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Use of Hydrogen Powered Vehicles in Transport in the Czech Republic

Final report

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Acronyms

AAHE	Australian Association for Hydrogen Energy
BEV	Battery Electric Vehicle
BMBF	Federal Ministry of Education and Research
BMUB	Federal Ministry for the Environment, Nature Conversation, Building and Reactor Safety
BMVI	Federal Ministry of Transport and Digital Infrastructure
BMWi	Federal Ministry for Economic Affairs and Energy
CEF	Connecting Europe Facility
CNG	Compressed Natural Gas
CHIC	Clean Hydrogen in European Cities
CO_2	Carbon dioxide
CVRP	Clean Vehicle Rebate Project
CR	Czech Republic
DPO	Transportation Company Ostrava (Dopravní podnik Ostrava)
EC	European Comission
EU	European Union
EUR	Euro
FC	Fuel Cell
FCEB	Fuel Cell Electric Bus
FCEV	Fuel Cell Electric Vehicle
FCH JU	The Fuel Cells and Hydrogen Joint Undertaking
FP7	The Seventh Framework Programme
HOV lane	High-occupancy Vehicle Lane
HRS	Hydrogen Refuelling Station
HYTEP	Hydrogen Technology Platform
ICE	Internal Combustion Engine
IPHE	International Partnership for Hydrogen and Fuel Cells in The Economy
LCA	Life Cycle Assessment
LVT	Hydrogen Technology Laboratory
MDBF	Mean Distance Between Failures
MPa	Megapascal
MW	Megawatt
(N)	Normal conditions ($T = 273{,}15$ K ($t = 0$ °C), $p = 101{,}325$ kPa)
NAP CM	National Action Plan of Clean Mobility
N.ERGHY	The New European Grouping on Fuel Cells and Hydrogen

NIP	National Innovation Programme
NOW GmbH	National Organization for Hydrogen and Fuel Cell Technology
NO_x	Nitrogen oxides NO a NO_2
NREL	National Renewable Energy Laboratory
OP PIK	Operational Programme Enterprise and Innovation for Competitiveness
OPD	Operational Programme Transport
PAP	Polish Press Agency
PHEV	Plug-in Hybrid Electric Vehicle
PPP	Private and Public sector Partnership
PR	Public Relations
PSA	Pressure Swing Absorption
R&D	Research and Development
R&D&I	Research, Development and Inovation
SHHP	Scandinavian Hydrogen Highway Partnership
SO_2	Sulfur dioxide
SOR	SOR Libchavy spol. s.r.o.
SORT	Standardised On-Road Test cycles
SUV	Sport Utility Vehicle
TCO	Total Cost of Ownership
TEN-T	Trans-European Transport Networks
THC	Total Hydrocarbon
UCB	UniCredit Bank
US DOE	The United States Department of Energy
USA	United States of America
USD	American dollar
V4	Visegrad Cooperation
VSB	Banska University – Technical University Ostrava
ZEV	Zero Emission Vehicle database

1 General information about the project

This study, titled "*Use of Hydrogen Powered Vehicles in Transport in the Czech Republic*", consists in evaluating the potential of their use within the context of global and pan-European technological progress and trends in this field and, in particular, in simulating the deployment of hydrogen mobility in the Czech Republic. This study also includes the setting up of a task force consisting of the representatives of the private and public sectors engaged in hydrogen mobility in order to discuss and review the progress of this study.

This study serves as a basis for the actualization of the National action plan for Clean Mobility, which set out a goal in the area of hydrogen mobility to construct between 3 to 5 hydrogen filing stations until 2025 in order to fulfill the requirements of the guiding principles which describe the establishment of infrastructure for alternative fuels. These principles follow up on the EU's goals for the reduction of CO_2 in transportation.

This study was drawn up by Grant Thornton Advisory with the assistance of Ministry of Transport of the Czech Republic. The project was implemented between 5th December 2016 and 5th June 2017.

