicle. This means that owning an electric vehicle becomes cheaper than driving a traditional vehicle after 8 years. However, it is not guaranteed that the battery will be able to reach a range of 200,000 km, as assumed in this case (20,000km each year for 10 years). In case the battery should be replaced, the total cost of the electric vehicle would considerably increase, making the investment unfeasible.

The analysis of the TCO is a good parameter to evaluate the feasibility of the investment in the electric car, emphasising that customers can have a relevant return on investment in a medium- to long-term perspective.

1.7 Other electric vehicle categories

Italian citizens are asking for more investments in the sustainable mobility. A large majority is motivated to make Italian cities more liveable places. As a consequence, they would like to reduce the reliance on cars in favour of alternative and more eco-friendly transportations, such as buses, car-sharing services or two-wheeled vehicles (motorbikes, scooters, bicycles). These options would help:

- Reducing the use of private cars,
- Reducing road traffic,
- Fostering collective (public transport, car sharing) and active mobility (bicycle, foot).

According to the 15th Report on the mobility of Italian people (carried out by ISFORT), almost one-third of the respondents would implement public transport, making it the main alternative to cars. The same public transport is also considered the most important weapon to reduce urban pollution caused by the huge amount of ICE vehicles circulating in our cities. Data confirm this trend: 94% of the respondents believe that public transport services should be improved and strengthened by public money. However, fuel-powered public transports are not the most sustainable answer to environmental issues and ICE cars. On the contrary, public buses should be replaced by e-buses in order to cut harmful emission. Full-electric buses running in Italy were 46 (at the end of 2017), making Italy one of the most underdeveloped markets in terms of electric public mobility. Rome and Milan have the largest fleet, whereas other cities are closed to zero units. It will be Milan the first Italian city to shift towards electrified public transports in the next few years. According to Il Sole 24 Ore, Milan's transport company (ATM) will abolish diesel-run buses by 2030, widening the e-bus fleet to 1,200 units. Starting from 2025, ATM will only buy zero-emissions buses, abandoning its reliance on fossil fuels for public transport. Premises are as ambitious as costly: ATM's board of direction has allocated funds for €1 billion to purchase full-electric buses. On average, a full-electric bus costs EUR 400,000 – 500,000 and has a range of 100 – 180 km (E-Mobility Report 2018, 2018:74). Current e-buses in Milan have a range of 180 km and take almost 5 hours to fully repower (data updated March 2018). Investments in the public transport cannot be limited to the uptake of the e-buses, but they also mean better infrastructures for road circulation. For instance, dedicated lanes would enable bus to avoid road traffic and be on time. This would certainly lead people to benefit from public transport with a higher frequency, as electric mobility is not only a matter of environmental issues, but also a matter of time and punctuality. As previously mentioned in this chapter, China is the leading country in terms of e-bus fleet and today's best example for electric public mobility. The Chinese city of

Shenzhen has 16,000 e-buses that, according to its inhabitants, do not make any noise. This large uptake has also enabled to halve the fuel expenditures and to reduce CO_2 emissions.[16]

1.7.1 Electric car-sharing services

The car-sharing service reveals a new idea of mobility that is not based on owning a private car, but rather on renting a car when you need one. You don't need to purchase a car, fuel it and clean it. You only pay when you benefit from the service. This service is described as a new consumption method that has turned the purchase-oriented behaviour of consumers into a pay-for-use attitude. **In Italy, mostly in big urban areas, car-sharing services are increasing, with 24% of them producing zero emissions** (data updated end 2017). Electric car-sharing services increased by 12% in three years (2015 – 2017) and are expected to grow even more in the next decades. There are more than 1 million registered users who can benefit from the service, with a huge majority in Italian northern regions. In terms of service penetration, Milan is the leading city with more than 600,000 registered users and almost 3,300 vehicles (both electric and fuel-powered).[17] There are different models of car sharing, depending on where the car must be left after usage. In recent years, with the advent of the free-floating model, there has been a reduced interest in the station-based model because of the inconvenience caused in returning the vehicle to the same location. The free-floating model works differently: instead of giving back the car to a fixed parking area, affiliates can leave the car anywhere within a designated parking area. This model is more successful in cities with more than 500,000 inhabitants and a high population density.[18] Like buses, electric car sharing results in fewer cars on the road and fewer GHG emissions, and they can replace private electric cars that commonly have initial high costs of acquisition. Normally, car-sharing services are provided with small-sized vehicles (mainly Smart and Fiat 500), because they can be parked more easily around

[16] The Guardian (2018), *Shenzhen's silent revolution: world's first fully electric bus fleet quietens Chinese megacity*, available from: www.theguardian.com [Accessed: 10 April 2019]
[17] Osservatorio Nazionale Sharing Mobility (2017), 2nd National Report on the Sharing Mobility, pp. 20-29.
[18] *Car Sharing Business Model*, available from: movmi.net [Accessed: 10 April 2019]

cities. One of the main limits of this business model is its limited geographical diffusion and its scarce deployment in smaller urban contexts. At the end of 2017, the Italian fleet counted 7,679 units (both electric and fuel-powered), with 90% of them running in four cities: Milan (43%), Rome (24%), Turin (15%) and Florence (8%) (2nd National Report on the Sharing Mobility, 2017:20). Data provided in table 7 outline a highly limited geographical framework of the car-sharing services available in the Italian territory (data updated December 2017).

CITIES	TOTAL UNITS	E-UNITS	% OF E-FLEET
Milan	3,290	788	24%
Rome	2,188	534	24%
Turin	902	152	17%
Florence	550	200	36%
Venice (Metropolitan City)	37	0	0%

Table 7: Car-sharing fleet in Italy updated December 2017 (source: Osservatorio Nazionale Sharing Mobility)

Table 7 shows the gap between the four main cities (in terms of car-sharing service penetration) and the Metropolitan City of Venice. The Metropolitan City of Venice embraces 44 municipalities and counts more than 850,000 inhabitants (ISTAT, 2018). All 44 members have a high population density that often causes massive road traffic along the main commercial streets. Moreover, the lack of an underground line contributes to making this setting even worse and constrains people to move mainly by car. In this context, electric car-sharing services would be a strategic plan to cut vehicle emissions, reduce the reliance on private cars and replace ICE cars, thus reducing the negative impact on the environment. In the Metropolitan City of Venice there are a lot of points of interest like shopping malls, cinemas, big stores, etc., and people use cars to reach them. Although these centres are located in commercial out-of-town areas, they are geographically only few kilometres far from the majority of the Venetian municipalities. These premises aim to prove that electric vehicles (both car-sharing services or private BEVs) can easily cover those ranges and be zero-emissions alternatives to today's private cars, which are normally powered by internal combustion engines.

In June 2018, the mayor of Venice, Luigi Brugnaro, announced a partnership with Toyota that has started to provide the city with its first hybrid car-sharing service. *YUKÕ with Toyota* is the name of the commercial deal with Toyota that now counts 50 hybrid units. These cars can run electric for 50% of their driving time, thus producing no emissions. The service gives users some incentives: affiliates can drive through limited traffic zones and can park the car within blue-line parking areas for free. In January 2019, the service had 2,500 registered users, and since its launch YUKÕ with Toyota has contributed to saving 6 tons of CO_2.[19] According to Brugnaro L., hybrid car-sharing mobility tackles road noise, air pollution and makes the city greener. The same mayor also announced that upcoming projects aim at providing Venice with its first fleet of electric buses.

1.7.2 Electric two-wheelers

The most popular two-wheelers are the bicycle, the scooter and the motorcycle, but today's two-wheeled mobility also includes other small-sized vehicles, such as the kick scooter and the self-balancing stand up scooter, which are low-speed scooters mainly used for short distances. Two-wheeled mobility is an innovative way to cut through traffic and reduce the alarming jams of the most congested cities. However, it is not clear if e-scooters and e-bikes can be a viable urban alternative to cars in terms of environmental impact. The main problem is their lifetime cycle. Lightweight two-wheelers are accused to last less than electric cars and this results in massive waste production. On the contrary, producers of electrified two-wheelers clearly state that future more robust scooters and their better hardware design will help this category to last longer and therefore have a lower negative impact on the environment.

Small-sized two-wheelers and related scooter-rental services have had a huge success in the US. Cities like San Francisco have been literally invaded by these vehicles that often cluttered sidewalks. The reason is that these e-scooters are dockless

[19] *Venezia, il car sharing Toyota è un successo*, available from: www.lautomobile.aci.it [Accessed: 15 April 2019]

and can be left anywhere by riders, causing commotion on sidewalks, wheelchair ramps and doorways. VanderZanden T., chief executive of Bird (a US e-scooter company) replied this way when his scooters were accused to be dockless: “Go back to the early 1900s, and people would have a similar reaction to cars because they were used to horses. They had to figure out where to park all the dockless cars.”[20] He thinks that valuable solutions will be found soon.

Drivers are also accused to ignore traffic rules and to ride through crowded places careless of pedestrians, often causing accidents and dangerous falls. The biggest problem is that such scooters do not have any transit regulations or permit. This is what the US government must work on. The *New York Times* says people can rent the e-scooter for $1, plus 10-15 cents a minute to use. This disruptive business model seems to have high acceptance among the young generation, whereas disabled and old people strongly disapprove this new trend, accusing riders to whizz at 15 miles a hour careless of other people.

Electric scooters are also threatening the American car stock: the majority of journeys by car are short, and if scooters were evaluated as relevant alternatives to traditional four-wheeled vehicles, they could help to alleviate road congestion and mitigate the impact of cars on the environment.[21] This new model of electric mobility also caused the e-bicycles downfall in the US. Start Ups like Bird, Lime and Spin are providing people with thousands of kick scooters that have substituted bike-sharing services. These lightweight e-vehicles enable people to cover short distances around the most congested US cities.

According to the Global Market Insight 2018, **electric motorcycles and scooters are expected to increase by 5% from 2018 to 2024 worldwide**, with a higher uptake in Europe (+15%) during the same period. The problem is that 85% of today’s circulating e-scooters are equipped with lead-acid batteries, which are highly polluting compared to lithium-ion batteries. In 2017, 31,409 units (e-bikes and e-scooters) were sold in the EU, accounting for 3.4% of the all two-wheeler market. In the same year,

[20] Bowles, N., Streitfeld, D., (2018) *Electric scooters are causing havoc. This man is shrugging it off*, The New York Times, available from: www.nytimes.com [Accessed: 12 April 2019]
[21] Irfan, U., (September 2018) *Electric scooters' sudden invasion of American cities, explained*, available from: www.vox.com [Accessed: 11 April 2019]

only 1,500 units were sold in Italy, making it one the worst electric two-wheeler market in the European Union.[22]

Chinese giant Niu, which owns the biggest portion of the Asiatic market, is the world's leader for smart electric scooter and aims to enter the European market in the next few years. In 2018, Niu presented in Milan its fleet and its new models. New models are equipped with two lithium-ion batteries that expand their range capacity to 100 km with a single charge. The Chinese company was founded in 2014 and describes itself as the first smart electric two-wheeled vehicles producer in the world. Niu scooters can be connected to the smartphones through a mobile app and can share data on the battery status, daily distance covered, riding history and location. Company's purpose to target the European market is an ambitious plan, but Niu has sufficient financial resources to launch several models. Starting prices in Europe will be higher than Chinese ones, from €2,400 up to €4,700 approximately, depending on the adopted model.[23]

Overall, today's electric two-wheeler market is at the forefront in China and other Asiatic countries, with a positive deployment in the US west coast as well. The main producers are Niu (Chinese market) and Bird, Lime and Spin (US area). E-scooters are more popular in the Asiatic countries (China, India) whereas American roads and sidewalks are invaded by lightweight two-wheelers like kick scooters. On the contrary, numbers highlight the scarce reliance on these alternative vehicles in Europe. However, investments from foreign world's leaders in Europe will implement the electric two-wheeler fleet.

Despite its underdevelopment, Italy can rely on its historical and iconic Vespa, Italian two-wheeler masterpiece manufactured by Piaggio. Synonym of style, freedom and elegance, the Vespa has become a world's icon for two-wheeler lovers. The company has recently unveiled the new electric model with a 100km range capacity, though maintaining its enviable design. Vespa has not only turned electric, but it has also become smart: the Italian iconic scooter can be connected with the smartphone. Drivers can control the device from handlebars and swap songs, make calls or

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[22] Del Barba, M., (2018) *Lo snob aumenta ma l'Italia snobba lo scooter elettrico*, available from: www.corriere.it [Accessed: 11 April 2019]

[23] Toll, M., (September 2018) *China's largest electric scooter maker Niu files for $ million IPO in the US*, available from: electrek.co [Accessed: 11 April 2019]

reproduce music. The new Vespa costs around €6,000. Piaggio also launched a hybrid Vespa, additionally equipped with a gas-powered generator to ensure an additional range. Both models are entirely produced in Italy. Piaggio's chief executive Colaninno said Vespa is "a gem of all-Italian technology, all made at home - that's why it's beautiful, works well and is innovative." [24] This is a good opportunity for made-in-Italy producer Piaggio to put together tradition and technological innovation, with a gaze at today's environmental challenges.

Image 3: The electric Vespa (Source: dueruote.it)

[24] *Made in Italy, the first electric Vespa*, available from: www.thelocal.it [Accessed: 11 April 2019]

CHAPTER 2 – The electric vehicle ecosystem

Business ecosystems address business opportunities that require a diverse set of capabilities to meet customer needs that are beyond the capability of any single company.[25] The partnership of several players can tolerate financial risks, reallocate resources, integrate diverse capabilities and innovate faster. **The final goal of the ecosystem is not to produce a multitude of different products to be sold separately, but to develop a range of products or innovations that are combined to deliver a single proposition** (a single output). Furthermore, ecosystems require a hierarchical structure and therefore the identification of the leaders and followers. However, leaders alone cannot succeed: for the whole system to succeed, every player must win. The main difference between the two is the way they win: leaders are rewarded with a higher ROI and payoffs, since in the beginning they make investments, take up risks and accept the responsibility of establishing and running the ecosystem. Further information on the ecosystems, with a specific focus on the EV ecosystem, will be outlined later throughout this chapter. The analysis now focuses on the demand side of electric vehicles and what customers think about the EV as an alternative to ICE cars. It is important to figure out what undermines a faster take-up of electric vehicles in our roadways and a good way to do this is to examine thoughts, doubts and feedback of the end customers, who are the final links of the chain in the EV ecosystem.

2.1 The electric vehicle demand

Customers' needs and preferences, as well as their uncertainties will be discussed in this paragraph. The EV market is young and therefore it is not easy to gather a lot of data from the demand side. Statistics institutes or agencies have carried out some national surveys analysing the EV demand and customers' needs and expectations, though there is room for improvement.

The American Automobile Association (AAA) carried out a national survey in 2018, testing Americans' willingness to drive electric. The major findings of the survey

[25] Carbone, P. (2009), *The emerging promise of business ecosystems*, available from: imreview.ca [Accessed: 14 May 2019]

show that 20% or 50 million Americans will likely buy an electric vehicle as their next car.[26] However, some respondents believe EVs are not suitable for them. Below are the main factors that constrain unwilling buyers to go electric:

MAIN CONCERNS IN THE US	%
Insufficient charging points	**63%**
EV short range	**58%**

Table 8: Main concerns in the US (Source: electrek.co)

If 63% are unwilling to go electric because of the scarce availability of charging stations, more than a half (58%) still believes that EV range is the main problem, as they fear to go out of charge while driving. Range anxiety is a bigger concern for older people (65%) rather than for millennials (48%). However, range anxiety is less of a concern than it was in the past years (it has diminished by 10% in one-year time: 2017-2018). The EV price and charging time are other limiting issues for the American public to go electric, though precise percentages are missing. In this regard, 68% say that a charging time overcoming 30 minutes would not be reasonable while they are on the road.[27] What about EVs attractiveness? US customers think that electric vehicles can have positive outcomes for the environment. The **environmental factor** is still the major motivator for customer purchasing choice. Along with that come other two elements, which are influencing customers' choice:

- Advanced technology features
- The lower long-term costs. As mentioned in the first chapter, the purchase of an electric vehicle is on the one hand a monetary effort at the beginning, on the other hand a long-term investment. In the long period, the costs for the maintenance and the energy refilling enable the final user to save money.

Moreover, **reliability** is the main request of EV buyers. 92% of the American respondents believe that reliability is the main characteristic they are seeking in their new electric car. With relatively high percentages, US buyers also look at other deciding

[26] Barry, K. (2018), *More American drivers want electric cars, AAA survey says*, available from: www.consumerreports.org [Accessed: 13 May 2019]
[27] Lambert, F. (2018), *Survey shows that 20% of Americans will go electric for their next car, great progress but could improve*, available from: electrek.co [Accessed: 13 May 2019]

factors when evaluating what car to buy, such as the advanced safety technology and car performance (acceleration, braking system and handling). On the contrary, there are some features of electric vehicles that are not as important as the previous ones for the majority of US customers: few drivers consider colour, style and design of the vehicle (34%) or its brand (33%) as priorities when selecting their new e-car.[28]

Another survey, carried out in the UK by the motoring Group Automobile Association (AA) in 2018, revealed that, in a poll of 10,200 drivers, 50% of young people in the Great Britain would like to own an electric car, compared with 25% of their parents.[29] The respondents expressed the following concerns with multiple-choice possibilities:

MAIN CONCERNS IN THE UK	**%**
Insufficient public charging points	**85%**
EV short range	**76%**
EV high price	76%
Charging time	67%
Limited choice of EV models	67%

Table 9: Main concerns in the UK (Source: theaa.com)

The UK's two major concerns correspond to American biggest fears, marking similarities across the two English-speaking countries. A more efficient network of charging stations and a longer range would undoubtedly ease the large-scale uptake of EVs in most countries. The problem with public charging stations is that most governments and energy providers are evaluating this issue the wrong way: they plan to implement charging station systems as long as more electric cars will be running in our roads. They see charging stations not as incentives, rather as supplements after a larger sale of EVs. They should indeed consider them as incentives, regardless their main function that is refilling out-of-batteries cars. Their marketing function would play a massive role in leading people to buy electric and increasing customers' trust on EV-related infrastructures. Tough costly, this would be a purposeful investment that would

[28] *AAA: 1-in-5 US drivers want an electric vehicle*, available from: newsroom.aaa.com [Accessed: 26 April 2019]

[29] *Drivers still need to be convinced about electric vehicles*, available from: www.theaa.com [Accessed: 26 April 2019]

directly ease customers' concern for the lack of charging infrastructures (today's major concern for both the UK and US public).

The acquisition cost is a problem today, but the analysis has showed that it will decrease in the next few years because of the future less expensive batteries. Further government incentives and tax exemption policies are making the investment cheaper for a larger majority of customers. There are reasons to believe that the EV price of sale and the availability of EV models will no longer be a major hurdle for future buyers. Due to the phase-out of new petrol and diesel cars by 2040, all renowned carmakers are producing or planning to produce new EV models and innovative cars. Upcoming models will be thought and produced to target the mass market, which is now a segment dominated by traditional fuel-powered vehicles. The same president of the AA stated that the biggest challenge is the EV range. He believes that, once the automotive industry and the production line will manage to ensure a decent range, EVs will sell themselves.

2.1.1 A European Commission survey

In 2012, the European Commission published a report based on a survey that aimed at examining the attitude of European car drivers towards electric vehicles. The survey was mainly conducted by the Joint Research Centre (JRC) with some additional collaborations.[30] The study included 6 European countries: the UK, Italy, Spain, France, Germany and Poland. In terms of new sales of passenger cars in the EU, these countries accounted for 75% of the whole market share (data updated 2011). Total responses outnumbered 3,700 (3,723 precisely) among all six EU members.

[30] Thiel, C., Alemanno, A., Scarcella, G., Zubaryeva, A., Pasaoglu, G., European Commission, Joint Research Centre (JRC), Institute for Energy and Transport (2012), *Attitude of European car drivers towards electric vehicles: a survey*, Publications Office of the European Union, Luxembourg.

COUNTRY	RESPONSES
UK	716
Italy	613
Spain	617
France	623
Germany	606
Poland	548
	TOTAL: 3,723

Table 10: responses per country of a European Commission survey (Source: European Commission)

This analysis will select the most important topics that arose from the survey. Data and considerations will be analysed with the aid of some tables throughout the following paragraph. Although the survey was conducted in 2012, it is however important because on the one hand it accesses whether customers' main concerns and interests for the EV have changed over time (2012-2019), on the other hand it evaluates to what extent has the EV market improved in the same period. The survey was divided into three main sections:

SECTION	QUESTIONS
1st Section	Awareness of electric cars (familiarity and knowledge) Relevance of public incentives for electric cars
2nd Section	Relevance of some features of electric cars Propensity to consider electric car as the new car
3rd Section	Expected future background for the fuel price Features to improve in the electric car

Table 11: Structure of the survey (Source: European Commission)

Outcomes of the survey:

1st Section – Awareness of electric cars: data highlight a low level of familiarity with this technology. The reason can lie in the period when the survey was carried out: in 2012 the electric vehicle market was not as popular and discussed as it is today, though it started to gain its importance. Eight years ago, customers underestimated this issue and the market penetration of the electric vehicles was close to zero. As a result, almost half of the respondents say to be not at all familiar with this new form of mobility. **Relevance of public incentives for electric cars**: 84% of the sample think that government incentives are key factors to support the diffusion of electric cars. Geographically, this idea was more widespread in Italy. It is obvious that people consider incentives as great facilitators, especially when one of the main barriers is the EV price of sale.