2 Introduction

The study on the "*Use of Hydrogen Powered Vehicles in Transport in the Czech Republic*:" is divided into several separate but related parts. The first part assesses the current situation of hydrogen mobility both from the global and pan-European perspectives. It also presents interesting projects that demonstrate how hydrogen mobility can be put into practice. The end of this part is dedicated to detailed SWOT analysis, which highlights the main factors influencing potential development of hydrogen mobility considering the local conditions in the Czech Republic. This SWOT analysis focuses on opportunities and potential threats and seeks to find a way to mitigate them in order to ensure potential successful development of this transport sector in the Czech Republic.

The second part of the study evaluates the collection of primary data needed to determine relevant demand and supply, both in quantitative and qualitative terms. The quantitative part of the survey was implemented via a questionnaire survey using a sample of potential car buyers/passengers (the public). The qualitative part of the survey was conducted through in-depth interviews with representatives of the entire transport sector and through discussions with the expert group. The aim of this survey is to identify key entities on the supply side that can offer hydrogen vehicles and entities that produce hydrogen and are interested in developing hydrogen filling infrastructure. On the demand side, there are potential customers from a number of cities, public transport companies and others who ask for alternative/clean fuels for their vehicle fleets. A separate topic is then the assessment of hydrogen mobility attractiveness for potential investors.

The third part of the study describes a model simulating potential future market development scenarios in the Czech Republic with respect to demand and supply. This chapter describes the basic assumptions used in the model and, in relation to this, it defines predictions of likely development in the number of hydrogen-fuelled vehicles in the Czech Republic based on various forms of support. These predictions also focus on the development of filling station infrastructure, differential costs needed to achieve the required number of vehicles, and savings generated through the use of hydrogen-powered vehicles instead of the conventional ones. Depending on the rate of state support, 4 scenarios are outlined. The end of the chapter provides recommendations of priority localities for the newly constructed filling stations using the geographic information system.

The penultimate part of the study provides analyses of the relevant forms of support. It seeks to define the scope of potential forms of public support, describe them and makes a pilot assessment of the suitability and effectiveness of this support for the development of hydrogen technology in the Czech transport sector. This pilot estimate is made in terms of time and benefits. In addition, forms of support offering the greatest added value for the development of hydrogen mobility are highlighted based on information collected so far from in-depth interviews, expert group information and international and Czech experience. Based on the definition of scenarios of possible development, these scenarios are matched against the forms of support that might facilitate implementation of the given scenario.

Strategic recommendations to implement the selected scenario are then formulated based on the findings obtained during the preparation of this study. The final chapter summarizes these recommendations that should not be left unnoticed in the framework of the government strategy promoting the use of hydrogen technology and these recommendations should be paid attention to if the Czech Republic decides to take this path.

3 Executive summary

Hydrogen mobility and its use in transport may sound like a futuristic vision of the transport of the future. However, experience from abroad supported by this study shows that this could become a reality in the near future.

At present, there is a growing demand for environment-friendly transport. Hydrogen, just like electricity, is a good alternative for clean mobility. No emissions are produced during the operation of these vehicles. Hydrogen, following the experience with electromobiles, is another logical step towards meeting EU targets related to CO_2 emissions by 2030. In this context, it is important to note that a hydrogen-powered vehicle is essentially an electric car. The only difference is that it uses hydrogen as a source of el. power generation. The conventional electric car uses battery cells while hydrogen vehicles are fitted with hydrogen tanks. Therefore, the hydrogen-powered vehicles cannot be viewed as a competitor to electric cars but rather as another clean alternative in transport and as an intermediary used by the government in its pursuit for a better environment.

It would be foolish to assume that hydrogen mobility will become widely used by itself as it is too investment-intensive for that. The development of fuel filling infrastructure involves high financial costs. Furthermore, it is necessary to convince public transport operators about the advantages of using hydrogen buses and, last but not least, encourage citizens interested in purchasing hydrogen-powered cars. If the government decides that hydrogen mobility is the direction worth following, it will be necessary, as the first step, to set up a sustainable concept of hydrogen mobility development and back up this concept with clearly defined forms of support. The concept is therefore a necessary; however not sufficient, prerequisite for development.