2nd Section - Relevance of some features of electric cars: when asked about how much they agree on several statements about electric cars, 75% of potential customers think that electric cars are quite expensive. A large majority (69%) also believe that e-cars have no tailpipe emissions and are not noisy. Some respondents were not able to share their opinions on some statements because of the lack of information and knowledge. For example, 30% of them were not able to answer the question regarding the charging time of the battery, whereas the majority could not give any feedback on the cost of electricity to cover a range of 100 km. Today, there is a higher awareness of these issues that have also become some of the biggest barriers for a larger adoption of the electric vehicles. As a result, the charging time is a hurdle both for customers and other stakeholders, like the EV carmakers and the energy providers. The sample also reveals a scarce knowledge on the maintenance costs, which are considered to be high by 42% of them. Several times throughout the first chapter, the argumentation explained that maintenance costs for electric cars are lower than those for traditional fuel-powered cars: today, maintenance costs for electric cars are roughly three times less expensive than those for ICE cars. Moreover, 64% of the respondents believe that the driving pleasure and performances of electric cars are not as good as traditional ICE vehicles. This is clearly a lack of knowledge on the topic, proved by the fact that in 2012 people could not properly evaluate e-cars driving performances because almost nobody had driven one before. Moreover, the driving experience and the performance of the electric car has deeply improved, almost equalling that of the ICE vehicles. **Propensity to consider electric cars as their new car**: in Italy, Spain and Poland, more than 50% of the sample say that there is a high probability to purchase an electric car as a new car in the next few months. People keener to purchase an electric car are daily car drivers and those who say to have a good familiarity with the e-car. In terms of age range, young drivers (18-34), who correspond to 1,123 respondents, state they would buy an electric car more likely than elders (37%). Moreover, people living in metropolitan areas have a higher probability to buy an electric car (40.5%), compared to people living in rural areas or small urban contexts. Big cities and metropolitan areas seem to be the proper settings for a larger uptake of the e-vehicles, because normally in those areas people make short journeys by car, resulting in a lower risk to exceed the maximum range. Moreover, e-cars in metropolitan areas can cut harmful emissions and reduce the air pollution, typical of congested roads.

3rd Section - Expected future background for the fuel price: all six EU members have common expectations regarding the fuel price in the near future. A full majority believe that the fuel price will increase considerably. The percentage of those who believe that it will decrease lies between 1 to 5%. The high expenditures for refuelling can lead to a faster transition towards the electrified mobility. According to the US Department of Energy, in terms of consumption costs (fuel and energy expenditures), on average, it costs about half as much to drive an electric car today.[31] Costs can vary depend on the geographic area and driving habits. Moreover, electricity prices are generally stable, registering fewer fluctuations over time than gasoline prices. This trend could certainly change provided that electric cars will deeper penetrate the market. **Features to improve in the electric cars**: respondents were asked to choose which features they would like to improve in their electric car, if willing to purchase one. The table below sums up the preferences of the sample:

%	**IMPROVEMENT**	**COUNTRY**
32%	Increase the car range	GER, UK
32%	Decrease the purchasing price	**IT**, SPA
25%	Recharge the car at home without a private garage	FRA, POL
9%	Speed up the recharge time	SPA
2%	Increase the maximum speed	EQUAL

Table 12: Most wanted improvements in the electric car (Source: European Commission)

[31] *Saving on fuel and vehicle costs*, available from: www.energy.gov [Accessed: 14 May 2019]

38% of Italian respondents would like the purchasing price to decrease, while almost one third (30%) would like to increase the distance covered with a single recharge (car range). Overall, the sum of the first three improvements reached 89% of preferences among all six countries.

When asked why they would not be interested in buying an electric car, the majority of respondents selected the price and the battery as the main reasons. Again, **the main reasons that slow down the take-up of electric vehicles are the price and the battery capacity**. Today however, batteries ensure the driver a longer range (up to 400 km) with a single recharge (the maximum mileage is going to increase steadily), whereas prices are still rigid. In the period 2012-2019, what differs among customers' biggest concerns is the charging time. Only 9% of the sample would like to speed up the recharging time, whereas drivers today consider the charging time one of the main obstacles that restrain them to buy an electric car. Since people in 2019 have a higher knowledge of the EV and are generally keener on purchasing one, they better evaluate all issues related to the electric car and give therefore more importance to the charging time. This reflection points out that nowadays consumers are more demanding and expect the electric vehicle to be a profitable and feasible alternative to traditional cars in all its features.

2.2 The electric vehicle ecosystem

"It isn't enough for an auto manufacturer to produce a reliable, fast, eco-friendly, efficient car: it also needs to offer state-of-the-art computer navigation and entertainment systems" (Adner, 2013:9). Success in the electric vehicle market requires mastery of ecosystem strategy, because it is made up of an array of players that must work together in order to create value and make the EV a mainstream product. The success of an ecosystem is rooted in the ability of all players to deliver their own promises. Players are not only companies, suppliers, distributors, retailers and customers, but they also encompass governments and agencies, which can work as facilitators and policy makers. The electric car has various components and hits multiple markets that need to improve and innovate themselves in order to turn a niche market into a mass market. At the moment, automotive firms have understood to leverage external supply chains to outsource activities, because innovation is no more a stand-alone process, it is instead a matter of joint efforts. Almost every player in the EV market can rely on a great execution, which means excellent managers, top-class business models, potentials to beat the competition and abilities to satisfy customers' needs. On the contrary, most of them underestimate two other threatening risks that every innovation ecosystem can face:

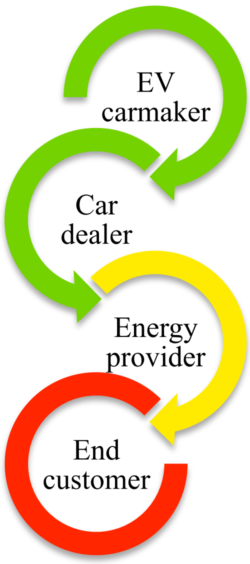
1. Co-innovation risk: the success of the whole ecosystem depends on the successful commercialisation of other innovations (Adner, 2013:33). If a single player is late or is not fulfilling its tasks, the ecosystem must find valuable solutions to speed up the process and try to help all latecomers to fulfil their goals, otherwise the whole structure could fall. In this direction, there are some mitigating actions that aim at lowering the risks of failure into an ecosystem (Adner, 2013:49-51):

- **Add resources**: partners could allocate financial resources to the weakest player in order to increase the probability of success of the whole ecosystem.
- **Reallocate resources**: a solid partner can remove resources from its project and reallocate them to the weakest player, without investing additional money.
- **Re-evaluate the vision**: the ecosystem can decide to re-evaluate the value proposition, making it more modest but more likely to be successful.
- **Re-evaluate the timeline**: the possibility to widen the timeline and make it less aggressive gives your weakest co-innovators the chance to catch up with all other players.

For example, one of the biggest fears in the EV market is the driving range, which is determined by the capacity of the batteries. The ecosystem should therefore consider investing more money to battery technological innovations rather than on product design. The same is true for charging time. Gasoline stations enable drivers to fuel the car in a minute, whereas EV charging stations take longer. Customers are asking the EV ecosystem to find joint solutions to overcome both issues: the driving range and battery charging.

2. Adoption chain risk: before end customers access your value proposition, all your partners in the ecosystem must adopt and accept your innovation (Adner, 2013:34). A range of intermediaries stands between your product and the final customers, and your success depends on each of these partners adopting your innovation and seeing the value it will create for them (Adner, 2013:55). Unless all intermediaries benefit from the value proposition, your innovation will not reach the end customer. The chain is therefore made up of a lot of customers because everyone has to be rewarded for the innovation: the distributor, the retailer, the salesperson as well as the final customer. In the EV ecosystem there are several players who have to adopt the innovation and benefit from it: the carmaker, the dealer, the energy provider, the insurance company, the salesperson, the final customer and many others. In the adoption chain, it's not only satisfying the end customers, but it also encompasses the creation of value for all other intermediaries.

These rules can be applied to the EV market. First, it must be said that the electric car is not a modern innovation. The first EV prototype was launched in 1900 by the American Electric Vehicle Company. However, the discovery of cheap oil and the higher efficiency of internal combustion engines made the EV disappear from all roads. In the early 21st century, the EV came out again. The first models designed by Nissan, Honda and Toyota had big constraints, like the driving range and limited charging infrastructures. Today, the society is experiencing a third wave due to environmental issues, high prices for oil and many other factors that have been mentioned in the previous chapter. However, the EV today remains a niche product. It is thus important to examine how the adoption chain is structured and what concerns it arises. The assumption is that the end customer does not benefit from the electric car innovation because of the high cost of the car, the scarce availability of charging infrastructures, the limited range and the long charging time. This implies that the total costs of the EV adoption exceed the relative benefits of the same EV. "Innovators think about benefits in terms of what their product actually provides, whereas customers think about benefits in terms of added value, that is the relative benefit compared to the available alternatives." (Adner, 2013:56-57)



Player	Benefits
EV carmaker	+
Car dealer	+
Energy provider	/
End customer	-
Total	+
Result	Failure

Figure 3: The EV adoption chain (personal elaboration)

In this simplified version of the EV adoption chain, the EV carmaker also includes all other players that provide the manufacturers with various components to produce the car: original equipment manufacturers (OEMs), battery providers, computing companies and all other external suppliers. Players are marked with a green, yellow or red spot, depending on their propensity to adopt the innovation and get a surplus from it. The green spot means that the innovation is giving that player a surplus, whereas players marked with yellow have the potential to get a surplus but still need to adopt the innovation completely. The red spot means that the innovation does not satisfy that player, leading to a fracture in the adoption chain.

The total costs of **the EV carmaker** initially outscore the benefits, because of the high expenditure on newer production facilities and cars components, like the battery. Moreover, the EV carmaker has to set up new marketing initiatives and pay for promotional campaigns. On the contrary, in a long-term perspective, the selling price of the car ensures the carmaker relatively high margins and the scale down of ICE cars considerably cut costs. Moreover, electric cars need fewer components than traditional fuel-powered cars. Carmakers can afford this transition because they have ample funds for investments and excellent managerial skills to oversee the process, even in the short period.

The car dealer positively accepts the innovation. Since the dealer is selling a car, he does not have to implement the sale system extensively. The dealer should update both salespeople and pre- and after-sales services, without transforming them completely. Conversion costs would not therefore exceed the benefits, resulting in a surplus for the car dealer. The dealer also has good margins and the business could give them extra value.

In the adoption chain, **the energy provider** is a key player. It is responsible for handling the electric grid and all related services: charging infrastructures, home charging stations, charging time improvements, etc. The major energy-providing companies need to invest a lot of money for the deployment of the charging infrastructures and implementation services. Despite their initial costly investment, they will benefit from it once the EV market will cross the edge of the niche market. However, energy providers are unwilling to install charging stations on a large scale, because the EV market penetration today is still limited. Potentially, energy providers can rely on massive financial resources to allocate in these projects, but their current commitment is still below what would be necessary. Despite the feasibility and affordability of the transition in the short period, the energy provider is marked with a yellow spot, meaning that it has the potential to do but is lacking investment, because of the low ROI (return on investment) they would currently have. This scepticism contributes to weakening the whole ecosystem and sets the scene for the fracture of the adoption chain. The electric grid capacity is therefore a hidden threat for the EV ecosystem, because if electric vehicles turned to a mass-market product, the current electric grid capacity would not be enough to charge a huge amount of EVs at the same time.

What generates the failure of the whole chain is **the end customer** who has not accepted the innovation so far, because the total costs exceed the relative benefits (resulting in a minus). Customers struggle with four big hurdles, which make the electric vehicle not appealing enough: the purchasing price, the car range, the charging infrastructures and the charging time. Moreover, the total costs for customers also include all the other changes they need to undertake in order to use the innovation. For example, they need to change their habits and learn how to recharge the car with the plug-in system. They also have to be aware of the new recharging tariffs and payment methods. All these features combined contribute to making the customers reluctant to foster this transition. What is true is that the end customer also has relative benefits when driving an electric vehicle: environmental benefits (zero or low harmful emissions), fewer expenditures on fuels and maintenance, tax exemption for some years, the possibility to drive through limited traffic zones and park within blue-line parking areas, and an excellent driving experience. Customers also evaluate to what extent the electric car is affordable and worthwhile compared to the traditional ICE car. Today, the gap between the total costs and the relative benefits remains too wide, signalling a fracture in the adoption chain.

2.3 Solutions to heal the fracture in the ecosystem

Ecosystems have led to a profound shift in the economy: **relationships, partnerships, networks, alliances, and collaborations** have become fundamental to pursue successful innovations and make them effective in the real world (Kelly, 2015:5). The EV ecosystem encourages partnerships and fosters new innovations, but it also faces critical challenges. This paragraph lays out potential solutions that could heal the fracture that breaks the adoption chain. To begin with, it is important to shape the pathway made up of three steps:

- Identify the risks in the ecosystem and the main problems that create the fracture,
- Identify the main responsible for the fracture,
- Identify a solution to heal the fracture.

Although the adoption chain reveals a real fracture at the stage of the end customer, who is still unwilling to purchase the electric car, the player that first undermines the chain is the energy provider, which is marked with a yellow spot. The combination of the two players unbinds the chain, leading to the failure of the ecosystem. The identification of the risks and the main problems has been already analysed in the previous paragraph.

Customers' main hurdles	**Responsible**
EV Purchasing price	EV carmakers and OEMs
EV range	EV carmakers and OEMs
Charging infrastructures	Energy providers, policy maker and the utility industry
Charging time	Energy providers, tech companies and the utility industry
Hidden Threat	**Responsible**
Electric grid capacity	Energy providers

Table 13: Customers' main hurdles and hidden threat (personal elaboration)

All challenges that loom over the EV ecosystem must be overcome by solving problems that mainly affect other players in the chain: the EV carmaker, OEMs and the energy provider. What could be the feasible solutions?

2.3.1 Standardisation of the battery pack and charging infrastructure

A single car battery that suits every electric car would be a great advantage. It would be easier for the end customer to replace it or buy it, and it will create a new marketplace, meaning that a new competition will rise. This would also lead to economies of scale and would cut production costs that will **reduce the purchasing price** of the e-vehicle. The battery is both the main and the most expensive asset of the e-car. Hence, the electric mobility will have a quicker uptake on condition that batteries will be produced at lower costs and perhaps with a single shape and material. It is not only the batteries, but **standardisation also applies to the charging methods**. With a throwback to the refuelling methods of ICE cars, the standardisation of the process positively affected the large-scale deployment of fuel-run cars: as a matter of fact, all car brands can rely on the same types of fuel, which can be found at any petrol station. This has been a huge advantage for all players in the automotive industry, because it set common regulations to refuel every car available on the market. The same is not true for the EV market today: there are different charging-up methods that are not necessarily compatible with every vehicle. Moreover, drivers ask for fast charging stations, as they do not want to wait too long when running out of energy. If the market produced a single standard, potential EV buyers would take the plunge more easily, as they would be more confident to find a station when they need to charge up their vehicle. Carmakers would collectively benefit from it: they would not only sell more vehicles, but they would also get others to pay for royalties for patent usage licences.[32] If standardisation is the final goal, collective decisions and a cross-industry interplay will be the pathway: EV carmakers, energy providers, public authorities, technical suppliers must cooperate to settle on a common standard, otherwise the EV ecosystem will turn into the battlefield of the war of standards. However, two aspects are preventing the EV ecosystem to accomplish the standardisation:

A. The car battery market has been constantly developing and is aiming to find new technologies that enable the car to have a longer range. Another goal of the upcoming batteries is to enhance the driver's safety. Lithium-ion batteries are wet and "the motion of the liquid electrolytes generates heat, and in certain situations, this can slip into a runaway effect that results in a fire."[33] Other cutting-edge technologies are therefore trying to lessen battery-related issues. Probably, the automotive industry and all other stakeholders are waiting for further improvements before settling on a common action plan for a single energy storage solution that fits every e-car.

B. The EV ecosystem itself has been failing to set up common regulations and directives to standardise the production of the batteries and the charging stations. The EV carmakers, the battery suppliers, the energy providers and other players, such as international institutions and public authorities, should reach an agreement and harness the development of a single battery and standard charging types. This is indeed the essence of the ecosystems: an innovation alone will not be effective unless all players accept to undergo the transition and adapt their production processes to the innovation. The competitiveness among single manufacturers is huge because every player has its

[32] Crampes, C., Lefouili, Y. (2019), *Which standard should be implemented for charging electric vehicle battery?*, available from: http://fsr.eui.eu [Accessed: 14 May 2019]
[33] O'Kane, S. (2018), *Electric cars could use another big battery breakthrough – this CEO says he's got it*, available from: www.theverge.com [Accessed: 14 May 2019]

interests and would like to set its standards, resulting in an inevitable fight. Probably, the best solution would be a continent-wide regulation, imposed by international organisations and public authorities.

2.3.2 Battery Swapping Stations (BSS)

What about swapping one of your batteries when you are driving long distances? In an ideal BSS system, a third party will have the ownership of the battery (leasing model) and will be responsible for replacing the unloaded batteries with full ones, as well as monitoring the status and health of the batteries. The question is: is this process feasible and financially affordable? There is no answer today, since this service is barely available on the market, though some companies like Better Place had tried to enter this business but failed because the overall ecosystem was not ready to undergo this transition towards an e-car with no battery pack included. What is true is that this model requires the participation of several players of the EV ecosystem in order to be successful. It is not only the EV carmaker and original equipment manufacturers, but it also involves the energy providers, the policy makers, and private companies. It is not a matter of who will be the main actor, but rather what consequences this business is going to give the EV owners. The main actor can be either the EV carmaker, the energy provider or a private company that decide to set up a range of battery swapping stations. What will be worth the risk are the final outcomes and their impact on the end customers. As a matter of fact, this leasing model would give the EV owners several advantages:

- It would considerably **reduce the EV price of sale** and make EVs more affordable for a larger number of customers, because the electric car would not include the cost of ownership of the battery;
- The possibility to replace unloaded with loaded batteries would solve the problem of the **charging time.** As a matter of fact, recharging processes would take a few minutes to swap the battery, compared to traditional plug-in charging that take at least 30-40 minutes with direct current fast charging (DCFC);
- It would also defeat drivers' **range anxiety**, allowing longer journeys;

- It would **ease drivers' concerns on the battery lifetime**, as the BSS operators check and monitor the status of the batteries accurately and run the business healthy;
- It would **decrease the expenditure on household charging infrastructures**, because the EV owner does not need to plug-in the car at home.

The cruel truth behind BSS ecosystem is that the installation and deployment of similar services clearly require big financial resources, as well as several prerequisites and players:

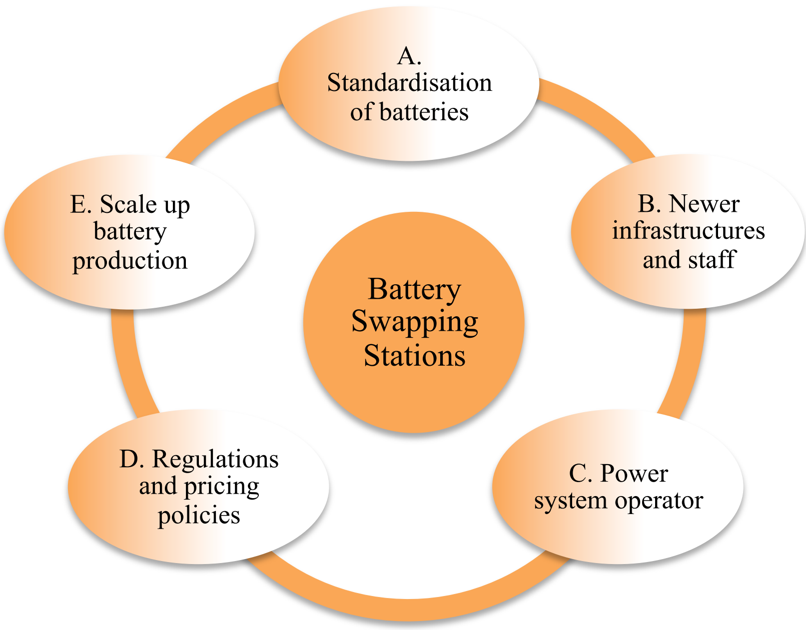


Figure 4: Battery swapping station (BSS) ecosystem (personal elaboration) (Source: Adner, 2013)

A. Standardisation of the battery pack: the non-standard battery pack is more than a concern for the BSS. The EV carmakers and the original equipment manufacturers (OEMs) tend to have their proprietary battery pack technology and a low propensity to a standardisation of the battery pack. This is due to market competitiveness and the architecture of some car models, which are designed to fit with only a specific battery pack (e.g. Tesla). However, for the BSS to succeed, the standard battery pack is the key prerequisite, because a larger range of car models could access the battery swapping stations and benefit from the service. It would be instead too costly for the BSS business model to store different battery pack versions. Before having a widespread deployment of those services, it is therefore necessary to limit the battery packs to one or maximum two standards (one would be ideal).

B. Newer infrastructures and trained staff: start-ups or private companies have to invest a lot of financial resources to establish a battery swapping station. Costs include the BSS facility, workers (trained and specialised staff), the battery pack supply, which is extremely expensive, technological and automated swapping systems and the electricity, as well as fiscal duties. Obviously, if a company has funds and a consistent well-structured business model, it will not have problems to make the investment. What is crucial is the timing: although conventional wisdom has often honoured earlymovers, sometimes the complexity and the dimension of an ecosystem require a less aggressive timeline. The EV ecosystem is facing co-innovation challenges and has not set common standards for the battery pack yet. Consequently, it would be better to move on fairly slower and be more patient to avoid being wasteful of money. It is sometimes the latecomers that reap the benefits of pioneering failures (Adner, 2013:148).

C. Power system operator: once EVs will be copious on roads, the demand of electricity will rise exponentially. Power system operators for the BSS approach need therefore to be smart and control the charging strategy: they should charge the batteries during off-peak hours or at night, when the demand of electricity is low. With a huge amount of EVs in the next future, a circuit overload still remains a concern. However, risks of overloading and power blackout can be flattened by an efficient schedule and monitoring of the energy consumption.

D. Regulations and policies: policy makers and local governments must be involved in this transition. They play a key role in providing private investors with subsidies or financial incentives to start the business. They should also regulate the new business, introducing limitations and fiscal policies, as well as discussing with the major players the pricing strategies, in order to ensure its commercial viability and make it accessible to everyone owning an EV.