Hydrogen, similarly to electromobility, faces the basic questions: "What should come first? Infrastructure or vehicles? "No one will drive a car when there is no place to refuel it. On the other hand, it is not profitable to build a filling station when no hydrogen cars are driven. This situation clearly indicates that one thing cannot exist without the other. And if no-one starts to actively promote the development of infrastructure while supporting the purchase of very expensive hydrogen cars, hydrogen mobility will never develop.

The good news is the involvement of private companies in hydrogen mobility. Unipetrol, on its own initiative, is preparing construction of two hydrogen filling stations which should be in operation by the end of 2018. Some automakers are already offering hydrogen-powered cars in countries neighbouring the Czech Republic. If they see the opportunity, they will certainly offer them to the citizens of the Czech Republic, too. For example, Toyota plans hydrogen car test drives at several regional events to promote this type of transport as an efficient and environmentally-friendly alternative to conventional fuels.

Within the context of the above situation this study recommends the following:

- support the construction of infrastructure, i.e. filling stations, both in the public transport sector and for commercial use by the public
- support the purchase of passenger cars and buses for public transport.

Experience from abroad shows that the correct way is to ensure pilot deployment of hydrogen buses in public transport in selected agglomerations and regions. At the same time, this variant has the highest added value in terms of the cost of technology, usability and environmental impacts (CO_2 emission savings).

Four scenarios of hydrogen mobility development have been drawn up based on the inputs collected during the study preparation. The zero (business as usual) variant is based on the assumption that hydrogen mobility will be left "to its fate" and its development will not be systemically supported. The opposite to this variant is an Ambitious scenario stemming from the assumption that alternative mobility will be based primarily on hydrogen. All emission targets set by the EU to be met by 2030 will be met through the hydrogen technology deployment. Hydrogen mobility development is modelled without calculating the benefits associated with hydrogen production in the Czech environment where the Czech Republic can be considered a strong stakeholder in the European area.

Between these notional extremes there are other two scenarios. One of them is the Basic scenario where compliance across the hydrogen mobility group has been reached. It is based on the assumption that hydrogen mobility will be supported in a reasonable extent, i.e. there will be gradual development of infrastructure and hydrogen cars and buses market promotion. Here we can rely on experience with similar CNG development and the current development in electromobility.

The adequate rate of support that the Basic scenario centres around envisages the construction of 117 filling stations to serve 115 thousand hydrogen-powered cars (of the total number of about 5.1 million cars) and a thousand of hydrogen buses (of the total of number of about 20 thousand buses). All this at a cumulative cost of CZK 42.3 billion (CZK 3.9 billion to construct the filling stations, CZK 35.4 billion as an injection to support the hydrogen market and CZK 3.0 billion for buses) over the next 13 years. Additional effects of hydrogen mobility support can also be seen in the positive impacts on Czech economy in the years to come (support for research and development, need for new experts, increase in employment rate, competitiveness of the industry, etc.).

The above indicates that within the NAP CM update, the part of the document concerning hydrogen should be significantly extended and the main recommendations presented in this study should be taken into account. Likewise, it is necessary to review the national target as the number of hydrogen filling stations by 2025. The current target, as indicated by model calculations, has proved to be insufficient and not supportive of the development of hydrogen mobility in the Czech Republic. Therefore, at least 12 filling stations should be operational in 2025 based on this study (Basic scenario). As a result of the increase in the considered number of stations it is necessary to take into account an increased allocation under the planned Operational Programme Transport (currently CZK 100 million for hydrogen filling stations) to twice the value as a minimum in order to ensure adequate development according to the plan.

3.1 SWOT analysis

Strengths

- During the operation of provable zero emission of NOx, SO2, CO, all hydrocarbons (THC)
- Refueling duration comparable to conventional fuels
- More types of manufacturing resources (oil, gas, electricity – electrolysis, refinement of chemical waste)

Weaknesses

- New technology linked to uncertainty
- High price of serial automobiles
- Missing networks of filling stations in ČR

Opportunities

- Production of hydrogen in CR as side product (with low expenses)
- Tool for accomplishing Czech emission commitments relatively to EU
- Hydrogen as non-emission resource with the improving state of the living environment

Threats

- Uncertainty of customers (unfamiliarity with the market opportunities)
- Business case regarding infrastructure development will be negative in the long-term
- Lobbying of the current market (oil, electricity, conventional car manufacturers, gas station operators)

3.2 Recommendation

The primary goal of this study is to formulate strategic recommendations for successful fulfilment of predefined scenarios of hydrogen mobility development in the Czech Republic on the grounds of positive findings from not only hydrogen technology adoption abroad but also from the domestic experience. These recommendations are supported by not only a series of expert opinions obtained from in-depth interviews, but also by a survey conducted among broad public. All this was done under constant supervision and activities of the expert group.

In the context of potential hydrogen usability in the Czech Republic for all users, it is appropriate to define a clear vision in the form of **clearly defined concept of governmental support** which is also supported by foreign experience. The following section thus **summarizes fundamental strategic recommendations** which should be focused on, in case the Czech Republic decides to head towards hydrogen mobility.

The long-term implementation of hydrogen mobility depends primarily on **two pillars**. **The first one requires the existence of functioning and safe infrastructure of filling stations**, which would ensure hydrogen tank filling of the cars. **The second pillar is then represented by the cars themselves.**

This study´s findings imply the need to support basic infrastructure for hydrogen mobility development. It cannot be expected that the initiating costs will be paid by the private entities in full. This recommendation is thus introduced first. It is estimated that this will be the basic building block of development in order to achieve potential development of hydrogen industry. **It is desirable that the state actively supports both the construction of public filling stations for common citizens and also the non-public**

part of hydrogen infrastructure for public transport or communal services. The key focus should be also directed towards effective location of such infrastructure in both cases.

It is advisable to concentrate on covering the main communication paths at public stations so that the serviceability of the vehicles is as comfortable as possible for both domestic and foreign owners of hydrogen cars using trans-national transport corridors. Primary interest of the Czech Republic should be thus continuous support aimed at linking international hydrogen infrastructures. The reason is that the number of filling stations is still increasing beyond the western borders of the Czech Republic (Germany). The Directive 2014/94/EU of the European Parliament and of the Council offers further recommendations towards effective allocation of infrastructure as the filling stations should be built along the Trans-European Transport Network (TEN-T).

In the **segment of public transport** within the hydrogen infrastructure, the low number of filling stations is undisputed advantage which are necessary for the operation of vehicles in the depot. At first, some Czech agglomeration which is interested in this mobility could be involved and subsequently after successful implementation and demonstration of the positive results, the example could be followed in other Czech regions.

The second pillar for the successful implementation of hydrogen mobility is represented by the cars themselves. The foreign experience of countries which actively support the implementation of hydrogen mobility on their territory shows that it is evident that only **permanent and clearly defined concept of support for the purchase of hydrogen cars motivates both private and also the public sector towards their purchase.**

In support of the purchase of passenger cars among the Czech public, it is crucial to focus primarily on pilot projects implemented in the segment of the Czech business sector. After testing the allocation of donations within the business sector, it is possible to introduce support for regular users as well.

According to this study, the support of public transport serves as the best option in the ratio of costs and performance, respectively its impact. It is thus desirable to implement a donation programme with optimal allocation so that the investment costs are covered for substantially strong agglomeration where the potential of hydrogen bus usage will be high and it will be possible to test it in the real life.

This study shows that the support of public transport seems to be the best option considering the ratio of expenses, utility and impact on the living environment. Based on the Basic scenario, CZK 3 bn. would have to be expended by 2030 in order to support hydrogen buses which presents 8 % of total hydrogen vehicle expenses. Hydrogen buses should save up to 32 % of total saved CO_2 emissions (99,000 tons) by that time. Therefore, it is desirable to implement the subsidy programme with optimal allocation, in order to cover all investment expenses for sufficiently strong agglomeration, which will have the potential to utilize hydrogen buses and it will be possible to test the programme in real life.