E. Scale up the battery production: along with the standardisation of the battery pack, the BSS needs a huge amount of batteries to run the business. Obviously, battery scaling up depends on the previous standardisation of the battery pack that would reduce the production costs and enable battery pack producers to enlarge the stock with fewer total costs.

2.3.3 Smart grid and V2G technology

The electric grid capacity is a hidden threat for the EV ecosystem. With a future higher penetration of electric vehicles, the grid could face serious challenges and the overall power system could fall. It is predictable that EV drivers will load their cars either when they are at work around 8:30 a.m. or 9:00 a.m., or in the evening when they come back home. This simultaneous connection to the electric grid could overpower the distribution networks of most big cities, causing an inevitable power blackout. The problem of the insufficient distribution grid will arise when the EV will become a mainstream product. Today, the EV market is still young, but all players involved in the EV development processes must consider that the inability of the grid could cause a massive failure in the future. The answer could be **smart grid technology**. Using smart charging spots that are able to transmit and receive data and react to external signals to control levels of charging will be crucial to managing the impact on the electricity grid.[34] Governments and utilities in the world are investing in intelligent transport systems, which entail the integration of information and communication technology (ICT) in the transport sector. For example, the ICT devices are used to access the local status of the electricity grid in a given place, obtained by smart meters. This measurement optimises the EV loading process and gives information about the capacity of the electric grid. Another important innovation is the **vehicle to grid (V2G) technology**. V2G aims to turn electric cars into virtual energy storage vehicles, meaning that EVs would store electricity in their batteries and dispatch it during the peak hours (send their stored energy back to the grid when the demand of electricity is high). The V2G technology entails smart meters, dynamic pricing (lower price at night when the demand of electricity is low), automated control and real-time information exchange.[35]

[34] Frankland, O. (2018) *The role of electric vehicles in a smart grid*, available from: www.regen.co.uk [Accessed: 20 May 2019]
[35] *Learn more about Vehicle to Grid*, available from: www.sciencedirect.com [Accessed: 20 May 2019]

Therefore, EVs communicate with the power grid that can buy from the EV owner when necessary. The same high-tech innovation would enable the EV owner to check the status of their vehicle through smartphone apps. Moreover, it helps monitoring the energy costs and it collects data useful to optimise the time of recharge. What are the prerequisites of the vehicle to grid technology? According to David Slutzky, CEO and founder of Fermata Energy, a US-based pioneer in V2G tech, for V2G to work successfully, you need three things: a bidirectional vehicle, a bidirectional charger, and software that enable you to monetize the system.[36] The Nissan Leaf is the only bidirectional car on the market. It understood the power of converting the stored energy into money and the chance to get into other markets. On the contrary, bidirectional chargers are yet to be approved for the V2G technology, but they will be soon available. What about the monetisation of the process? A broader interaction with the utility industry will increase the possibility for the EV owner to earn money from their contribution to the electric grid. In Italy (Geneva), Enel in collaboration with Nissan launched in 2017 the first pilot project involving charging infrastructures equipped with the V2G technology.[37] This project was applied to companies' fleet and was founded to evaluate the feasibility of the V2G system, waiting for a legal legitimisation. As a matter of fact, the Italian government has not issued a regulation yet, though governmental leaders are optimistic for an early rollout of the V2G technology. However, this legal delay is keeping Italy steps behind other European countries, such as the UK and Denmark.

2.3.4 Alternative energy sources

According to multiple sources, the fuel cell technology could be a feasible solution to replace or integrate current batteries, but only in the next future. The fuel cell combines hydrogen and oxygen to power an electric motor. **The range of fuel cell electric vehicles** (FCEVs) **is comparable to that of conventional fuel-powered cars**.

[36] Casey, T. (2019), *Electric vehicle-to-grid technology gears up for the mass market*, available from: cleantechnica.com [Accessed: 20 May 2019]
[37] Pini, S. (2017), «*Vehicle to grid*»*: Nissan, Enel e Iit lanciano le prime infrastrutture italiane*, available from: www.ilsole24ore.com [Accessed: 22 May 2019]

The same technology would also **cut the charging time**, taking almost 4 minutes to fully refill the hydrogen tank, solving one of customers' main hurdle. The question is: is fuel cell technology ready to replace ICE cars today? Infrastructures and today's reliability of Hydrogen Refuelling Stations (HRS) is even behind that of electric cars. Although hydrogen-powered cars do not release toxic tailpipe emissions, which make them a sustainable resource to chase a greener mobility, problems arise when we consider the phases to get hydrogen. Hydrogen does not exist as a pure element in the planet and get it is extremely costly, both in terms of money and electricity. Today's processes to get hydrogen involve a high quantity of carbon monoxide and dioxide, meaning that the process is unsustainable for the environment. If the ecosystem evolved and made it less costly and eco-friendlier to produce, the fuel cell would be a sustainable and affordable alternative to current batteries.

Today, the efficiency of battery electric vehicles is more than half that of fuel cell vehicles. Evidence comes from Toyota: the Japanese automaker giant believes hydrogen will become a source of clean energy within 100 years. The Toyota Mirai has been the world's first fuel cell vehicle ever launched, but due to its high cost (€66,000 plus local taxation), only 6,000 units have been sold since 2014. It costs a lot because the hydrogen storage system has high production costs due to its components including platinum, titanium and carbon fibre. As a result, fuel cell technology will not solve the problem of the EV price of sale in the near future. As a matter of fact, the process requires more time and large investments. Another pathway to reduce production costs is "to use as many parts from existing passenger cars and other models as possible"[38], said Ikuo Ota, Toyota's manager of new business planning for fuel cell projects. Mass-producing common parts of different models can lower costs to produce other fuel cell vehicles. On the contrary, hydrogen-based cars can rely on an excellent driving range: Toyota aims to hit 1,000 kilometres range by 2025, compared to today's 700 kilometres. The role of hydrogen as an alternative fuel to power future vehicles (not only limited to road transport) will be analysed in more detail in the third chapter.

[38] Tajitsu, N., Shiraki, M. (2018), *Toyota plans to expand production, shrink cost of hydrogen fuel cell vehicles*, available from: www.reuters.com [Accessed: 16 May 2019]

2.3.5 Electric car-sharing services

One of people's main hurdles to turn electric is the EV purchasing price. While waiting for a future drop of the price, customers could therefore reconsider the function of the car: **from ownership to service**. As a result, customers would not pay for the car, as they would not own it. They could instead benefit from car-sharing services. In response, private or public investors (car-sharing companies, energy providers, public agencies) could bet on sharing services as initial pathways that can lead end users to a wider reliability on the electric car as propriety in the future. In this analysis, the e-car sharing fleets are described as facilitators for a later car purchase. This new approach could change the original EV adoption chain (figure 3), introducing two new players:

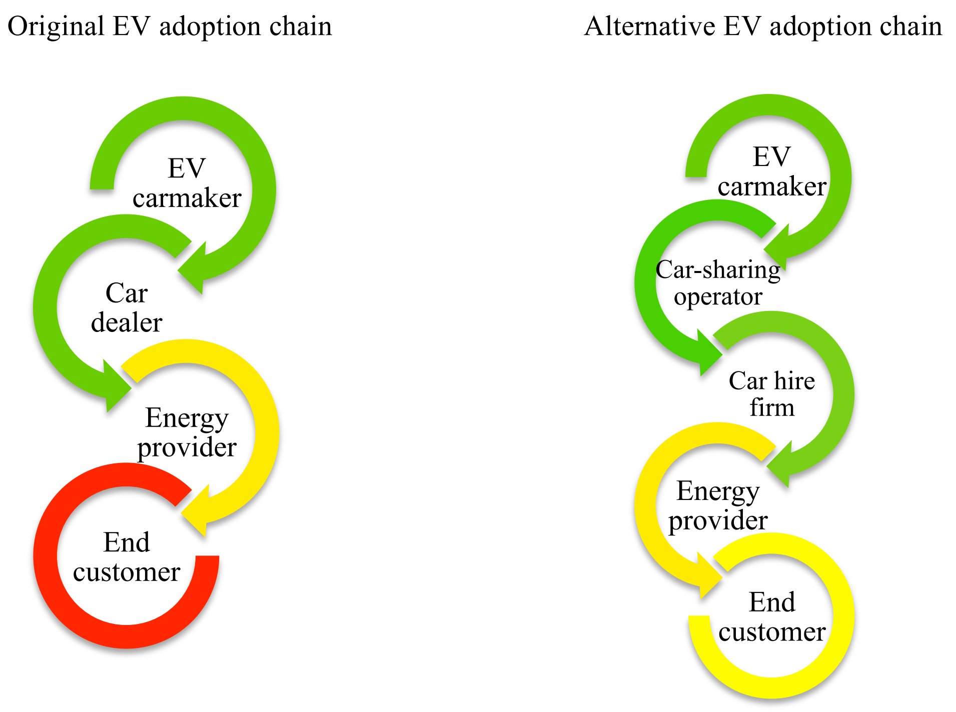


Figure 5: Alternative EV adoption chain (personal elaboration)

The scheme of the alternative EV adoption chain is a personal interpretation of the phenomenon, though this model is supported by real data and evidence from multiple sources. Assumptions and considerations are based on the current market penetration of electric car sharing services, which remains a niche market. Overall, the new chain has no red spots, meaning that the innovation has been to a good extent accepted by all players, though the EV ecosystem is not mature enough to light up green. As previously anticipated, the alternative EV adoption chain may play as the precursor of the transition towards a largely widespread electric mobility. The resulting EV adoption chain has three main differences with the original one: two new players, which are the car hire firm and the car-sharing operator, and the shift to yellow at the final stage. In this frame, the car-sharing operator is often led by the EV carmaker. The growing interest of the automotive sector in the car-sharing services is leading to new types of business relationships. **Car hire firms** are traditionally major purchasers of new cars from carmakers, and this relationship continues today. However, both carmakers and car hire firms deliver car-sharing services nowadays, thus finding themselves in competition with one another.[39] In some cases, EV carmakers and car hire firms also cooperate and deliver a joint service, meaning that together they establish a car-sharing service. Carmakers keep the green spot because they have financial depth to undergo the investment, even though they have massive insurance issues. Moreover, carmakers have the possibility to leverage existing organisation strengths, like information technology systems and market research capabilities. Hence, the nature of the **car sharing operator** may be diverse, either an independent operator (rarely) or a carmaker or a car hire firm. The analysis will focus on carmakers that have decided to invest in car-sharing systems, for which car sharing is not their core business. The e-car sharing operator (often the EV carmaker) invests huge financial resources to launch, implement and innovate the e-car sharing services: electric vehicles' production, running costs, incl. maintenance, insurance, infrastructures, etc. However, in the medium-to-long term the business can have relevant ROI and ensure the investors quite high profits. Usually, car-sharing initiatives grow gradually, starting with a few vehicles and a few members. This gradual penetration limits the investment in a first phase. If

[39] Le Vine, S., Zolfaghari, A., Polak, J., (2014) *Carsharing: Evolution, Challenges and Opportunities*, ACEA, available from: www.acea.be [Accessed: 27 May 2019]

then the business turns to be profitable, it will start growing faster in a second phase and get margins. Sometimes, automotive giants like Daimler, BMW and Toyota, which have invested in car sharing services, use this alternative business model to enhance drivers' confidence with their car models, as drivers can try and experience the advantages and functionalities of the electric vehicle, hoping they will purchase the car for a private use in the future. Moreover, since those services have proved to be very profitable in big cities, other investors could be keener to allocate funds in similar projects, reducing their investment risks. Evidence from smaller urban areas could be a turning point for an even bigger deployment of the service.

The **end customer** is marked with yellow, signalling that the gap between total costs and relative benefits has reduced, compared to that of the original EV adoption chain. The main reason is that customers do not have to purchase the car. On the contrary, what prevents the colour to turn green is today's uncertain and scarce reliability on the electric car sharing service. Although numbers show good results, the service is geographically limited and a full customer trust is still to be earned. Once the service spreads across small-sized cities and urban centres, perhaps connecting people to bigger metropolitan areas, it will be accessible to a larger amount of customers, meaning that people's experience and belief in the electric vehicles will rise exponentially. The car as a service is a relatively new concept in the society. Traditionally, people have always considered the car as a private ownership, as something personal with a high emotional value. Hence, the shift of paradigm from ownership to service is not easy to undertake, as people would lose their emotional bond with the car. Furthermore, adults and old people have higher conversion costs than the young users, because car-sharing services are integrated with technology, smartphones, apps, credit cards, and are therefore not easy to learn. The learning process for adults requires more time and today the market is not able to evaluate whether people of all ages would positively accept and adopt the innovation. These uncertainties justify the yellow spot. In the context of sharing mobility, the interdependence between all players of the ecosystem is even more important. The e-car sharing operator needs to cooperate with several players in order to get its innovation adopted by the whole chain. The interplay includes local authorities, utilities and insurance agencies. For example, local regulations and negotiations with the policy maker are major requirements for the success of this model. They can concede subsidies and permissions to operators: for example, public authorities could grant access to limited traffic zones and support the installation of charging points under beneficial conditions. The energy provider usually negotiates the pricing strategy for the electricity consumption and can claim payback in return for the installation of charging spots. Offering people an efficient service instead of a costly ownership can benefit both the car sharing operator and the driver. As a matter of fact, the driver can gain confidence of the electric car and experience its performances, perhaps an electric car they might be thinking of purchasing. Drivers can evaluate all advantages and disadvantages and understand how the charging processes work. Electric car sharing services could therefore be used as experimental projects, aiming at a later purchase and ownership. Not owning the car gives you less comfort, but massive economic benefits. In case no car is available, you can’t drive anywhere. However, drivers can rely on smartphone apps that show the location and availability of the cars and give the possibility to book one of them.

CHAPTER 3 – Hydrogen for road mobility

3.1 Hydrogen-powered vehicles for road mobility

Hydrogen-powered vehicles (FCEVs) have been described as viable solutions to heal the fracture in the EV adoption chain (p. 12 chapter 2), though in the next future. As stated by the IEA in its *Technology Roadmap Hydrogen and Fuel Cells*, hydrogen is an energy carrier that well suits fuel cell applications that efficiently use hydrogen to generate electricity. Hydrogen is a source of low-carbon energy that can be applied to end-use applications that are challenging to decarbonise, including transport. Hypothetically, "deploying a 25% share of FCEVs in road transport by 2050 can contribute up to 10% of all cumulative transport-related carbon emission reductions" (Technology Roadmap Hydrogen and Fuel Cells, 2015:6). However, H_2 for road mobility is as promising as challenging. As a matter of fact, use hydrogen to fuel passenger cars would solve some of customers' main hurdles to turn electric, such as the EV range and refuelling time, and it would cut the whole CO_2 emissions. At the same time, according to a report carried out by the IEA, the H_2-mobility is unfeasible today because "producing hydrogen from low-carbon energy is costly at the moment. The production of hydrogen from renewable electricity could fall 30% by 2030. Moreover, the development of HRS is slow and holding back widespread adoption" (The Future of Hydrogen – Seizing today's opportunities, 2019:14). The system therefore cannot be applied to today's passenger cars, as mentioned in the previous chapter. As a matter of fact, the EV ecosystem struggles with customers' inclination not to accept the innovations, thus generating the failure of the whole chain (see figure 3, chapter 2). What restrain customers to support the electric mobility revolution are the 4 main hurdles in table 14:

Customers' main hurdles	Responsible
EV Purchasing price	EV carmakers and OEMs
EV range	EV carmakers and OEMs
Charging infrastructures	Energy providers, policy maker and the utility industry
Charging time	Energy providers, tech companies and the utility industry
Hidden Threat	**Responsible**
Electric grid capacity	Energy providers

Table 14: Customers' main hurdles and hidden threat (personal elaboration)

Hydrogen for passenger cars would necessarily require huge investment in HRS and hydrogen production. Moreover, today's FCEVs purchasing price is extremely high, as evidence from Toyota Mirai reveals: during its early market introduction phase, its price was set at around USD 60,000 (2015). The market is therefore facing the problem of **complementarity**. Ron Adner, in his book *The Wide Lens,* writes:

> It isn't enough for an auto manufacturer to produce a reliable, fast, efficient car: it also needs to offer state-of-the-art computer navigation and entertainment systems. Regardless of the nature of the complementary innovation, co-innovations risk transforms the odds of success (Adner, 2013:9,38).

The author emphasises that stand-alone innovations cannot lead to success. Hydrogen-based mobility requires therefore mastery of ecosystem strategy. As a matter of fact, there are two key components to hydrogen mobility: the vehicles and the infrastructures, and one must come first, though both require high initial investment costs. So far, automakers have been reluctant to invest in the development and commercialisation of FCEVs, since there are not enough HRS to give customers an appropriate service. According to multiple experts, – authors, academics, CEOs, consultants – most innovation failures are rooted in a shortfall in customer insight (Adner, 2013:5). If customers do not trust the innovation and do not see value in it, they will not pay the required price. The same is true for hydrogen operators, as the number of FCEVs does not exceed 7,000 units worldwide. The H_2 ecosystem needs a cooperation of an array of players to foster this transition: HRS operators should first install more refuelling points, but they ask for incentives and funds both from private and public authorities. Today's answer to fund H_2-related initiatives for road mobility is a public-private partnership that can contribute to building H_2 networks. Another big challenge is **producing green hydrogen**, thus chasing a **zero-emission hydrogen economy**. Most of the hydrogen in the world is produced from hydrocarbons and fossil fuels, resulting in harmful CO_2 emissions. Water electrolysis is today's best process to obtain high-purity hydrogen without emitting polluting substances. Worldwide, several projects have already tested the feasibility of this process: electrolysis would use the electricity generated from completely renewable energy sources (sun or wind) to power the electrolyser whereby water (H_2O) is split into hydrogen (H_2) and oxygen. Table 15 summarises the main hurdles for a widespread H_2 adoption for road mobility with related solutions:

Hurdle	**Likely solution**
FCEVs purchasing price	**-Economies of scale**: current costs for end users remain relatively high, as FCEV market penetration is limited and related technologies and infrastructures are expensive. **-Incentives for the end customer**
Infrastructures (HRS)	**-Public-private funding initiatives** **-European-led programmes**
H_2 green production	**-Water electrolysis from Renewables** (sun, wind mainly)

Table 15: Main hurdles and likely solutions for a widespread Hydrogen adoption (personal elaboration)

The **FCEV high purchasing price** is due to three main components: the fuel cell stack, the balance of plant (BOP) and the composite material of the high-pressure H_2 tank. On one hand, the high costs for the fuel cell stack and BOP are going to decrease quickly with economies of scale, making FCEVs more affordable for a larger mass-market uptake (Technology Roadmap Hydrogen and Fuel Cells*,* 2015:14). On the other hand, costs for high-pressure tanks are expected to fall more slowly, because of the expensive materials they are made of. Today, FCEVs are targeting the medium and upper size car segments and premium cars, due to at least $60,000 to buy an H_2-run car (Toyota Mirai). Compared to hybrid plug-in electric vehicles, FCEVs could enable very low-emission individual transport. If fuel cell systems and hydrogen storage tanks became cheaper and production rates were higher, FCEVs would have the potential to compete with plug-in hybrids or even become less costly. A massive decrease in the purchasing price would be mainly determined by fuel cell vehicles simpler engine composition, which does not require two different powertrains (Technology Roadmap Hydrogen and Fuel Cells, 2015:15).

3.2 State of the art of fuel cell electric vehicles (FCEVs)

Fuel Cell Electric Vehicles (FCEVs) are electric vehicles that use internally stored hydrogen and a fuel cell stack to produce the electricity required for traction. FCEVs can also be considered HEVs (hybrid electric vehicles), as they use regenerative braking to charge the battery inside the vehicle. The battery can be used to reduce fuel cell peak demand while accelerating or to optimize the operational efficiency. Since the driving performance of FCEVs is comparable to that of conventional cars and refuelling time is nearly the same, FCEVs can be the upfront technology to achieve a low-carbon mobility with fewer emissions, depending on the hydrogen generation pathways. Public policies (both EU and IT incentives) as well as private investment are key prerequisites to ensure the H_2-powered mobility a promising and successful future.

Several EU funding initiatives have been already carried out:

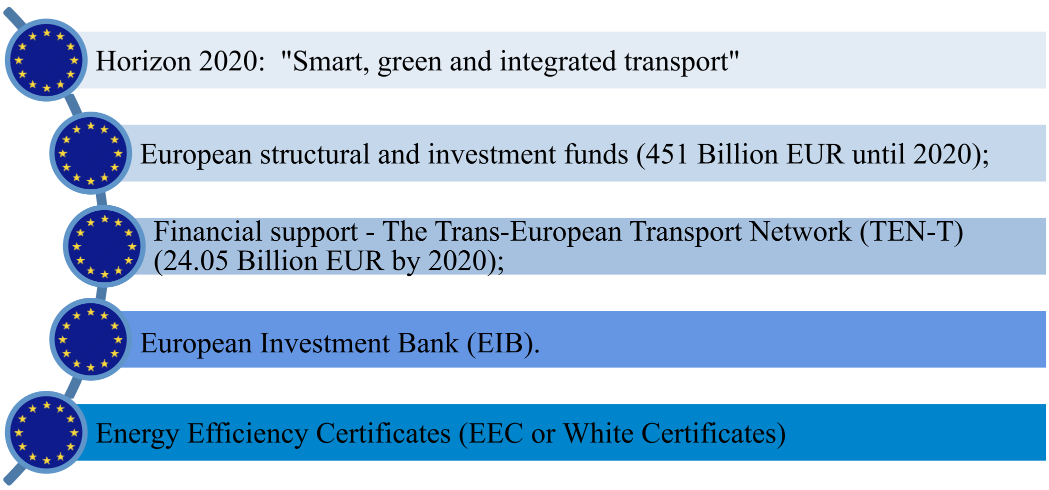


Figure 6: EU funding initiatives (Sources: European Commission, Horizon 2020, TEN-T)

Moreover, **the Directive 2014/94/EU** of the European Parliament and Council on the deployment of alternative fuel infrastructures states that national governments must set up a strategy to build appropriate infrastructures in order to achieve a reduction in the dependence of transport on oil and consequently rely on alternative sources of energy for transport, such as hydrogen.