To facilitate the launch of hydrogen mobility, there may be interesting changes to **local and state decrees**. Some of them are already used for electric cars therefore their implementation for hydrogen cars should only be a formality. These sub-adjustments would generate, for example, road tax omission, parking of hydrogen cars in reserved areas or in underground garages.

Public surveys further imply that even if among citizens‘ positive approach towards hydrogen mobility as such prevails, they do not have, however, enough information about the functioning, mechanism and undisputable advantages of this technology. **Strong PR thus represents an essential factor that will play key role in the hydrogen mobility development in the Czech Republic in the future.** An expert perspective has outlined that if hydrogen becomes a popular trend in a society, it will represent a major easement for the future use of alternative fuels in transport.

Last but not least, it is important to stress the **importance of continuing the work of the hydrogen mobility expert group.** The opinions of its members are the building blocks of hydrogen mobility reflected in this study. In addition, they know both the strengths, potential weaknesses and threats of the hydrogen mobility implementation. Therefore, the continuation of its innovative activities in this area is a driving force behind the **successful implementation of all related requirements and transfer of information among the particular subjects.**

Based on the above stated activities, it is necessary to update the target set in the NAP CM (there is a statement that 3 to 5 filling stations should be built by year 2025). The outcomes of this study clearly show that in case of complete fulfilment of the Basic scenario, **it is necessary to construct at least 12 hydrogen filling stations in the Czech Republic. Subsequently, it would be desirable to increase planned allocation of filling stations from Operational Programme Transport under the relevant sub-programme focused on the construction of hydrogen filling stations.**

4 Analysis of current hydrogen mobility situation

The analysis aims to describe the current status of hydrogen mobility. This status is viewed both in terms of technical readiness to use hydrogen-based technologies and fuel cells in the transport sector and in terms of the current expansion of hydrogen-powered drives on a global scale. Furthermore, the analysis is set to identify global trends in the development of hydrogen mobility. The following section lists interesting projects giving examples of how hydrogen mobility can be implemented in practice, including forms of support employed for interesting projects at various levels of self-government and companies. Chapter 5.7 provides SWOT analysis based on the collected data, the aim of which is to identify strengths and weaknesses, including opportunities and threats. Conclusions are drawn on the basis of the current status analysis findings while providing recommendations derived primarily from international experience that could subsequently be applied in the Czech Republic and also from the SWOT analysis while focusing on the opportunities for hydrogen mobility and threats, i.e. their mitigation in order to ensure potential successful development of this field of transport in the Czech Republic.

The final study presents the fulfilment of one of the tasks contained in the National Action Plan for Clean Mobility and, specifically, Task V2, under which the Ministry of Transport is requested, in cooperation with the Ministry of the Environment and the Ministry of Industry and Trade, to assess the potential of hydrogen drive applications in transport.

4.1 Executive summary

On a global scale, the development of hydrogen mobility is localized into three main regions. For the purposes of this study the most important region is Europe with conditions logically the most similar to the Czech Republic. The key motivation of all European countries and the European Commission in terms of implementing hydrogen mobility is the effort to reduce greenhouse gas emissions and to improve air quality. The most active country in this respect is Germany where the intention to develop hydrogen mobility is supported by a well-developed government strategy and the presence of a strong coordinator. Germany also spends substantial funds to support hydrogen-based technologies (a total of EUR 1.35 billion is estimated to be spent over 2017-2026). **The approach of other EU countries indicates that the key success factor for expanding the use of hydrogen-based technologies is a well-developed support system along with a comprehensive development strategy.**

However, the most important development centre is not Europe but Asia. In the technologically advanced countries of East Asia headed by Japan and South Korea, it is the industrial sector that is the driving force behind the development of hydrogen-based technologies. As regards hydrogen mobility, it is mainly car manufacturers (Toyota, Hyundai). The region is characterized by existing government development strategies. **State-funded support for the purchase of a hydrogen passenger car totalling USD 23k is offered in these countries.** The main motivation for the development of hydrogen technologies is to improve air quality in urban agglomerations, reduce greenhouse gas emissions, and gain technological head start in the use of modern technologies.