Governments have to pursue the following targets (Hydrogen Mobility Italy, 2016:7):

- Evaluate and identify the **appropriate alternative fuels** to be introduced in the transport sector,
- Development of a **network of infrastructures** to enable the transition to zero- or low-emission mobility,
- Set up policies to develop infrastructures that can boost the uptake of **alternative fuels for public transport**,
- Identification of urban and suburban areas to **install charging or refuelling stations for alternative fuels**.

With reference to emissions reduction targets, CO_2 impacts on climate change and sea level rise, whereas nitrogen oxide (NO_x) and particulate matter like PM_{10} contribute to worsening the air quality. Satellite simulations have shown that almost half of the oceans level rise is due to man-made global warming. Projections on sea level rise suggest that sea level will rise by approximately 15-20 meters in the next millennium**.** The alarming data is that CO_2, NO_x and particulate matter are mostly anthropogenic (IPCC, 2014:4).

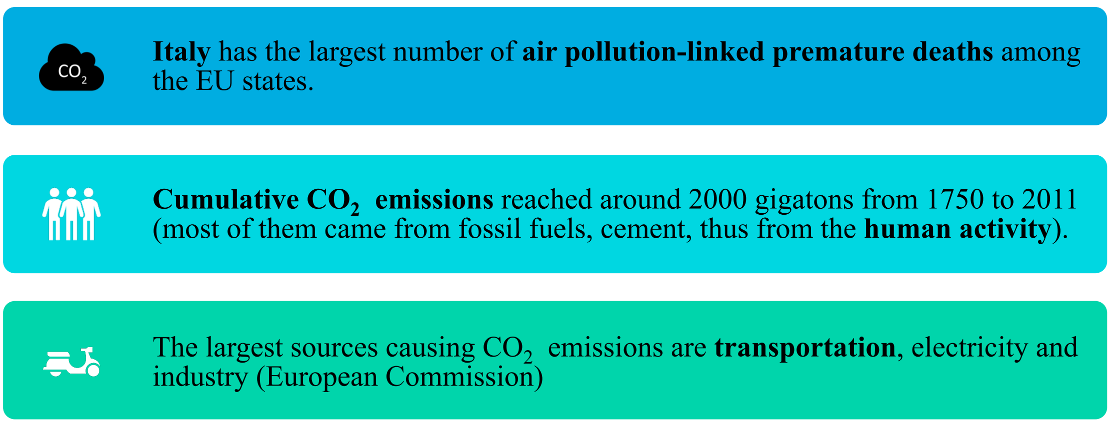
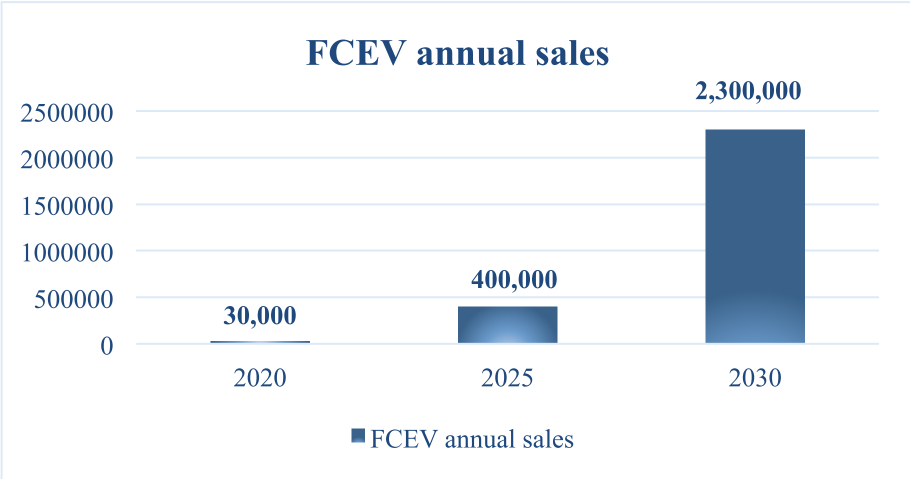


Figure 7: Impact of anthropogenic CO_2 and polluting substances (Sources: IEA, IPCC, European Commission)

According to the *Technology Roadmap Hydrogen and Fuel Cells*, the IEA forecasts that FCEVs in the three main markets (USA, EU4 (France, Italy, Germany, UK) and Japan) will reach 400,000 units sold by 2025. The share of FCEVs on total car sales will account for 30% of the whole automotive market by 2050. In the same period, the stock of ICE and hybrid vehicles with no possibility to enter the electric grid must decrease considerably to 30% of the whole vehicle stock (graph 4).

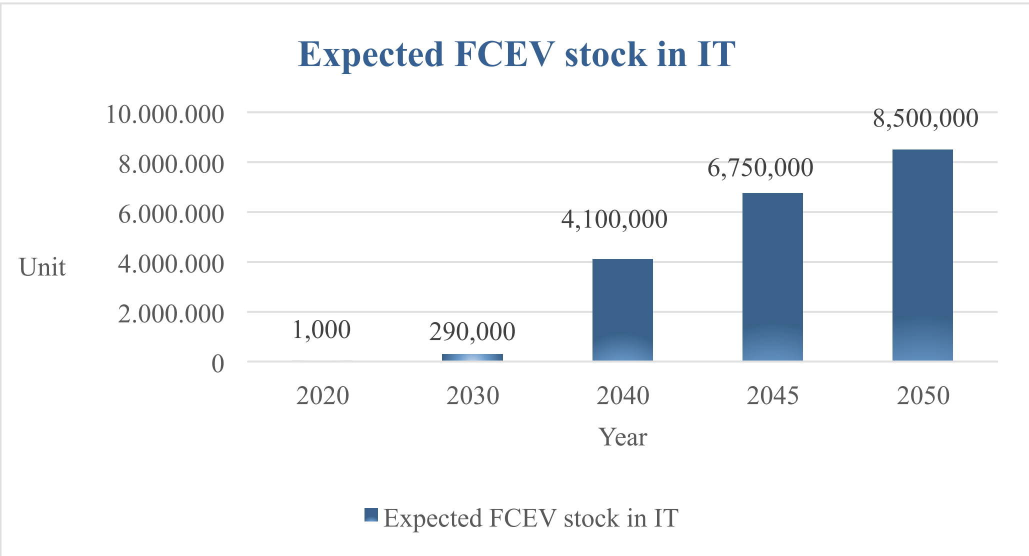


Graph 4: FCEV Annual Sales (Sources: OECD/IEA)

At a European level, there are several initiatives and organisations working on hydrogen transport alternatives that are trying to roll out hydrogen refuelling infrastructures and deploying FCEVs. The EU flagship hydrogen project H2ME brings together Europe's 4 most ambitious national projects on H_2 mobility (Germany, Scandinavia, France and the UK). The project aims at widening the network of HRS and the fleet of fuel cell vehicles (FCEVs) on European roads in order to boost a pan-European hydrogen fuelling station network.[40] Moreover, according to the American consulting firm McKinsey, **hydrogen will be the next wave in the transport sector and will enable over 30 million job opportunities in this field**. The same firm believes hydrogen will account for 1/5 of the whole electricity consumption by 2050; a promising scenario considering today's situation. According to Hydrogen Mobility Italy, FCEVs can perform as good as traditional vehicles in terms of range, consumption, refuelling time and driving pleasure. They also contribute to achieving

[40] *Horizon 2020 – Hydrogen Mobility Europe*, available from: https://cordis.europa.eu [Accessed: 1 October 2019]

ambitious goals, such as larger energy independence and a lower climate impact. For example, A 260L-capacity H_2 tank can fit a vehicle in terms of internal space and volume and can run up to 600 km with a single refuelling, making the FCEVs range comparable to that of traditional ICE vehicles. Forecasts show that FCEVs (passenger cars only) in Italy will register a significant growth in terms of stock over the period 2020-2050 (Hydrogen Mobility Italy, 2016:19). Italian expectations on FCEV stock is highly promising and probably too optimistic looking at the expected units in 2050. However, world's forecasts also show an increasing trend for FCEVs in the future, meaning that hydrogen as an energy carrier will be one of the most suitable solutions to be applied in the future transport sector. In terms of total units, FCEVs in Italy are expected to be around 290k in 2030, that is the 0.7% of the whole vehicle stock (heavy-duty trucks and buses excluded). In 2050, hydrogen-run cars will account for 20% of the whole vehicle stock and will presumably outnumber 8 million units.



Graph 5: Expected FCEV stock in Italy 2020-2050 (Source: Hydrogen Mobility Italy)

3.3 Hydrogen for public transport

Heavy-duty vehicles such as buses can be equipped with fuel-cell powertrains and evidence show that there are a few automotive industries that have been already producing FCE buses for public transportation for years. In Italy we have a bright example of innovation, the H_2 South Tyrol. Storing renewable energy in the form of hydrogen and distributing it as a "made in South Tyrol" fuel to emission-free vehicles is one of the aims of the H_2 South Tyrol project. The production plant is one of the largest and most modern of its kind in Europe, with three modular electrolysis systems capable of producing up to 180 Nm3 of hydrogen per hour. This quantity of hydrogen gas, stored in compressed form, is enough to supply up to 15 buses (covering 200-250 km daily) or up to 700 cars.[41] This successful player gives evidence that the project is sustainable and efficient, though it needs the cooperation of several players.

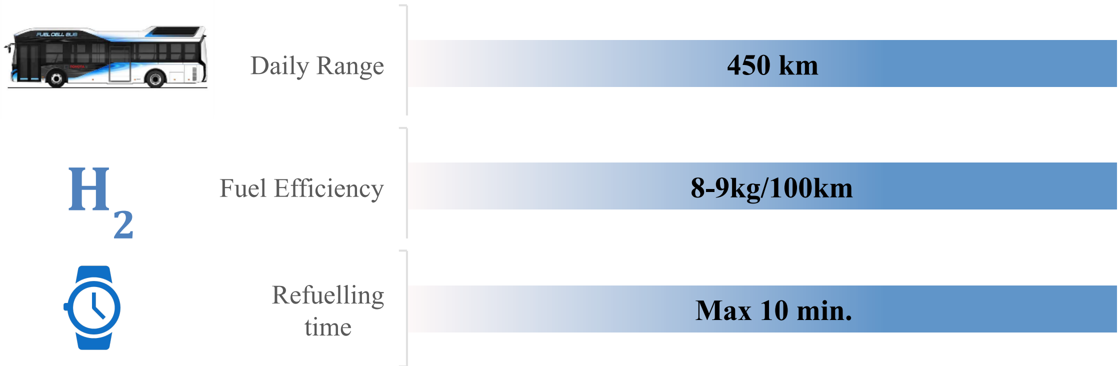
Why public transport?

	Subsidies for public transport are more common than those for passenger cars and given the high initial costs of the hydrogen transition, this model could ease the introduction of fuel cell technology in other vehicle categories.
	Co-benefits such as reduced air pollution can be an important argument for FCE bus deployment, especially in heavily polluted and densely populated urban areas. FCE buses **only emit water drops**, making it a zero-emission fuel.
	Over the last 10 years, FCE buses ran over 8 million km in Europe, proving that the technology is **flexible, efficient and safe**. Today, 84 FCE buses are going to serve public transport in at least 8 European countries (Ammermann et al, 2015:5).
	FCE buses almost have the **same daily range** of traditional ICE buses, without losing in performances and driving pleasure. They don't need to refuel during short-to-medium routes, as they rely on an extended range.
	FCE buses ensure passengers a **high level of comfort**, as the generated noises are deeply or wholly restrained.

Table 16: Hydrogen for public transport (Ammermann et al; Hydrogen Mobility Italy)

[41] *H2 South Tyrol*, available from: http://www.h2-suedtirol.com/it/ [Accessed: 1 October 2019]

State of the art of today's fuel cell buses in terms of range, fuel efficiency and refuelling time (Hydrogen Mobility Italy, 2016:11).



At a European level, although the purchasing price of hydrogen-fuelled buses is still high compared to conventional vehicles (outnumber ICE bus by at least $300,000 per unit), the TCO of FCE buses could equalise that of diesel-hybrid technology within the next decade. It means that running and maintaining a fuel cell bus will not be as much expensive as today. Oppositely, the cost per kilometre of a fuel cell bus will decrease by 8% in ten years, whereas running an ICE bus will be extremely more expensive in 2030 (+18%).

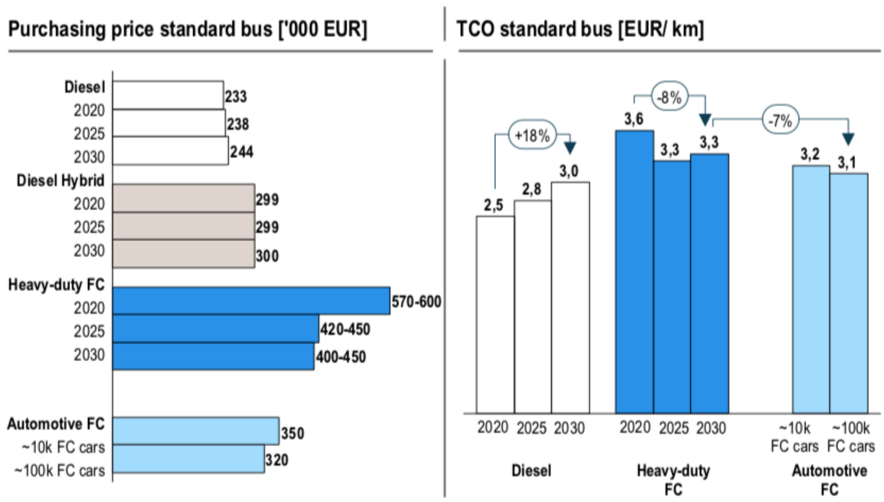


Figure 8: Comparison of bus purchasing price and TCO for different powertrains and fuel category (Source: Ammermann et al, 2015:28)

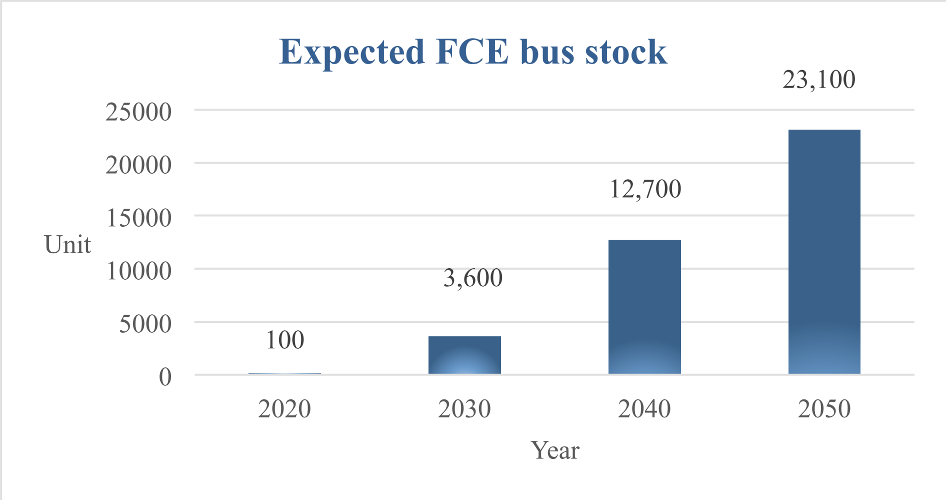
Figure 8 clearly points out that a purchase price premium to the ICE bus will remain also in a long-term perspective. Higher prices are also driven by costly warranties that currently need to be provided by bus OEMs for FCE buses. With an increasing maturity of the technology and economies of scale, these costs will fall (Ammermann et al, 2015:19). Costs for FCE buses are mainly driven by the powertrain components and system integration. When seizing synergies with passenger cars will be achieved, costs for fuel cell stacks and systems as well as for batteries can fall considerably. Lower costs can also be achieved by hydrogen storage systems, though the on-board tank cost will depend, to a large extent, on scale effects (Ammermann et al, 2015:25-26).

With reference to Italy, the purchasing price per unit of hydrogen buses will decrease significantly from 2020 to 2050, according to Hydrogen Mobility Italy. The same report believes that public transport operators will be key players to boost the H_2 transition towards a larger adoption of alternative sources in the transportation sector, mostly in a first phase.

Year	Diesel Bus	FCE Bus
2020	**233,000€**	**570,000€**
2030	244,000€	320,000€
2040	249,500€	318,400€
2050	**255,000€**	**316,000€**

Table 17: Bus purchasing price for fuel category 2020-2050 (source: Hydrogen Mobility Italy)

The expected prices for FCE buses in Italy will fall by up to 44% in ten years, whereas diesel buses will increase by 9% in the same window. The scenario seems to be far too promising and expectations on price fluctuations mostly depend on technological innovations and public-private incentives, the main drivers of the transition. Public transport operators have been selected to be main contributors for the initial launch and adoption of hydrogen-related technologies in the transportation sector. Hence, FCE buses are expected to fill our roads before passenger cars and will replace a quarter of Diesel-run buses by 2050. As the graph shows, **in 2050 the FCE buses fleet will count 23,100 units, that is the 25% of the whole bus stock**.



Graph 6: Ramp-up scenario of FCE bus stock (Source: Hydrogen Mobility Italy)

3.4 Hydrogen refuelling infrastructures

As mentioned previously in this chapter, H_2 adoption in the transportation sector must face the problem of infrastructures. The deployment of a network of **Hydrogen Refuelling Stations (HRS)** is a basic prerequisite to meet customers' needs and increase their interest in H_2 mobility, as well as a big incentive to boost FCEVs mass purchase. Image 4 shows the estimated number of HRS in Europe in the 5 largest markets for the fuel cell technology.

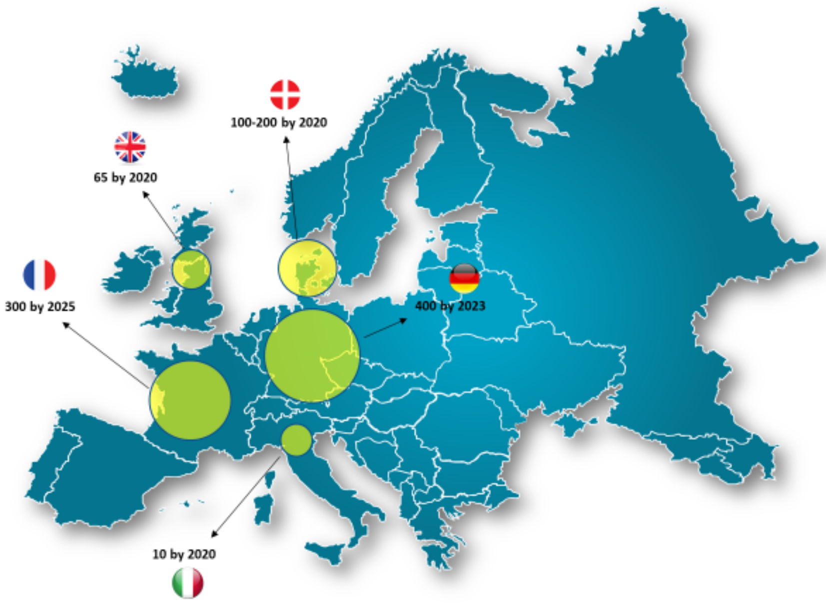
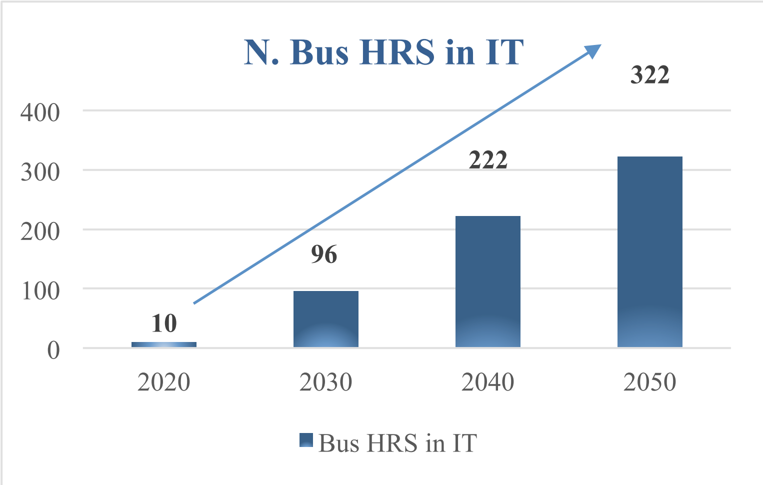


Image 4: Number of HRS in the 5 largest EU markets (personal elaboration) (source: H2Mobility)

Germany, France and Denmark will contribute the most to integrating the European network of H_2 stations, while Italy will grow at a later stage. Italian investment in hydrogen refuelling infrastructures will exponentially increase from 2020. The combined amount of HRS for passenger cars and FCE buses will presumably reach 3,000 units in 2040, widening even more by 2050, when the expected amount will be 5,590 units. (Hydrogen Mobility Italy, 2016:25). With reference to FCE buses, in all EU-countries the number of HRS is constantly increasing. Forecasts for the Italian market portray a growing scenario that, along with passenger cars' H_2 stations, will provide public transport operators with a higher number of HRS for buses, as shown in graph 7.



Graph 7: HRS for FCE buses in Italy 2020-2050 (Source: Hydrogen Mobility Italy)

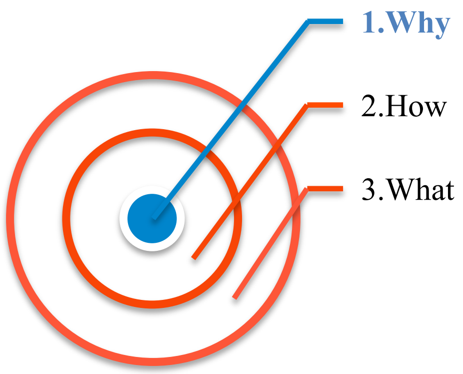
The positive trend of HRS for road public transport supports En Future's project to invest in alternative energy sources to improve the mobility in the Veneto region. After introducing the project with future estimates on the H_2-related mobility market and data on the increasing Bus stock, the thesis now focuses on En Future's marketing campaign and its role in the transition towards alternative energy sources for public transport services in the Veneto region. En Future, an Italian-based company that deals with renewable energy, energy storage systems (ESS) and investment in sustainable mobility projects, has launched a marketing campaign to make the region aware of how important it is to re-design the old-fashioned ICE mobility model by promoting hydrogen as the only gasoline of the future. I have personally worked on the campaign that aims at pointing out the reasons why the company has been involved in this project and what benefits hydrogen for mobility can bring to our territory.

3.5 En Future marketing campaign

During my internship at En Future, I had the possibility to work on a **R&D project in the field of hydrogen-based mobility**. Before describing the project in more details, it is important to briefly introduce the company's core business and its responsible and sustainable approach towards climate-related issues. En Future has been investing in renewable energy sources for years, with the main goal to give its customers and partners the pleasure of using the planet's main resources to heat or cool their houses. Its core businesses are photovoltaic systems, ESS and heat pump installations, all dealing with green energy from natural sources. In the past few years, the company has also branched out into sustainable mobility projects and is planning to invest even more in this field in 2020-2021. En Future does not produce nor sell any electric or hybrid vehicle but is willing to launch marketing campaigns to make citizens aware of how important it is to turn into a more sustainable and eco-friendly mobility. In this direction, the company bought and imported some Fiat 500e from California (US) to evaluate the reliability, capabilities and performances of the e-car, with the purpose to promote the electric mobility in the Veneto region and to use the Fiat 500e as a company fleet car. The same company has recently realised that hydrogen is the future of decarbonised mobility. Hence, it has planned to **set up a multi-player strategy to redevelop the public transport services in the Veneto region**. The marketing campaign I have worked on has been made in PowerPoint format in two versions: the original file in Italian language has been then translated into English, because the company's affairs also involve international players. Throughout this section, I have decided to report in the thesis some of the slides I made for En Future to explain what the main purpose of the company is and how it has planned to fulfil its project, as image 5 displays below.

Image 5: En Future's mission (personal elaboration - En Future srl All Rights Reserved)

En Future believes that an ethical approach with clients as well as with our planet is the main responsibility of the company. Hence, it decided to launch this initiative, in partnership with other regional and non-EU players, to overturn today's urban and suburban mobility. The campaign has a pure promotional approach, meaning that it does not mention partners, commercial deals or legislative references. It rather refers to the mission, the solutions and how this model can be applied efficiently to public transportations in the reference area.



Why comes first. What matters most is the ethics of our actions. We want to adopt a certain belief that is respectful towards the environmental challenges and able to respond to people's needs.

Figure 9: The golden circle (personal elaboration)

1. Why we do it is En Future's main responsibility. Our desire to innovate aims at improving the community life and renewing the region we live in. Together we can show other people that progress and change are possible through hard work, cooperation and ambitious projects: we have one. Now we need to act concretely and stop promising. Actions speak louder than words.

2. How we do it describes the process we want to adopt to fulfil our final goal. We have planned to harness the sun power to generate electricity. Our high-quality photovoltaic modules ensure a high efficiency and productivity, and can produce green energy in full respect of the environment. We want to combine photovoltaic plants with hydrogen production facilities, thus putting together two technologies that rely on Renewable Energy Sources (RES), both striving for a single goal.

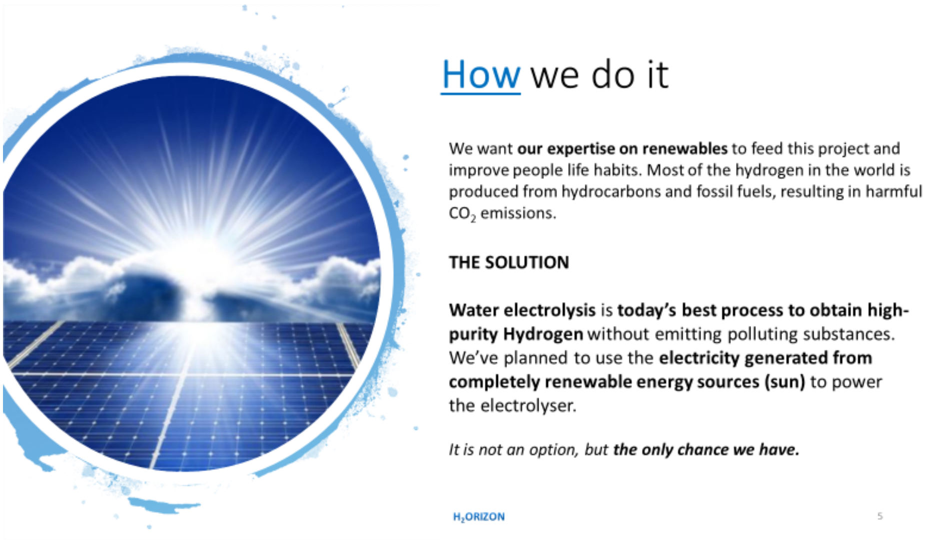
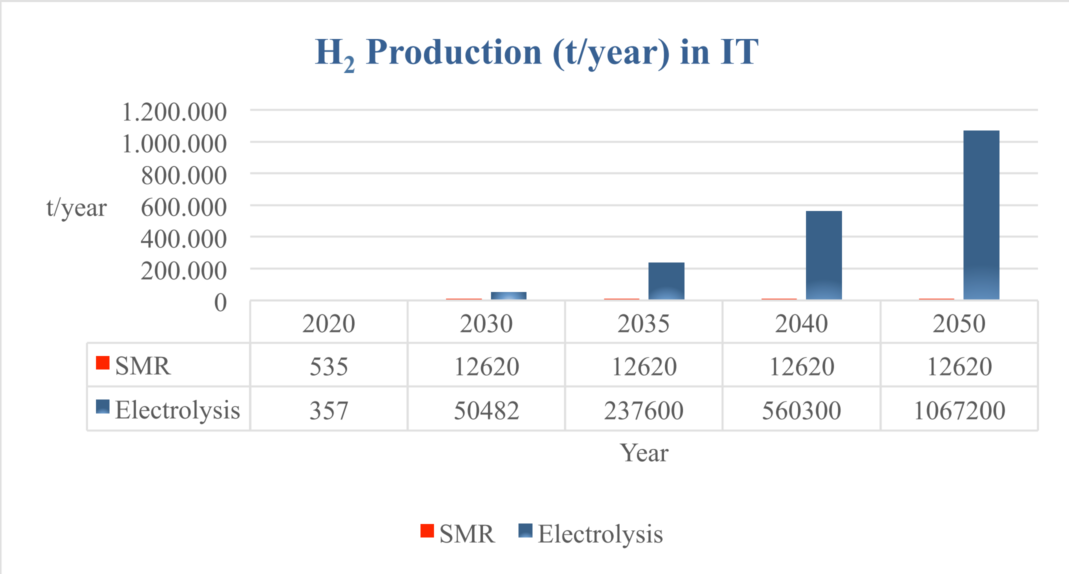


Image 6: En Future's method (personal elaboration - En Future srl All Rights Reserved)

Water electrolysis technology is key to enabling a decarbonised energy system, increasing proportions of intermittent renewable generation and acting as an energy vector (Hydrogen Europe, 2018:12). According to a future scenario theorized by Hydrogen Mobility Italy, H_2 production by Steam Methane Reforming (SMR) will stop growing from 2030, meaning that world's biggest H_2 producers will not rely on Methane as the main element to yield hydrogen. On the contrary, the availability of electrolysis facilities will deeply increase from 2020, attesting the massive contribution of RES to produce green hydrogen. By 2050, electrolysers will produce 1 million tons of H_2 a year approximately. The exponential growth of electrolysis from Renewables is as relevant as encouraging for En Future's project.



Graph 8: Comparison of H_2 production by SMR or Electrolysis (Source: Hydrogen Mobility Italy)

The huge economic growth of the last century carelessly considered the harmful impact of solid, liquid and GHG emissions on the environment. Our answer is **hydrogen production from Renewables**. Large and high-power photovoltaic plants can harness solar energy to extract hydrogen from water. This is the only method with no fossil fuels involved that does not release any polluting or harmful substances. The resulting hydrogen would be used as an energy vector to power fuel cell vehicles (FCEVs). European policies have set target to reach a share of 30% RES electricity by 2030. This growth is important to unfold the full potential of Hydrogen as a road fuel to become carbon neutral from a well-to-wheel[42] perspective (Ammermann et al, 2015:33).

En Future has identified two main methods to produce hydrogen:

1. H_2 production in centralised plants by water electrolysis from Renewables with H_2 transport by trailer to the HRS (Hydrogen Refuelling Station).
2. H_2 production on-site at the HRS (Hydrogen Refuelling Station) by water electrolysis from Renewables.

A fast transition towards a «green» H_2 production by electrolysis would fulfil the following goals:

[42] Definition: a *well-to-wheel* analysis assesses the environmental impact of a given product or service throughout its lifespan. Source: Eko-Wiki.

- Larger **uptake of fuel cell vehicles** with subsequent **reduction of CO_2, NO_x and particulate matter;**
- Strengthen **country's energy independence**;
- Create **new job opportunities**: the shift of the demand towards carbon-free fuels calls for new competences and experts in this field;
- Larger **integration of Renewables** (solar, wind, water) for energy production.
- **Decarbonisation** in various industries;
- **Multi-sectoral applications**: hydrogen is versatile as it can be applied to rail and maritime transport.

Carbon-free Hydrogen production is possible today:

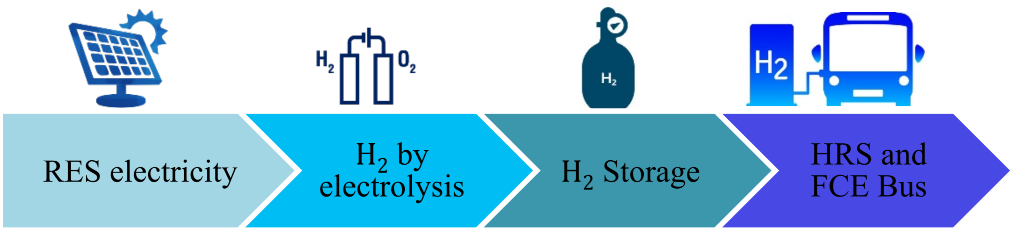


Figure 10: Production cycle of carbon-free hydrogen (personal elaboration - En Future srl All Rights Reserved)

En Future is mainly responsible for RES electricity production, as it will supply the photovoltaic modules. Other players will handle H_2-related equipment and the electrolysers. A foreign company is expected to supply the fuel cell buses that will replace the endothermic fleet. This is a clear example of a cross-sectoral ecosystem that involves plenty of experts in various fields and needs co-innovations to be successful.

3. What we do outlines our commitment to the project, the final goal and the process we have planned to pursue in order to make it possible.

FINAL GOAL		Substantially **modify urban and suburban mobility** in the Veneto region by replacing endothermic buses with a fleet of **hydrogen-powered buses** for public transport.
THE PROCESS		**Redevelop degraded areas** and use them to place both hydrogen storage sites and hydrogen production facilities from renewable sources, with full respect of the environment.

En Future has selected 4 macro areas for the installation of the high-power photovoltaic plants. The deployment of Hydrogen production facilities from Renewables is a good opportunity to restore those areas to a healthy condition and turn them into economic hubs. **The 3R framework** highlights the commitment of the company, not only from an economic and environmental point of view, but also from a social perspective.

The 3R	
	React **Our mission is reacting to today's environmental challenges**. These areas are ideal to install photovoltaic plants for H_2 production and thus reducing CO_2 emissions.
	Redevelop The **redevelopment** of degraded areas is a good opportunity to **renew abandoned areas** that are a social, regional and financial loss. These areas also worsen the stunning landscape of the Veneto region.
	Revolutionise The 4 areas will not only be used for H_2 production, but they will also create **new job opportunities**, **boost** the **regional economy** and contribute to substantially **modifying the current mobility**, in all sectors.

Table 18: The 3R framework (personal elaboration - En Future srl All Rights Reserved)

En Future believes that hydrogen is the only feasible alternative to fossil fuels that can run next-gen zero-emission vehicles. Concretely, the company has identified two solutions to fulfil its final goal (image 7). As mentioned previously, En Future is not the only player involved, but it shares financial and legal responsibilities with the other companies working on the project. For this purpose, companies have agreed to set up a Special Purpose Vehicle (SPV) to limit financial risks and fulfil specific objectives together. The two proposals outline what tasks the SPV and the public authority are respectively liable for. With reference to Solution A, the SPV will be responsible for handling Hydrogen production and storage, whereas in solution B the SPV will both fulfil H_2-related objectives and supply the new bus fleet. Today, the agreement has not been performed yet, as the project is still in its infancy.

Image 7: En Future's proposal (personal elaboration - En Future srl All Rights Reserved)

In order to achieve the expected results for the FCEV market, today's system must evolve into a solid multi-player ecosystem that relies on collaboration and multi-sectoral innovations. The H_2 transition needs a solid plan as well as funding initiatives and investors. In my research study with En Future, I have outlined a potential roadmap (Figure 11) for a successful H_2 transition:

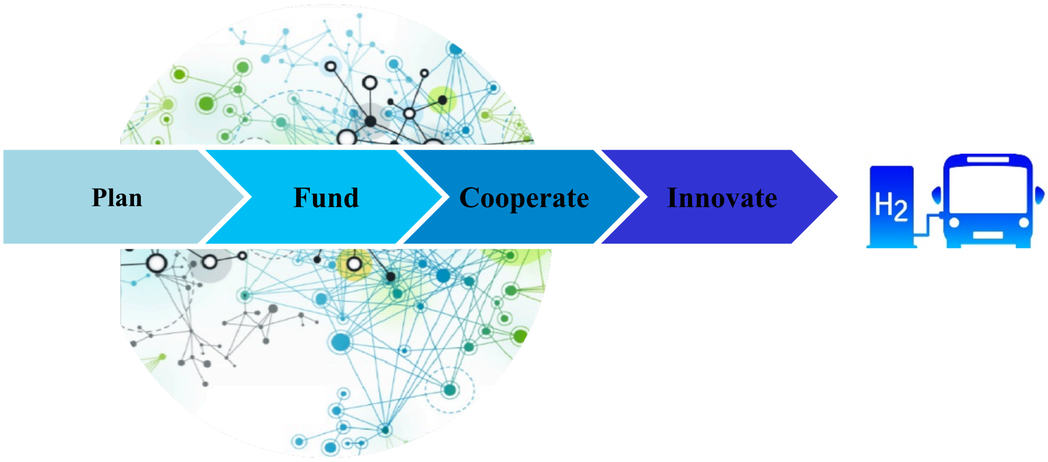


Figure 11: Roadmap for a successful H2 transition (personal elaboration - En Future srl All Rights Reserved)

Plan: set up a solid strategy to install hydrogen refuelling stations (HRS) and to produce hydrogen from Renewables. Identify the appropriate areas and implement the required infrastructures.

Fund: both legislative and financial support from governments at a European, national and regional level. Ambitious projects are expensive and require large investment and funding initiatives.

Cooperate: participation of an array of players in the hydrogen industry (creation of an ecosystem with interconnected relationships). Several players must cooperate to boost the technology related to H_2 mobility.

CHAPTER 4 – A Proposal of an integrated model for future road mobility in the Veneto region

4.1 Overview of the mobility in the Veneto region

Mobility is the lifeblood of our cities (An integrated perspective on the future of mobility, 2016:5). In the Veneto region, there are a lot of roads, highways and, due to a high population density, most of them are congested, noisy and contribute to emitting polluting substances. According to E_Mobility 2019, the Italian Conference on the Electric Mobility held in Milan last September, **in Italy there are almost 39 million passenger cars**, which are a huge quantity considering Italian whole population (60.55 million people). In the same region, people benefit from mobility services everyday at any time, because this territory is a relevant economic hub for the regional and national economy. As a result, the huge flow of people that flood everyday in this area causes road traffic and smog that worsen the beauties of our urban spaces, undermining the region's tourism potential. What is true is that the Italian population have always preferred to move by car because private vehicles simplify their travel experience. On the one hand, public transport services are inefficient in most Italian cities and therefore people prefer to use private vehicles. On the other hand, driving your own vehicle is easier as people do not need to check timetables and can generally reach their final destination in a shorter window of time. Thanks to its strategic location, Veneto is a crucial junction to other European countries and has a lot of commercial traffic roads that cross the region, increasing the number of the circulating vehicles. Regionally, in the areas of Treviso, Padua, Venice and Verona, a lot of manufacturing and industrial activities take place. As a matter of fact, the same areas are famous to host a lot of small and medium-sized enterprises (SMEs) that have always massively contributed to the regional economy and still determine nowadays a widespread demand for mobility. Moreover, Veneto attracts visitors and people from all over the world, thus increasing transits and road mobility. What is more, is that the Veneto region has a high degree of urbanisation, meaning that most of Veneto's municipalities are highly populated, which results in urban sprawls. According to ISTAT (Italian National Institute of Statistics), almost 54% of the Veneto population lives in medium-urbanised municipalities and another 40% in highly urbanised municipalities (PIMMS CAPITAL, 2012:39). This is a relevant issue for the efficiency of Veneto's mobility, especially concerning public transport impact on sprawled territory. It is both difficult and challenging to deliver a sufficient and efficient network of public transport services and infrastructures in congested urban areas. A study carried out by ISFORT (Italian Higher Institute for Education and Research on Transport) in 2011, **shows that people in the Veneto region moved by motor vehicles in 81% of the cases, of which 78% by private car.** In ten years (2001-2011), the overall number of heavy and light duty vehicles accessing Veneto's motorways increased by 17%, with a considerable growth of passenger traffic (+20%) (PIMMS CAPITAL, 2012:39). The steady growth of road traffic and the reliance on passenger cars is alarming considering today's environmental challenges and social issues. However, European targets for future sustainable mobility are threatening the current transport system in the Veneto region as well as in Italy. For this reason, public authorities with the partnership of Veneto's SMEs and citizens must work together in order to find valuable solutions to pursue an innovative sustainable model for future road mobility.

An overview of Veneto's most critical challenges related to road mobility is essential to understand what solutions might overturn today's system:

1.People prefer private cars for daily travel

2.Public transport services are often inefficient and disconnected

3. Accessibility, frequency and speed of public transport reveal territorial inequalities

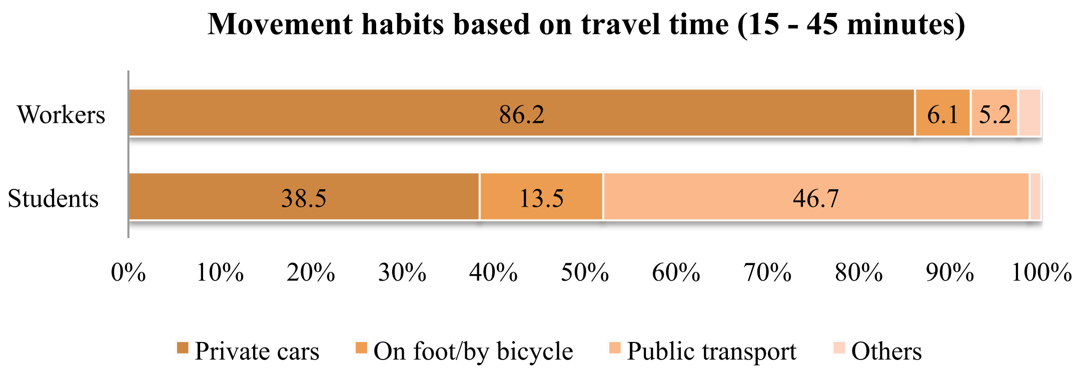
4.Veneto is a region of transit to other EU countries

5.Urban settlements are highly frangmented

6.Road mobility contributes to polluting and ruining our ecosystem

7.There is a lack of infrastructures and regulations for alternative fuel vehicles

One of the main goals to be fulfilled is **reducing the reliance on private cars** of Veneto's inhabitants. Statistics show that almost 73% of people in this region use private cars 3-4 times a week regularly. The frequency rate of passenger cars has increased in the window 2009-2019, because data on current Italian passenger car market reveal that people tend to purchase cars rather than moving by public transports or alternative means of transport. Comparing people different habits in term of daily mobility, students rely on private cars less than workers. Although cars are still the most prevalent vehicle in both categories, public transport services take the lead among students to reach universities or schools for travel times between 15 and 45 minutes or more, whereas workers are keener to drive cars to get to their offices in the same window. Time is a crucial factor that affects urban mobility and people's habits.



Graph 9: Workers and Students' movement habits based on travel time 15-45 minutes in the Veneto Region (2009) (Source: ISTAT, processed by the Veneto Region)

As the graph highlights, a critical **86.2% of workers still prefer to drive private cars to go to work.** There are four main factors that lead people to use private vehicles rather than other means of transport. Accessibility and comfort are the main hurdles that limit people to benefit from public transport services in the Veneto region. This is mainly due to Veneto's conurbations that require frequent travels to move people from one place to another in a short period of time. Overall, people in this territory think that public transportations are not very functional, difficult to access and often uncomfortable. Table 19 lists the four factors for not using **public transport services**:

Availability	People believe there is a lack of infrastructural connections related to public transport services. Some users cannot reach their final destination because rail or road connections are missing.
Accessibility	The widespread coverage of different public transport networks is inefficient and limited. As a consequence, people complain about match time, interchange, parking issues, frequency of travels and time to reach train or bus stations on foot or by bicycle.
Time	Public transports are often late, so people prefer their own car to avoid delays.
Others	Public transports are too crowded, noisy, often dirty and expensive.

Table 19: Main factors for not using public transport services (Source: ISFORT)

The fact that **Veneto is a region of transit** to other European countries is both an issue for road mobility and an economic advantage, as trade and commercial routes are important for the Italian and regional economy. As a result, the large infrastructures designed for long journeys affect the environment and worsen the beauties of our landscapes and cities as well as the capillarity of interconnections to Veneto's urban contexts. However, supranational interests claim international connections and pledge that the principle of open economy in the European Union is fulfilled. **The fragmentation of urban settlements** is a typical feature of the region and determines costly investment to ensure citizens high-quality public transport services. This is a relevant issue for future road mobility, because the location of most municipalities pushes commuters, workers and students to use private cars, as public transports do not efficiently connect small urban areas to bigger settlements, where most citizens go to work, school or university. **Statistics show that road transport account for 28% of total CO_2 emissions in the Veneto Region.** The regional vehicle fleet is responsible for 15% of total particulates and 47% of nitrogen oxide emissions. Moreover, the current vehicle fleet is generally 'old' and 44% of circulating vehicles meet emission standards equal or below Euro 3. The use of private cars, largely due to widespread urban settlements, entails some externalities:

- Road traffic affects the environment and the ecosystem, and impacts on climate change, greenhouse effect, acid rain, pollution, etc;

- Road traffic ruins the urban public spaces Road traffic affects people's health and their quality of life, often causing accidents, diseases, injuries, etc;
- Road congestion can lead to stressful situations and nervous behaviours.

With reference to the Po Valley, it is one of Europe's most polluted areas, where ozone levels are three times higher than the recommended safe limits. The main responsible is road traffic. Compared to other Italian territories, the Veneto region is facing difficulties to invest in a more sustainable mobility. There are several reasons that limit the uptake of sustainable forms of mobility like the EVs and FCEVs. It is not only the purchasing price and the recharging time that feed scepticism, but it is also the lack of a governmental regulation and infrastructures that slow down the development of low-carbon vehicles. According to Adiconsum, the Italian Association for Consumer Protection and Environment, public authorities in partnership with players of the EV market should foster three main actions to simplify Italian electric mobility:

A. **Reduce the costs for recharging**: the Italian EV charging fee is the highest among all European countries, even more costly than that for home electricity;
B. **Install recharging infrastructures in existing petrol stations**: drivers have always been used to fuel their cars in petrol stations, but electric charging points have been mostly installed in Points of Interest like shopping malls, cinemas and parking areas so far. EV operators have ignored the importance of maintaining customers' habits to charge their vehicles. It would be easier for them to recognise petrol stations as their main place to recharge EV batteries. This is part of a simplification process: people are experiencing new vehicles, with smart technologies and new recharging methods. There is no reason to make it even more difficult. The EV market must limit conversion costs as much as possible;
C. **Update the rules of the road for all kind of electric-powered vehicles**: as other forms of mobility are becoming increasingly popular (e.g. two-wheeled electric vehicles), cities and governments must upgrade and issue stricter regulations. With unclear traffic laws and a worrisome road safety, people would prefer to run traditional vehicles, slowing down the uptake of sustainable forms of mobility.

4.2 A new model of mobility

The future of urban mobility depends on how a number of social, economic and technological trends and innovations will integrate to reshape the traditional mobility. Past mobility is mainly based on a product-ownership model, resulting in congested, noisy and polluted cities. This model was predominant and did not match up well with other forms of mobility like public transportations, cycling or walking. The space for buses, bicycles and pedestrians was limited and road safety was undermined by a huge amount of vehicles. Over the last few years, people started to put liveability and sustainability higher on their agendas and world's organisations as well as local governments began to set up policies to overturn the old gasoline-based model. The identification of new trends and alarming challenges enabled the initiation of the conversion process towards a more sustainable mobility.

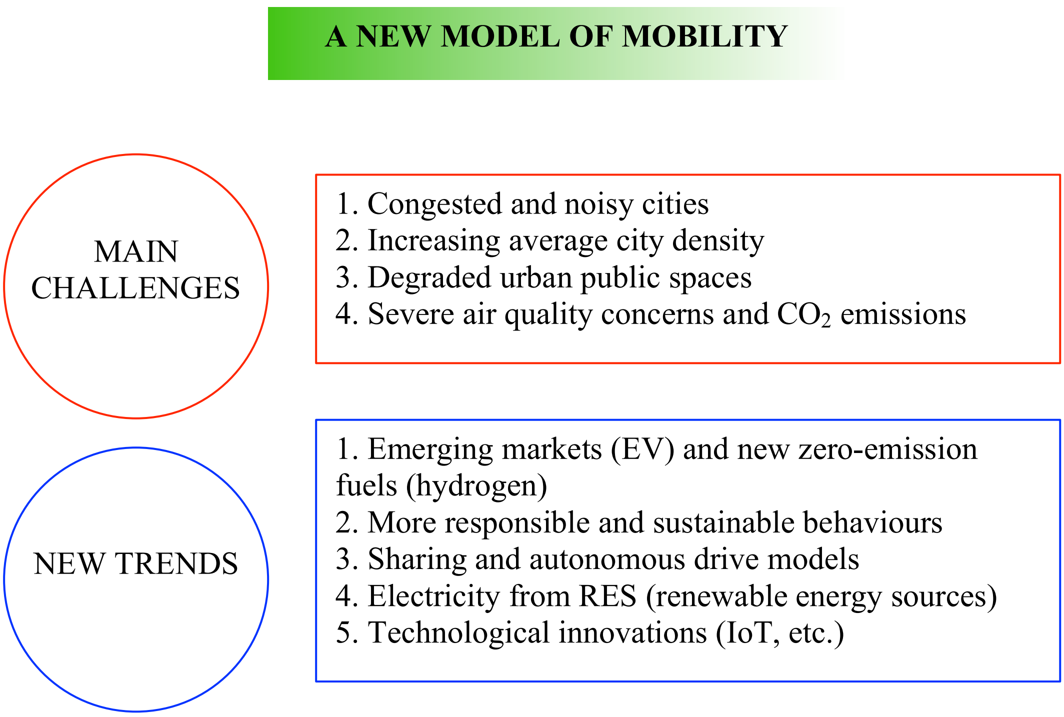


Figure 12: Challenges and trends affecting the mobility in the reference area (personal elaboration)

All these main challenges are affecting the Veneto region, making it a good candidate to head towards other mobility trajectories. Before introducing the proposed integrated model, it must be said that other local conditions, such as wealth and governmental capabilities, will be key factors to determine what direction the mobility will take and how quickly the new model will be effectively applied. According to the Veneto Region, there are almost 4.9 million inhabitants living in this area (data update 2017). Most of them live in the province of Padua, Treviso, Verona, Vicenza and in the Metropolitan City of Venice. The model predictions are based on previous market analysis (chapter 1, 2 and 3), incoming trends, general knowledge and the inevitable change of our behaviours towards the environmental issues.

4.2.1 A proposal of an integrated model for future road mobility

The model is called *Greener, Private and Seamless Mobility* and proposes a new perspective for future road mobility in the main conurbations of the Veneto region, with a major focus on the Province of Padua and the Metropolitan City of Venice. The model is divided into time intervals (2030, 2040 and 2050), because some innovations and trends will presumably occur later than others. As a matter of fact, the transition towards a more sustainable mobility is a step-by-step process that will gradually impact on the society.

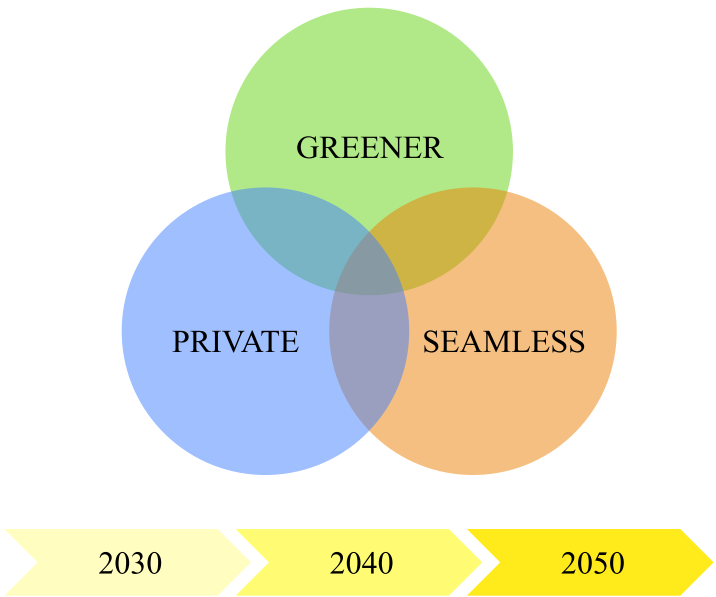


Figure 13: A proposal of an integrated model for future road mobility (personal elaboration)

GREENER MOBILITY

A greener perspective for future mobility encompasses all environmental and air quality concerns as well as degraded urban public spaces. Our region has an enviable history and marvellous attractions, ranging from historical buildings and monuments to stunning views and wonderful landscapes. As a consequence, all these elements combined must be protected and municipalities should give them even more value. The problem is that congested cities ruin the beauties of our urban spaces and the enormous amount of vehicles increases the necessity to create new parking areas. Parking areas are a main concern, as they often replace green areas and parks. The conversion of the latter into parking areas is a consequence of private road traffic. Moreover, the expected population growth could increase private cars demand to unsustainable levels.

PRIVATE MOBILITY

As described earlier in this chapter, people in the Veneto region have always been keen on car ownership and the advent of technological and customised vehicles will probably maintain consumers' appetite for private cars in a medium- to long-term perspective. The alarming factor is that, with lower costs of future electric vehicles and electricity, the amount of passenger cars could increase and generate more congestion. This foreseeable situation is unsustainable for our region. As a consequence, municipal and regional authorities must find viable solutions to avoid this scenario. Although private cars will probably maintain its dominance in the future, other forms of mobility must improve the liveability and sustainability of our urban and suburban environment. The table below lists a variety of solutions to make our region greener and open to other forms of mobility that may emerge to pursue a low-carbon era with fewer private vehicles.

GOAL 1: REDUCE PRIVATE CARS

SOLUTIONS

1.Foster electric shared-mobility models that enable zero-emission travels in the city centres. Car-sharing models have already appeared in Milan, Rome and Turin and are starting to appear in Veneto as well. However, to reduce congestion even more, it would be reasonable to incentivise **two-wheeled vehicles** like e-scooters and bicycles. A larger uptake of these vehicles would require newer road safety regulations, such as dedicated lanes and insurance policies. Existing bicycle lanes could be adapted to electrified kick scooters without requiring massive investment. Electric kick scooters can achieve a good speed, can commute short distances and occupy less urban space than conventional motor scooters. What is missing is a stricter regulation for parking them, without being hazards in pedestrian walkways or bicycle lanes. Good solutions to curtail disorderly parking would be dedicated docks at the railway stations and shopping malls or painted parking areas alongside streets. For example, kick scooters would be ideal in cities like Padua that welcome a lot of commuters daily.

2.Improve public transport services to connect city centres to suburban areas. Most commercial activities and universities are located in Padua, Verona and in the Metropolitan City of Venice, meaning that there is a considerable daily influx from suburban contexts to bigger urban areas. Moreover, data show that almost 80% of workers drive their private cars to go to work, thus generating congestion in highways and a huge amount of harmful emissions, both for humans and the environment. As a consequence, local governments should increase the travel frequency of trains and minimise delays, one of people’s main concerns. Rather than expensive underground systems, they should reshape today’s bus transportation system, how?

- **Replace endothermic fleets with electric or hydrogen-powered buses**: the first full-electric fleet is going to run in Milan by 2025, whereas other regional project are planning to invest in hydrogen-run buses, as they ensure greater performances and zero emissions. The Metropolitan City of Venice could harness lagoon’s water to produce hydrogen by electrolysis to fuel buses or cars.

- **Deploy dedicated bus lanes to bypass traffic and avoid delays**: if we could promise people there will not be any more delays, most of them would surely consider travelling by bus. For example, dedicated lanes have been working in Innsbruck for years and I have personally proven their efficiency. Punctuality places itself at the top of people's main requirements.
- **Boost electric shuttle services that connect suburban sprawls to the railway stations**: in the area of Padua, Verona and in the Metropolitan City of Venice, a lot of commuters tend to move by car to the nearest railway station to reach the university or office. If local municipalities launched public transport initiatives to connect small urban areas to the railway stations, they would ease private cars use and their contribution to road traffic and emissions. Electric shuttles would be feasible today because they should travel short distances, keeping its range below critical levels.

3.Restore urban public spaces: U-lab, a company involved in urban regeneration processes, has recently affirmed that mobility is the main actor of an urban context (E_Mobility 2019). As we are running out of green spaces in our cities, the same company believes that the shift toward the electrified mobility and a lower amount of circulating vehicles can restore urban public spaces back into something natural and beautiful. For example, U-lab has stressed its desire to convert some of the existing parking areas into greener spaces, where tourists and citizens can relax and enjoy leisure time. The availability of green spaces can positively influence people's mood and increase their propensity to walk and cycle, thus affecting mobility patterns.

GOAL 2: BOOST ALTERNATIVE FUEL VEHICLES (EVs, FCEVs)

SOLUTIONS

As solution 1 suggests, it would make sense to shift away from car ownership toward sharing models or a range of alternative transportation services. However, in fast growing metropolitan areas with a high population density, the demand for private mobility remains high. As a consequence, governments and operators should incentivise the purchase of alternative fuel vehicles, when people decide to replace ICE cars. How?

1.**Introduce zero- or low-emission zones in urban areas**: this regulation moves in parallel with future mandatory electrification. Banning drivers from entering some specific areas with their traditional vehicles lead them to rely on alternative transportations, either public transport or lower-emission vehicles.

2.**Bolster the electric grid capacity**: Energy providers operating in the region must make sure that the electric grid fully absorbs extensive electrification of transport. As a consequence, investment in decentralised renewable energy production can generate additional electricity, thus preventing brownouts. In the Veneto region, nearby the Venetian lagoon, there are degraded unused areas that might harness sun power thanks to high-power photovoltaic plants to produce RES electricity or hydrogen. These areas do not impact on tourism, as they are located far from Venetian major attractions. RES production in unused and abandoned sites has several side benefits: it can redevelop the territory, create job opportunities and support sustainable goals to produce zero-emission electricity. Moreover, regional incentives and fiscal deductions are making residential solar panel installations cheaper for private citizens, who might use decentralised generation and storage to power their vehicles, becoming energy independent.

3.**Deploy sufficient charging infrastructures in relevant and strategic places:** the problem of charging mainly affects occasional long-range journey, such as those in highways. For this reason, today's availability of charging points along north-eastern highways must improve to support the EVs larger uptake.

4.**Autonomous electric vehicles**: GlobalData, a renowned analytics company, forecasts that autonomous vehicles (AVs) are set to be the fastest-growing automotive sector, achieving more than 11 million sales by 2033.[43] However, in dense metropolitan areas where traffic is more than an issue, such as in the Veneto region, autonomous vehicles become less attractive and harder to operate. On the contrary, AVs could hit luxury market demand because of their high purchasing price and exclusivity factor, whereas the core of the vehicle fleet would remain human driven, at least by 2050. The integration of self-driving cars with human-driven ones will be of the main challenges of future road mobility, though unforeseeable nowadays.

SEAMLESS MOBILITY

As part of efforts to decarbonise the economy, governments are trying to change the way people travel, getting them out of their cars and on to public transport. The transport system of the future will have more rails, more buses, more two-wheeled vehicles and more cars that are self-driving and powered by alternative fuels.[44] Today's daily trips are often time-consuming, fragmented and cause frustration among most travellers. However, thanks to IoT devices, the dream of smart and seamless mobility looks achievable in the next future. A seamless model of mobility aims at defeating the fragmentation in the transportation sector thanks to advances in computing power, information technology, big data analysis, social media and apps development. For example, travellers will be able to plan and buy tickets for entire journeys before they leave their house rather than doing everything step by step – and even make journeys without having to use a ticket at all, thanks to new developments, such as beacon technology, which allows users to be charged automatically for the journeys they take. Although this process requires a high digitalisation rate, a data-driven approach as well as large investment, it embodies the final stage of an integrated model for future road transport.

[43] *Autonomous vehicles set to be the fastest-growing automotive sector with more than 11m sales by 2033*, available from: www.globaldata.com [Accessed: 15 October 2019]
[44] *What is seamless mobility and why is it important?*, available from: www.seamlessmobility.com [Accessed: 15 October 2019]

GOAL 3: FOSTER MOBILITY AS A SERVICE AND OVERCOME FRAGMENTED TRIPS

SOLUTIONS

1.**Invest in digitalisation and develop an integrated platform**: people can look up bus location, check delays and book cars or bikes by mobile phone apps. The larger availability of data is the key prerequisite to enable this transition. Venice is Italy's third most visited city, welcoming more than 10 million tourists a year. Although it is a crowded destination with copious daily arrivals, it is difficult to get there. What if a tourist could book their whole journey using a single app? Integrated platforms can offer people possibilities to choose either a car, a bike or public transports to move, as well as update them on traffic conditions, delays, travel times and costs. However, this model is still at its infancy and its fulfilment depends on a variety of factors, most of those are difficult to evaluate nowadays.

2.**Increase shared and autonomous driving modes**: Data availability and IoT devices can lead to on-demand mobility, resulting in a massive increase of shared and self-driving vehicles. As a consequence, less private cars and more sharing and autonomous vehicles open up opportunities for the redevelopment of urban public spaces. As a matter of fact, less need for parking areas can result in urban planning initiatives including more green spaces and more beautiful urban spaces, which can incentivise walking and cycling.

3.**Avoid daily traffic jams in territorial highways**: how many times have we heard that people were stuck in traffic along A4 highway connecting Venetian suburban areas to Padua? During the rush hours (early morning and late afternoon), a huge number of cars pour out onto A4 highway heading to Padua. This problem could be bypassed or limited by proposing an integrated travel model (figure 14):

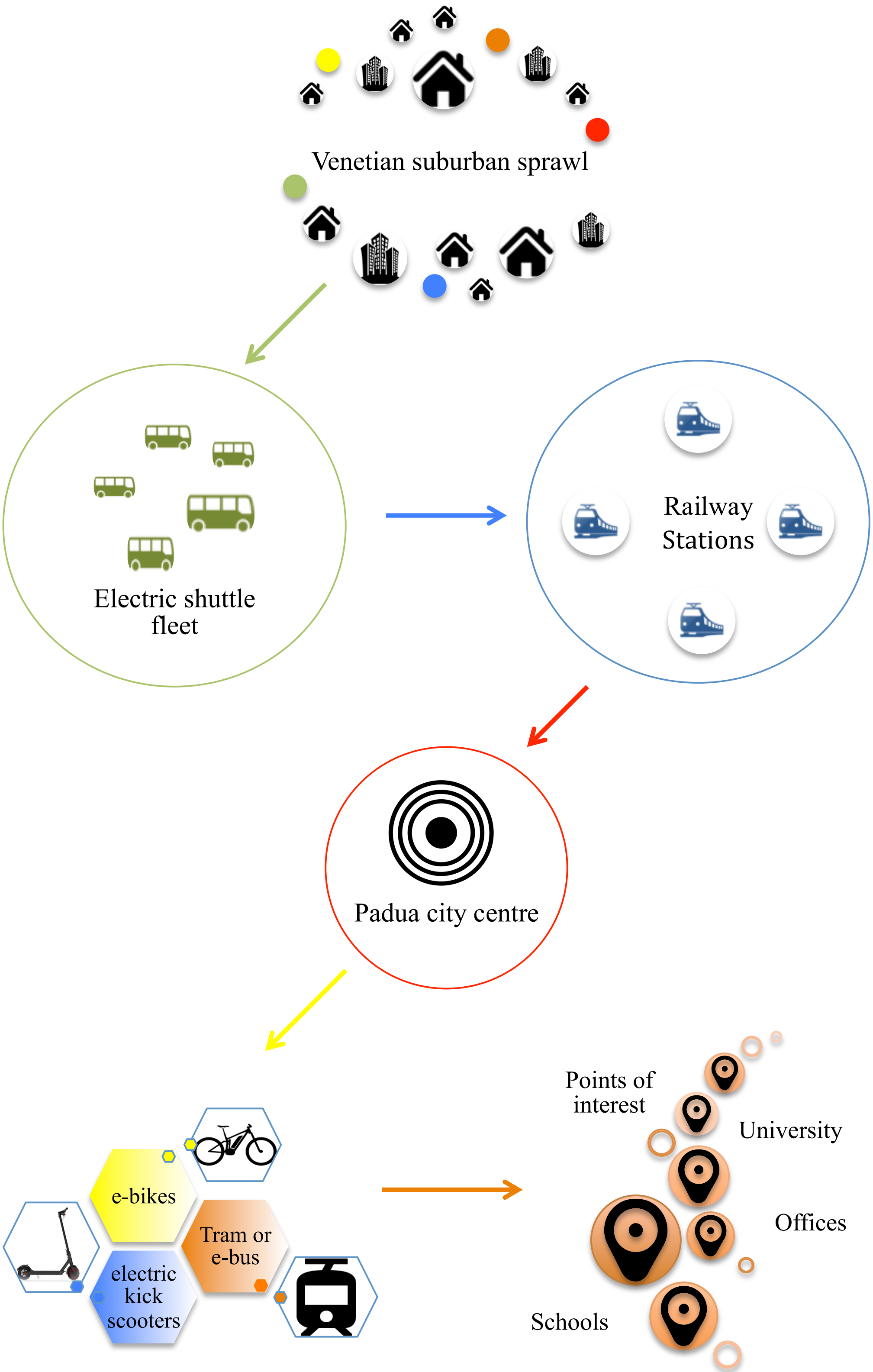


Figure 14: A proposal of an integrated travel model Venice – Padua (personal elaboration)

The majority of People in this area are unfamiliar with this kind of travel model, because they consider it uncomfortable, time-consuming and inefficient. What are the required improvements to make this integrated model working?

- **Launch electric shuttle fleet initiatives**: a robust dedicated shuttle service from suburban areas to railway stations is missing today. Only a few municipalities are delivering this service, but the number of people moving from home to the station by car is still too relevant. For example, Mira-Mirano railway station has a massive daily influx of people because it is strategically located near Mirano, Spinea, Oriago, Borbiago and Mira, which are small-sized municipalities with a high average population density. A rush-hour shuttle service able to drive through some of these small cities and pick up commuters would enable a lower use of private cars, lower emissions, less traffic and no parking issues. Hence, local governments, supported by local sponsors, or private players should fund and promote the initiative. The initial investment will presumably ensure a good ROI thanks to transport passes or seasonal and daily tickets. Travel tariffs should be affordable to appeal the mass market in order to discourage people to move by private car. The travel frequency depends on the mobility demand and could gradually increase.
- **Reduce train travel time and minimise delays**: Most people complain about the travel time of slow regional trains, which takes too long to reach Padua. In order to incentivise commuters to avoid using their cars, the integration of the shuttle service with faster train routes should equalise the efficiency of private cars. If we add occasional train delays, people do prefer to move by their own vehicles. Moreover, while travelling by train, people can read or check their mobile phones as well as interact with other passengers, thus nourishing social relationships. With more people boarding the train, costs for train seasonal tickets are expected to decrease, accelerating the uptake of public transport services.
- **Boost two-wheeled sharing models and strengthen public transportations in the city centre**: Once you get in Padua by car, people need to park it and this is more than an issue. Parking in busy cities is time-consuming, costly and frustrating, as people can rarely park their car truly next to their final destination.

Hence, Padua should deliver fleets of two-wheeled sharing vehicles, such as e-bikes and electric kick scooters, to connect people to their final destination. Walking is today's best option, but people are asking to cover medium-to-long distances in a shorter window of time effortlessly. As a consequence, two-wheeled electrified vehicles can satisfy people's requests and tackle Padua's traffic. They do not occupy a lot of space, run at slow speed, have less parking issues and contribute to the mobility transition. E-bikes are operating today, whereas kick scooters have been introduced in other Italian cities. As said throughout the thesis, those vehicles categories need clearer regulations on circulation and parking, and they preferably need dedicated lanes in order to minimise accidents and avoid obstruction with cars or light- and heavy-duty vehicles.

Overall, the above solutions to pursue an integrated model in the Veneto region highlight that the main priorities of future road mobility are to enhance faster and greener connections between dense metropolitan areas (e.g. city centres) and smaller urban settlements and to reduce the amount of private cars. Figure 15 summarises the various proposals listed in the chapter and builds up a single integrated model:

Figure 15: Summary of the integrated model for future road mobility in the Veneto region (personal elaboration)

4.3 The role of individual citizens

The individual traveller will be the main leader of this evolution, because consumers should be open to adopting new innovations, technologies and services that will radically change their idea of mobility. Obviously, the involvement of both the public and private sector will be a key factor in paving the way. As citizens are at the heart of this transition, they can obtain several benefits by accepting this new model, though they know it entails some costs too (figure 16):

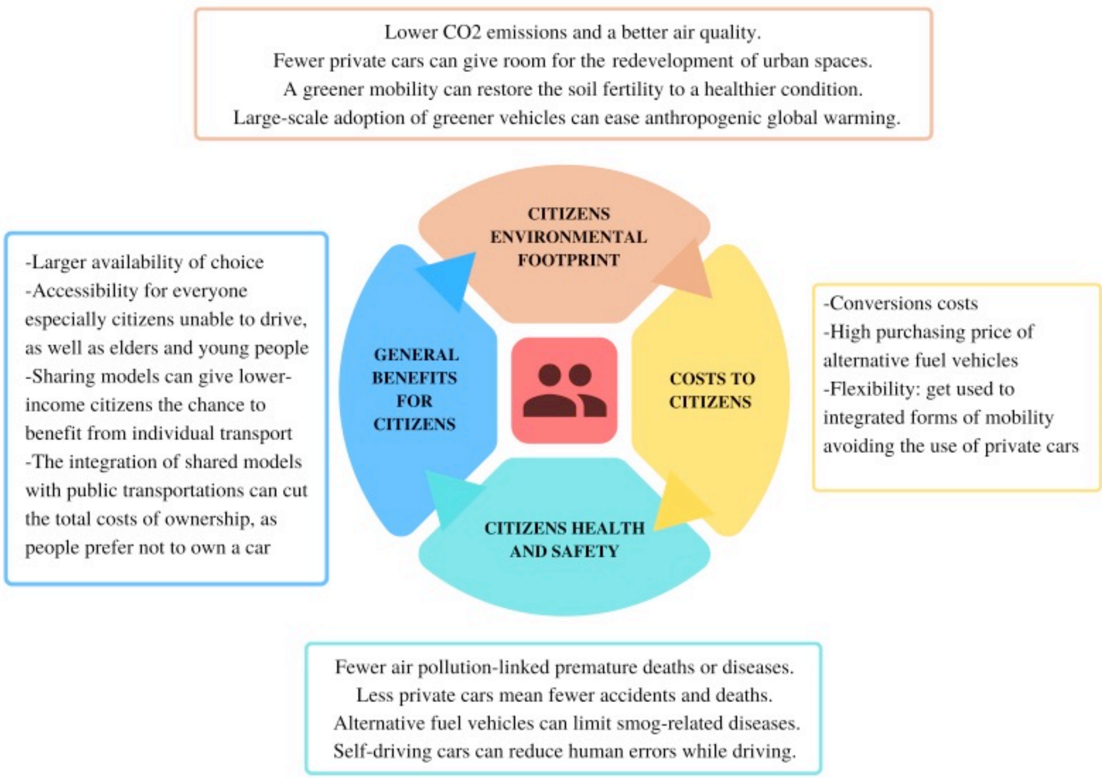


Figure 16: Benefits and costs to citizens (personal elaboration)

This chapter has tried to evaluate the growth potential of the mobility in Veneto's biggest metropolitan areas and smaller urban settlements. Shared mobility is a viable solution for populated urban centres (Padua, Verona…), whereas it risks being inefficient and unfeasible in suburban sprawls, where private mobility still holds the lead. Suitable sharing initiatives would be electric two-wheeled vehicles that can help citizens in the final step of their daily journey. A combination of shared mobility and public transport services can bypass the problem of connecting large urban centres to suburban areas. Seamless mobility is achievable in a long-term perspective, as it needs cutting-edge technologies, IoT devices and apps development to offer consumers an end-to-end connected travel experience. The EV market or alternative fuel vehicles may emerge faster in sprawl areas where private car use is still predominant.

Conclusions

The results obtained in chapter 4 reflect the idea that the mobility system of the future in the selected region is likely to be different from what exists today. As a matter of fact, the integrated model is based on versatility and dynamism, with a stock of solutions that aims at empowering alternative forms of mobility, such as the sharing vehicles, self-driving cars, and alternative fuel vehicles. These incoming innovations are integrated with public transport services and infrastructures, as well as greener methods to generate electricity. Massive changes in the mobility system can also lead to new business opportunities within and between sectors and can establish new ecosystems. As a consequence, traditional boundaries across different sectors might be blurred by the advent of an integrated perspective for future road mobility, as depicted in figure 17.

Multi-sectoral collaborations will be essential to pursue large-scale change in the mobility system. With reference to logistics and shipping activities in the Veneto region, this sector impacts a lot on road traffic and total emissions. Trucks and heavy-duty vehicles are very common in our roads and highways and deliver important services to citizens and enterprises. For example, long-distance trucks cannot turn into full electric vehicles nowadays, because the EV current range is limited and the recharging operations take too long. Therefore, trucks or coaches running long journeys could prefer a mix of alternative and renewable fuels, such as the fuel cell technology combined with large batteries. The integration of the electric propulsion with hydrogen traction can extend their range and reduce their time for charging as well as their emissions. However, this shift to alternative fuels does not solve the problem of congestion. As a consequence, logistics companies should invest in rail freight for long-distance journeys and use road transports to reach the destination place or the buyer’s warehouse.

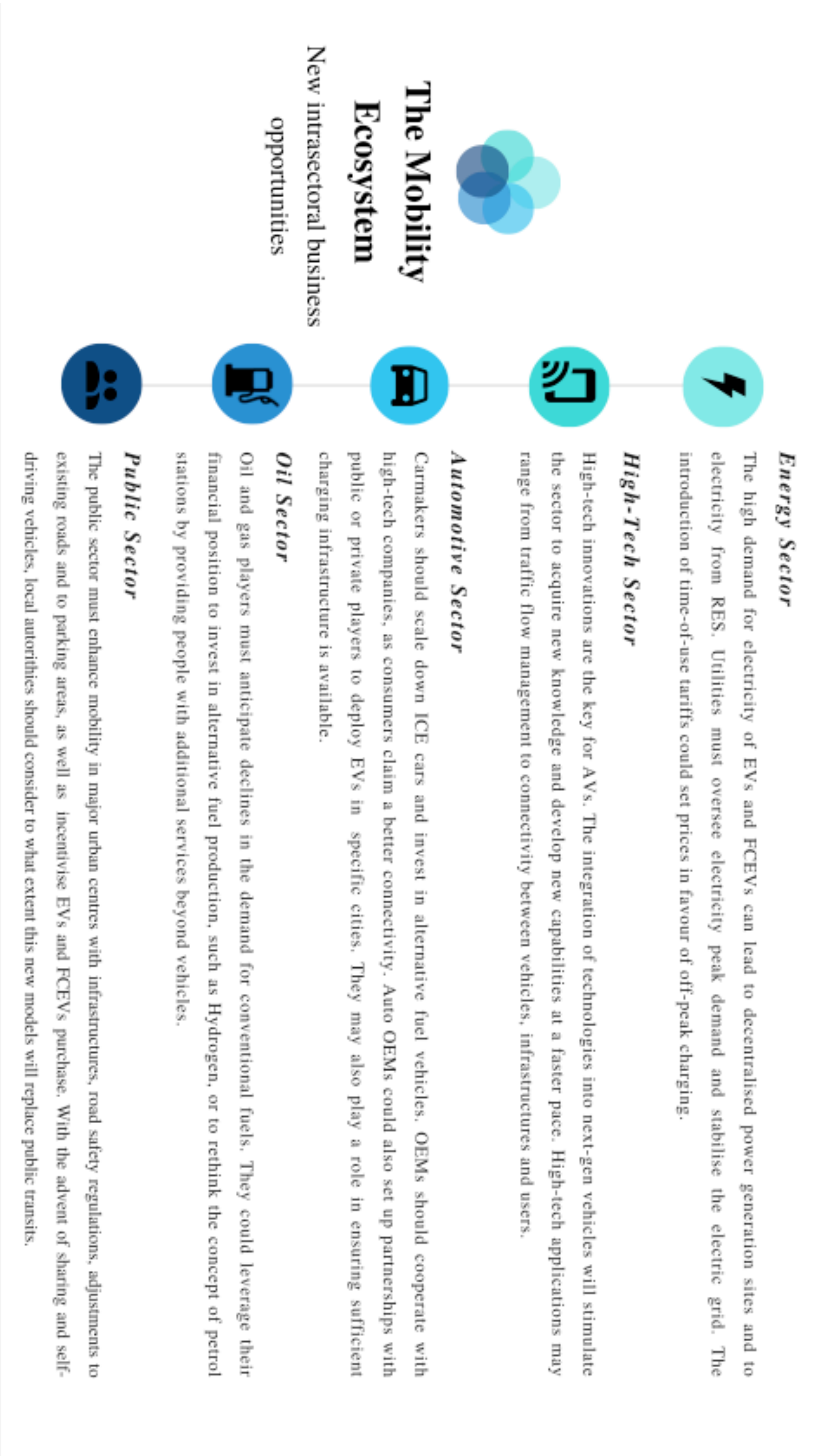


Figure 17: The mobility ecosystem: new intrasectoral business opportunities (Sources: McKinsey, Bloomberg)

Moreover, changes in the mobility ecosystem will cause a chain reaction in many other fields, such as banking, insurance, legal, medical, media, etc.

- Banking institutions can provide financial loans for investment in renewable energy sources or large-scale hydrogen production facilities, as a radical shift in the mobility sector requires huge financial resources. With the advent of cashless economies and digital payments, banks could have greater control on the monetary system and could encourage people to invest, lend and spend instead of amassing money. Today, payment methods for sharing vehicles are cashless transactions, as well as payments for the electricity charging.
- Insurance companies can achieve bigger profits by offering insurance policies for new vehicles categories, such as two-wheeled electric scooters or self-driving cars. They must therefore develop new skills and competences in order to offer up-to-date qualified services.
- Media and marketing companies can display on future high-tech cars digital location-based ads and personalised in-car marketing messages. Media will have to play a massive role in speeding up the conversion process toward a more sustainable mobility by influencing people's thoughts and promoting advanced car technologies through communication.
- Cars of the future will have active health monitoring systems installed that can track vital parameters thanks to wheel sensors or thanks to the pairing of mobile phones with wireless connection. Therefore, cars either will be able to detect health anomalies and caution people to undergo medical examinations.

As a consequence, governments and private companies should look at any emerging mobility trend not as isolated entities. Rather, they should lay out a clear adoption strategy that can steer consumers towards new forms of mobility in synchrony with technological development and societal benefits. For example, governments could carry out initiatives ahead of consumers, including:

- Incentives for EVs and FCEVs purchase,
- Investment in public transport infrastructures,
- Support for self-driving vehicle pilot programmes,
- Investment in dedicated lanes for buses and self-driving vehicles,

- Regulations for two-wheeled vehicle circulation and parking.

Market analysis and international regulations foresee massive transformations in the transportation sector, which is expected to undergo the biggest change in its history. The thesis has tried to describe the electric vehicle market and has identified the existence of an EV ecosystem, which emphasises that today's disruptive revolutions cannot be looked in isolation. The EV market is not mature enough at the moment, even though it is growing extremely fast worldwide. The same is true for hydrogen-powered vehicles that are considered to be one of the most promising alternatives to conventional ICE cars in the future, even more than pure electric vehicles. Fuel cell electric vehicle applications could firstly be embraced by public transport services, such as buses and trains. With economies of scale and further investment, they will also hit passenger car segment, though in a long-term perspective. A larger uptake of electrified powertrains for road mobility calls for reinforcement of the electric grid, peak demand management and greener methods to generate electricity, for example harnessing sun power thanks to photovoltaic modules.

The analysis carried out in the fourth chapter has identified some priorities to be fulfilled in the Veneto region to enable a faster transition in the mobility sector and overturn today's problems and challenges that affect road mobility in the same area:

- Reduce private cars;
- Incentivise alternative fuel vehicles by setting up low- or zero-emission zones;
- Improve public transport services to connect city centres to suburban areas;
- Invest in green fuels for public transports;
- Boost two-wheeled sharing models in city centres for last-mile mobility;
- Promote integrated models to bypass A4 highway congestion;
- Deploy dedicated lanes for buses, e-bikes and e-scooters to limit hazards and accidents.

Moreover, the integrated model has evaluated the state of the art of self-driving cars, hydrogen-run vehicles and seamless mobility, which are considered to be long-term goals. Although expected to be disruptive breakthroughs in the future, the current status of the technology, massive congestion and weak road safety regulations are liming the evolution of these trends. Experts believe that self-driving cars will be suitable for sharing models and need dedicated lanes to set apart from human-driven vehicles, thus reducing nuisance episodes. Seamless mobility will be the heart of smart cities and will enable citizens to overcome travel fragmentation and benefit from end-to-end travel experiences. Seamless mobility is likely to occur in high-income, dense metropolitan areas, as well as in highly populated suburban sprawls with high-quality mass public transit. Ideal places for seamless mobility would be Milan and Turin, whereas today's situation in the Veneto region would not ease the development of seamless models. However, Veneto's conurbations have a high population density and a good GDP, though public transit and infrastructures are below the required levels. A better connectivity and investment can make it feasible for the region to aim for a future with fewer private cars and more integrated journeys.

Abbreviations and acronyms

AAA	American Automobile Association
AC	Alternating current
ATM	Azienda Trasporti Milanesi
AV	Autonomous vehicle
BEV	Battery electric vehicle
BOP	Balance of plant
BSS	Battery swapping stations
CCS	Combined charging system
CEO	Chief Executive Officer
CHAdeMo	Charge de Move
CO	Carbon monoxide
CO_2	Carbon dioxide
DC	Direct current
DCFC	Direct current fast charging
EAFO	European Alternative Fuels Observatory
EAP	Environment Action Programme
EEA	European Environment Agency
EEC	Energy Efficiency Certificates
EIB	European Investment Bank
EMP	E-mobility provider
EPA	Environmental Protection Agency (US)
ESS	Energy storage systems
EU	European Union
EUR	Euro
EV	Electric vehicle
EVI	Electric Vehicles Initiative
FCA	Fiat Chrysler Automobiles
FCEV	Fuel cell electric vehicles
FRA	France
GDP	Gross Domestic Product

GER	Germany
GHG	Greenhouse gas
H_2	Hydrogen
H2ME	Hydrogen Mobility Europe
H_2O	Water
HEV	Hybrid electric vehicle
HRS	Hydrogen refuelling stations
ICE	Internal combustion engine
ICEV	Internal combustion engine vehicle
ICT	Information and Communication Technology
IEA	International Energy Agency
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISFORT	Italian Higher Institute for Education and Research on Transport
ISTAT	Italian National Institute of Statistics
IT	Italy
ITF	International Transport Forum
JRC	Joint Research Centre
LCV	Light commercial vehicle
eLCV	Electric light commercial vehicle
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
OECD	Organisation for Economic Co-operation and Development
OEMs	Original equipment manufacturers
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
POI	Point of interest
POL	Poland
PM_{10}	Particulate matter
RES	Renewable energy sources
ROI	Return on Investment

SDGs	Sustainable development goals
SMEs	Small and medium-sized enterprises
SMR	Steam methane reforming
SPA	Spain
SPV	Special Purpose Vehicle
TCO	Total cost of ownership
TEN-T	Trans-European Transport Network
UK	United Kingdom
UN	United Nations
USA	United States of America
USD	United States Dollar
V2G	Vehicle to Grid
WHO	World Health Organisation
ZEV	Zero-emissions vehicle

Units of measure

g	grams
kg	kilogram
km	kilometre
kW	kilowatt
kWh	kilowatt-hour
l	litre
Nm3	Normal cubic metre

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Riassunto in italiano

Alcune delle sfide più importanti che la nostra società dovrà affrontare nei prossimi decenni sono la questione ambientale – e del relativo cambiamento climatico – e l'integrazione delle nuove tecnologie nella vita delle persone. Se guardiamo la terra dall'alto, capiamo che le nostre strade sono le arterie del mondo e i veicoli il sangue che in esse scorre. La mobilità è dinamica, vitale per la vita degli individui in quanto permette i nostri spostamenti quotidianamente e condiziona il nostro stile di vita.

In quest'ottica, è proprio il settore della mobilità che contribuisce maggiormente ad emissioni di sostanze nocive sia per il pianeta sia per gli essere umani. Di conseguenza, vi è la necessità di rendere la mobilità più sostenibile e integrata, con un minor uso di vetture a benzina e di auto private, responsabili dei più evidenti disagi legati al trasporto su strada. La tendenza ormai è incontrovertibile: la mobilità del futuro sarà estremamente diversa da quella che conosciamo oggi. Infatti, la mobilità sostenibile e i veicoli ad alimentazione alternativa (elettrici, ad idrogeno) segneranno l'inizio di un'era a ridotte emissioni e con una minore dipendenza dai combustibili fossili. L'uso di carburanti alternativi, l'energia prodotta da fonti rinnovabili e il dirompente sviluppo tecnologico saranno i driver principali che determineranno il futuro dei nostri spostamenti. I leader mondiali e le istituzioni internazionali, spinti da una necessità di ridurre l'impatto dei trasporti sull'ambiente e sul clima, si stanno impegnando per favorire ed agevolare questa transizione. I tradizionali veicoli a combustione interna dominano ancora oggi il mercato, ma regolamenti più restrittivi sulle loro emissioni, così come la necessità di un minor numero di autovetture e l'avvento di tecnologie all'avanguardia, stanno imponendo dei limiti all'uso dell'auto privata e ai veicoli altamente inquinanti. In parallelo, i servizi di trasporto pubblico locale e i nuovi sistemi di mobilità – la mobilità condivisa, i veicoli elettrici a due ruote e i futuristici veicoli a guida autonoma – dovranno creare modelli di mobilità integrati e rendere gli spostamenti meno frammentati e più veloci, rispondendo alle esigenze delle persone.

L'obiettivo primario del seguente lavoro di tesi è proporre un modello integrato per la mobilità del futuro su strada nel territorio del Veneto, con un focus principale sulla Città Metropolitana di Venezia e sulla Provincia di Padova. Queste zone infatti sono caratterizzate da un'alta densità di popolazione, numerose strade e collegamenti autostradali e un consistente flusso di persone giornaliero. Inoltre, gli spostamenti nel territorio della Regione Veneto avvengono tipicamente per mezzo dell'auto privata. Questo fattore contribuisce ad alimentare il traffico su strada, creando congestione e soprattutto dannose emissioni di anidride carbonica, particolato e ossidi d'azoto, tra le più alte del territorio nazionale. La proposta del modello integrato è materia dell'ultimo capitolo della tesi (capitolo 4), mentre i primi tre capitoli introducono il tema della mobilità sostenibile e pongono le basi per sostenere la prospettiva integrata del capitolo conclusivo. Per giustificare l'avvento di una drastica rivoluzione nel settore dei trasporti, nei primi tre capitoli sono stati inseriti dati, numeri e previsioni sullo stato attuale e futuro di mercati e tecnologie emergenti in materia di mobilità sostenibile. Dati, numeri e previsioni sono stati recuperati e talvolta rielaborati da diverse fonti online certificate – come siti istituzionali dell'Unione Europea, dell'ONU, e altre agenzie e associazioni riconosciute – e da una numerosa reportistica pubblicata dalle medesime fonti, da istituti di ricerca o da iniziative di ricercatori universitari.

La tesi è suddivisa in quattro capitoli. Il **primo capitolo** fornisce una panoramica del mercato del veicolo elettrico a livello globale, europeo e italiano. Il mercato del veicolo elettrico è in forte crescita e prevede che i motori a propulsione elettrica sostituiranno quelli alimentati a benzina o diesel molto rapidamente. Secondo quanto riportato da Bloomberg New Energy Finance, un ente di ricerca del settore energia, a partire dal 2030, i veicoli elettrici saranno più economici rispetto a quelli a benzina e l'ammontare degli stessi raggiungerà 560 milioni di unità entro il 2040 a livello globale. La Cina è ad oggi il mercato più solido in termini di quantità di veicoli elettrici venduti, seguita da Europa e Stati Uniti. A livello europeo, i paesi nordici, in particolare la Norvegia, si trovano ai vertici in termini di vendite annue di veicoli ad alimentazione elettrica. Secondo i dati riportati dall'E-Mobility Report 2018, uno studio sul mercato del veicolo elettrico promosso dal Politecnico di Milano in collaborazione con Energy & Strategy Group, i quattro maggiori mercati europei in termini di unità vendute a fine 2017 sono Norvegia (22% del totale), Germania (19%), Regno Unito (16%) e Francia (13%). L'Italia occupa ancora una posizione marginale nel ranking europeo, registrando solamente il 2% delle vendite nello stesso anno.

Lo stesso capitolo evidenza che, nel processo di transizione verso una mobilità full-electric, la mobilità ibrida svolgerà un ruolo chiave in quanto sarà un compromesso momentaneo per creare un ponte tra mobilità tradizionale (a benzina) e mobilità elettrica o sostenibile del futuro.

Come tutte le grandi rivoluzioni, vi è bisogno di un legislatore che, in qualità di facilitatore e regolatore, permetta l'evolversi di questa transizione. In quest'ottica, risulta fondamentale il ruolo delle istituzioni e locali e internazionali. Il capitolo descrive le maggiori iniziative in termini di salvaguardia dell'ecosistema e dell'ambiente promosse da enti internazionali come le Nazioni Unite, l'Unione Europea, l'Organizzazione Mondiale della Sanità, così come da numerosi governi nazionali. Infatti, lo scenario descritto dall'International Transport Forum condanna il settore dei trasporti in quanto responsabile del 23% delle emissioni di CO_2 a livello globale. A livello Europeo (fonte EEA), tra le diverse categorie di mezzi di trasporto, le autovetture hanno il maggiore impatto, contribuendo al 43,7% del totale (anno 2017).

Con riferimento alle infrastrutture di ricarica per i veicoli elettrici, l'Italia totalizzava 2.000 punti di ricarica a fine 2018, contro i quasi 23.000 della Germania, evidenziando un ritardo notevole rispetto ai maggiori mercati europei. Un'adeguata rete infrastrutturale di ricarica è un requisito fondamentale per l'avanzamento della tecnologia e un'adozione su larga scala di questa tipologia di veicoli.

Il capitolo inoltre propone dei casi studio per valutare la convenienza dell'investimento in un veicolo full-electric rispetto ad uno a benzina, confrontando il costo totale di proprietà (TCO – *Total Cost of Onwership*) di un veicolo elettrico a batteria (BEV) con quello di un veicolo a combustione interna (ICEV) dalle caratteristiche simili. Allo stato attuale dell'arte, l'investimento in un veicolo a zero emissioni risulta conveniente nel medio-lungo periodo, dato il prezzo di acquisto elevato. Tuttavia, incentivi all'acquisto, l'abbassamento dei costi delle batterie ed economie di scala contribuiranno nel breve periodo a ridurre notevolmente il prezzo del veicolo a batteria, rendendo l'investimento meno oneroso.

La parte finale del capitolo introduce altre categorie di veicoli elettrici che potrebbero ridurre l'utilizzo dell'auto privata, tra cui i servizi di car sharing, veicoli elettrici a due ruote e mezzi di trasporto pubblico più efficienti.

Il **secondo capitolo** definisce il termine ecosistema, una pluralità di attori che lavorando e innovando assieme devono creare valore e rendere il veicolo elettrico un prodotto accessibile alla maggior parte dei consumatori. Il successo di un ecosistema risiede nell'abilità di tutti i suoi partecipanti di adempiere ai loro compiti e rispettare le loro promesse. Un ecosistema può comporsi di aziende, fornitori, agenzie, consumatori finali, così come istituzioni governative e autorità pubblica. Ciò che lo caratterizza è l'aspetto della complementarità: gli ecosistemi infatti necessitano di diverse competenze e una pluralità di capacità per soddisfare le esigenze del cliente finale che vanno oltre alla capacità della singola azienda o del singolo partecipante. L'obiettivo finale non è produrre una moltitudine di prodotti diversi tra loro, bensì sviluppare singoli prodotti, singole componenti, che messi assieme contribuiscono alla realizzazione di un unico prodotto finale.

Il capitolo analizza inoltre il lato della domanda, ovvero le opinioni dei consumatori sul veicolo elettrico. Dai pochi dati finora disponibili, i consumatori attribuiscono al veicolo elettrico numerose barriere all'acquisto, che coincidono con le maggiori sfide che l'ecosistema sta cercando di superare. Nel Regno Unito, così come negli Stati Uniti, i maggiori ostacoli all'acquisto sono la mancanza di infrastrutture di ricarica e la limitata autonomia del veicolo, che crea ansia nel consumatore. Ad esse si sommano il prezzo d'acquisto elevato e i tempi di ricarica. All'individuazione degli ostacoli principali, segue l'identificazione di alcune soluzioni per facilitare un'adozione di massa del veicolo elettrico e ricucire lo strappo nell'ultima fase dell'ecosistema, ovvero al livello del consumatore finale, ancora poco incline ad accogliere l'innovazione. Alcune delle soluzioni proposte includono l'utilizzo di carburanti alternativi, la standardizzazione del pacco batterie e modelli di mobilità condivisa (sharing). I carburanti alternativi come l'idrogeno potrebbero estendere l'autonomia dei veicoli e ridurre i tempi di ricarica, mentre un pacco batterie standard comporterebbe un minor costo per le batterie, determinando un calo del prezzo di acquisto del veicolo elettrico, una delle principali barriere all'acquisto per il consumatore. Il passaggio alla mobilità condivisa eliminerebbe i costi di proprietà dell'automobile (manutenzione, rifornimento, assicurazione, ecc.) e ridurrebbe il parco circolante dei veicoli privati su strada.

Il **terzo capitolo** propone un'analisi del mercato del veicolo alimentato ad idrogeno (FCEVs), focalizzandosi nello specifico sul trasporto pubblico locale. Parte integrante di questo capitolo è una campagna marketing che ho personalmente svolto presso un'azienda del miranese, En Future S.r.l., durante l'attività di tirocinio. I veicoli ad idrogeno funzionano grazie alla tecnologia fuel cell (celle a combustibile), nelle quali l'idrogeno reagisce chimicamente con l'ossigeno generando energia ed emettendo soltanto goccioline d'acqua. L'Agenzia Internazionale dell'Energia (IEA) prevede un forte sviluppo di questa tecnologia: entro il 2025 si stima che verranno vendute 400.000 unità nei tre principali mercati mondiali (Stati Uniti, EU4 (Francia, Italia, Germania, Regno Unito) e Giappone). Lo sviluppo su larga scala dei veicoli fuel cell necessita una maggiore produzione di idrogeno, che non esiste come elemento puro in natura. Per questo motivo, la crescente domanda di idrogeno sta portando numerose aziende ad investire in fonti di energia rinnovabile per la produzione di idrogeno a zero emissioni, sfruttando ad esempio l'energia del sole tramite impianti fotovoltaici di grosse dimensioni e potenza. Questi impianti sono funzionali al processo dell'elettrolisi, mediante il quale si estrae l'idrogeno dall'acqua. Anche in questo caso è fondamentale la cooperazione di diversi player per la realizzazione di un ecosistema di successo nel pieno rispetto dell'ambiente.

L'azienda per cui ho lavorato si occupa di efficienza energetica, investimenti in fonti di energia rinnovabili, impianti fotovoltaici e mobilità sostenibile. La campagna marketing che ho incluso nella tesi ha l'obiettivo di promuovere l'idrogeno come l'unico combustibile applicabile al trasporto pubblico locale nel territorio del Veneto per perseguire una mobilità pubblica a zero emissioni. L'iniziativa, promozionale e informativa, sottolinea anche l'importanza di attuare un ciclo di produzione dell'idrogeno svincolato dall'uso di combustibile fossile e perciò privo di qualsiasi emissione dannosa per l'ambiente, grazie ad impianti fotovoltaici e al processo dell'elettrolisi. La tesi include alcune slide della presentazione svolta per l'azienda e sostiene come l'idrogeno sia ad oggi applicabile preferibilmente al trasporto pubblico (su strada o ferroviario) piuttosto che alle auto private, dato l'elevato costo attuale della tecnologia e i pochissimi punti di ricarica presenti sul territorio. Secondo Mobilità Idrogeno Italia, sul territorio nazionale dal 2020 al 2050, il costo degli autobus ad idrogeno calerà drasticamente, da 570.000 euro a 316.000 euro per singola unità. Entro la fine del 2050 ci saranno all'incirca 23.000 autobus ad idrogeno circolanti nel territorio italiano, a testimoniare che l'idrogeno giocherà un ruolo importante per la mobilità del futuro a partire dai servizi di trasporto pubblico. L'Italia inoltre detiene un record negativo, essendo la nazione con il maggior numero di morti premature causate dall'inquinamento atmosferico di tutta l'Unione Europea. L'integrazione di diverse fonti di alimentazioni alternative per la mobilità del futuro risulta quindi non solo una prospettiva futura, ma anche una necessità del presente.

Il **quarto capitolo** è il fulcro nonché il traguardo finale del lavoro di tesi. Grazie alle informazioni elaborate nei tre capitoli precedenti, l'ultimo capitolo si pone l'obiettivo di proporre un modello integrato per la mobilità del futuro su strada nel territorio del Veneto, con una particolare attenzione all'area della Città Metropolitana di Venezia e alla Provincia di Padova. Cosa significa prospettiva integrata? Non dobbiamo più pensare alla mobilità come un insieme di servizi e mezzi di trasporto sconnessi tra di loro. La mobilità attuale si fonda sul modello di proprietà del veicolo e fa affidamento all'auto privata per la maggior parte degli spostamenti. Ciò ha provocato nel tempo congestione autostradale, strade urbane ed extraurbane trafficate e alti livelli di inquinamento urbano. Questo modello è tuttora predominante e non si integra bene con le varie altre forme di mobilità: trasporto pubblico, mobilità condivisa, bicicletta e pedoni. Infatti, lo spazio per gli autobus, le biciclette, così come per i pedoni è limitato a causa dell'enorme quantità di veicoli privati circolanti. Negli ultimi anni, la crescente necessità di un cambio di paradigma ha spinto le persone e le istituzioni ad adottare politiche e comportamenti più ecologici e sostenibili per sovvertire l'attuale modello di mobilità tradizionale, basato su auto privata e combustibili fossili. Perseguire un modello integrato significa quindi trovare un equilibrio tra diversi mezzi di trasporto, combinando talvolta i veicoli a guida autonoma con quelli condivisi, o i mezzi di trasporto pubblico con i mezzi elettrici a due ruote per la mobilità nei centri città. Bisogna indebolire il modello tradizionale, affezionato all'auto privata a combustione, e incentivare la mobilità on-demand o come servizio, ovvero favorire altre forme di mobilità che riducano la congestione stradale, minimizzando le emissioni dannose per noi e per il nostro pianeta. Inoltre, bisogna rendere i nostri spostamenti meno frammentati e più veloci, investendo in connettività e tecnologie all'avanguardia.

Solamente in Italia, ci sono 39 milioni di veicoli privati registrati su una popolazione totale di 60,55 milioni di abitanti. Un numero elevatissimo, considerando anziani, bambini e persone non abilitate alla guida. L'Italia in generale è un paese che storicamente ha sempre fatto moltissimo affidamento sull'uso dell'auto privata, per un fattore di comodità e frammentazione. Con riferimento all'area presa in esame, il trasporto su strada contribuisce al 28% delle emissioni totali di CO_2 nella Regione Veneto. Inoltre, il Veneto ha un alto grado di urbanizzazione e i comuni sono altamente popolati, decretando un aumento della domanda di mobilità in quest'area. Secondo un'indagine ISFORT del 2011, nel 78% dei casi gli abitanti compivano i loro spostamenti per mezzo di veicoli privati. Il trend dal 2011 ad oggi è in continuo aumento. Il territorio del Veneto può essere definito un esempio italiano di città diffusa: vi sono tanti centri urbani, paesi, cittadine con un'elevata densità di popolazione che si espandono a partire dai centri più popolosi, come Mestre-Venezia e Padova, formando degli agglomerati urbani. La domanda di mobilità è altissima, le strade sono spesso trafficate e il livello di inquinamento è spesso sopra la soglia limite. La tesi ha quindi elencato i problemi prioritari da dover affrontare per ambire ad una rivoluzione della mobilità nel medesimo territorio:

1. Elevato utilizzo dell'auto privata per spostamenti quotidiani
2. I servizi di trasporto pubblico sono spesso inefficienti e sconnessi
3. L'accessibilità, la frequenza e la velocità dei mezzi per il trasporto pubblico rivelano disuguaglianze territoriali
4. Il Veneto è una regione di transito verso altri paesi europei
5. Gli insediamenti urbani sono frammentati
6. Il trasporto su strada inquina e rovina il nostro ecosistema
7. Mancanza di infrastrutture e ritardo normativo per i veicoli ad alimentazione alternativa

La proposta di un modello integrato: il modello integrato si basa su tre obiettivi principali da perseguire nell'area di riferimento:

- Ridurre l'utilizzo di auto private;
- Promuovere l'utilizzo di veicoli ad alimentazione alternativa;
- Promuovere la mobilità come servizio e minimizzare i viaggi frammentati.

Il modello è stato denominato *Greener, Private and Seamless Mobility.*

Greener perché il nostro territorio ha un valore storico invidiabile e un patrimonio ambientale e naturalistico da preservare. Una prospettiva più verde implica anche una rivalutazione degli spazi verdi urbani e un miglioramento della qualità dell'aria, respirata da noi e dai nostri visitatori. La mancanza di spazi verdi è conseguenza della cementificazione di molte aree adibite a parcheggi per i veicoli privati. Un cambio di prospettiva, con una riduzione del parco circolante, potrebbe incentivare opere di riqualificazione urbana per rendere la città più vivibile, più verde e più adatta anche a spostamenti in bicicletta o a piedi.

Private significa due cose: da un lato bisogna riconoscere che le persone nel nostro territorio difficilmente abbandoneranno la loro auto privata del tutto e nel breve periodo, dall'altro c'è un'incombente necessità di minimizzare il più possibile gli spostamenti per mezzo di veicoli privati. In questa logica, l'autorità pubblica gioca un ruolo fondamentale: essa dovrà infatti incentivare, qualora il cittadino ne avesse bisogno, l'acquisto di automobili ad alimentazione alternativa, imporre limitazione alla circolazione dei veicoli ad alte emissioni e investire in forme di mobilità alternativa sia per tragitti lunghi (autobus, treni, tram) sia per tragitti brevi (veicoli elettrici a due ruote).

Seamless significa promuovere forme di mobilità integrate con soluzione di continuità, ovvero investire in connettività, Internet of Things, applicazioni per smartphone e social media per rendere i nostri viaggi meno frammentati, più veloci e facilmente programmabili. L'aspetto della non frammentazione è essenziale per la mobilità del futuro: le persone potranno beneficiare di diverse forme di mobilità per raggiungere la destinazione finale programmando tutto anticipatamente ed utilizzando diverse forme di mobilità condivisa o di trasporto pubblico. Alle diverse soluzioni proposte dal modello integrato sono state assegnati degli intervalli temporali. Considerato lo stato attuale di alcune tecnologie e le problematiche del territorio, alcuni obiettivi sono perseguibili prima di altri. Ad esempio, conseguire una mobilità sostenibile non frammentata e connessa (*seamless*) con un alto livello tecnologico rimane un target di medio-lungo periodo. Seguono alcune delle soluzioni pensate per far fronte alle maggiori problematiche del territorio.

Ridurre l'utilizzo di auto private. Soluzioni:

1. **Promuovere forme di mobilità elettrica condivisa che permettano spostamenti a zero emissioni nei centri città**. Ideale sarebbe dislocare una flotta di veicoli elettrici a due ruote (monopattini, biciclette) per evitare la congestione stradale e facilitare spostamenti dalla stazione al punto di interesse finale. Le attuali piste ciclabili potrebbero fungere da corsie dedicate alla circolazione dei mezzi sopracitati. Tuttavia, vanno aumentate le misure di sicurezza e tutela verso questi mezzi di trasporto che sono molto vulnerabili al contatto con i mezzi a quattro ruote, potendo recare danni e infortuni agli utilizzatori. Inoltre, vanno istituite delle zone per il rilascio dei monopattini, che, in numerose metropoli nel mondo, costituiscono ostacoli ai passanti e ai cicli essendo abbandonati a terra in zone non idonee al loro collocamento.
2. **Migliorare il servizio di trasporto pubblico locale per collegare i maggiori centri urbani ai paesi periferici**. Come?
    a. Sostituire gradualmente gli autobus endotermici con una flotta a zero emissioni (preferibilmente ad idrogeno): l'area della laguna di Venezia si presta moltissimo alla produzione di idrogeno, grazie alla presenza di acqua.
    b. Modificare la viabilità urbana introducendo corsie dedicate per gli autobus: le corsie preferenziali permettono di bypassare il traffico ed evitare ritardi.
    c. Promuovere servizi di navetta elettrici per collegare i centri periferici alle stazioni ferroviarie più vicine per ridurre l'impatto giornaliero delle auto private, che in massa raggiungono le stazioni per spostarsi a Padova, Treviso, Verona o Mestre-Venezia (vedi figura 14).

Promuovere l'utilizzo di veicoli ad alimentazione alternativa. Soluzioni:

1. **Introdurre zone a basse o zero emissioni nei centri urbani**. Padova è una delle città più inquinate in Europa, tuttavia il traffico giornaliero è ancora troppo consistente e il numero di automobili circolanti causa danni fisici e ambientali oltre a danneggiare e deteriorare le bellezze del territorio.
2. **Potenziare la capacità della rete elettrica** per evitare un sovraccarico della linea e permettere a tutti i veicoli di ricaricare. Fondamentale risulta investire in fonti di energia rinnovabili, come il solare o l'eolico, per produrre un surplus di energia necessario per sostenere la rete. La generazione tradizionale di energia è troppo inquinante e va integrata con soluzioni più ecologiche. Ad esempio, sono state individuate delle aree dismesse presso la laguna di Venezia che potrebbero essere riqualificate ed adibite a siti di produzione di energia elettrica tramite impianti fotovoltaici.
3. **Dislocare una rete di infrastrutture di ricarica sufficienti in luoghi rilevanti e strategici**. Il numero delle attuali colonnine di ricarica dislocate nel territorio del Veneto rispecchia i valori del territorio nazionale, segnalando un ritardo evidente rispetto ad altre potenze europee. Questa limitata disponibilità di punti di ricarica pubblici è un fortissimo disincentivo all'acquisto di veicoli elettrici.

Promuovere la mobilità come servizio e minimizzare i viaggi frammentati. Soluzioni:

1. **Evitare il traffico intenso nelle autostrade del territorio per raggiungere i maggiori luoghi di interesse**. Durante le ore di punta, mattina presto e tardo pomeriggio, il tratto autostradale Venezia – Padova direzione Padova è quasi sempre travolto da un flusso di persone giornaliero che crea congestione, perdite di tempo, ritardi, spesso incidenti e soprattutto un altissimo livello di emissioni nocive ed inquinanti. La figura 14 propone un modello integrato per aggirare in maniera alternativa questo problema:

a. Rendere operativo un servizio di navetta elettrico per raggiungere le stazioni ferroviarie (es: Mira-Mirano, Dolo) senza dover ricorrere all'automobile privata.
b. Aumentare il numero di corse dei treni regionali nelle ore di punta o rendere più veloce la percorrenza dei treni regionali lenti già in funzione.
c. Promuovere forme di mobilità elettrica condivisa a due ruote nelle stazioni di arrivo per raggiungere il luogo di destinazione finale.

   Il minor utilizzo dell'auto privata per questi spostamenti rende il centro città più vivibile e meno trafficato, facilitando il passaggio di veicoli a due ruote o modelli di mobilità condivisa a zero emissioni. Inoltre, le persone non devono preoccuparsi di trovare parcheggio, operazione che spesso provoca frustrazione ed enormi perdite di tempo.

Lo schema descritto nella figura 15 riassume le varie proposte del modello di mobilità integrato nel territorio e segnala anche il periodo stimato di attuazione di ciascuna soluzione. Gli intervalli temporali sono suddivisi in cicli decennali: 2030, 2040, 2050. Un radicale cambiamento nel settore della mobilità provocherà indubbiamente una reazione a catena in altri settori economici, come ad esempio gli istituti bancari, le agenzie assicurative, le compagnie di logistica, le società di marketing e le aziende di comunicazione, così come il settore legale e della medicina. Inoltre, i numerosi cambiamenti nel settore della mobilità comporteranno nuove opportunità commerciali all'interno dei singoli settori economici, così come la creazione di collaborazioni multisettoriali tra diversi settori economici. L'avvento della mobilità integrata, che necessita di diverse tecnologie ed innovazioni, contribuirà a rendere i confini tra i diversi settori molto più labili, creando un ecosistema ancora più grande. Ad esempio, alcuni colossi del modello tradizionale come le società petrolifere dovranno conformarsi al nascente modello di mobilità ed investire in nuovi ambiti, facendo leva sulle proprie risorse finanziarie e competenze per investire nella produzione di carburanti alternativi (idrogeno).