Last but not least, another major centre is the United States. The main development driving force in this region are business corporations looking for new opportunities for their business. There are strategies and plans in place to build several dozens of filling stations. **In the past, investments were co-financed by the California Energy Commission in the form of subsidies covering 70-85 % of capex**. Overall, USD 80.9 million was provided in the form of infrastructure support by the end of 2015.

The current situation in the Czech Republic can be characterized **by inadequate legislation related to the development of hydrogen mobility**. On the other hand, a prototype of hybrid bus with hydrogen fuel cell, TriHyBus, was introduced as early as 2009. As part of a project supported by the Ministry of Transport of the CR, a non-public hydrogen filling station was established in Neratovice. At present, other activities are being developed which indicates a positive shift towards greater hydrogen-based development. Comparison with other active regions shows that the **Czech Republic slightly lags behind.** On the other hand, it can make use of experience and know-how from already implemented projects (both its own and those from abroad) and **significantly accelerate the development of hydrogen technologies in the medium term.**

There is a huge pool of experience from abroad that the Czech Republic may profit from. One of the examples is the Bee Zero project which showed how even a minimum investment in the infrastructure (one filling station) can result in the operation of a passenger car fleet. Another example may be the CHIC project which proved sufficient maturity of hydrogen drives for buses. As part of a Hamburg project, a strategy for addressing public transport and establishing hydrogen filling infrastructure in an agglomeration was formulated, including public support.

Besides strengths and opportunities, the use and development of hydrogen technologies also entails certain weaknesses and threats. **The greatest opportunities** can be seen in the production of hydrogen as a by-product, in the possibility of establishing strong positive PR for the Czech Republic and local governments, it is also possible to make use of the knowledge gained from the introduction of electric cars and CNG several years ago, the interconnection with the neighbouring countries developing hydrogen infrastructure and, last but not least, the current interest in hydrogen technologies with respect to supply, demand and investors. On the other hand, it is necessary to mention threats to the development in the form of uncertain interest, insufficient support for the development of hydrogen mobility, lobbying by the existing conventional fuel market and poor infrastructure.

Information gathered to date predict good future of this industry and it is more up to the market (market stakeholders) and the government how they will react to these future developments. A prerequisite for this is a government strategy that will clearly define areas of interest and state involvement.

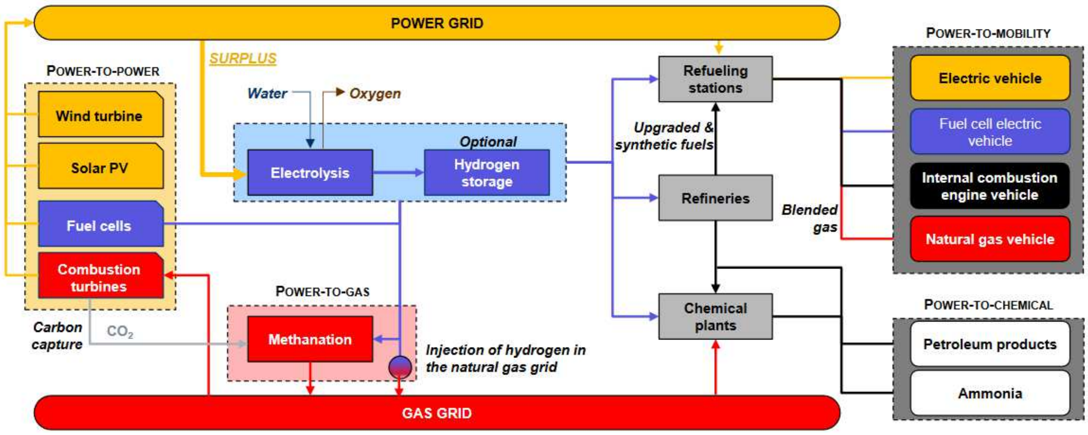
4.2 Hydrogen technologies for clean mobility

Hydrogen mobility is nowadays based almost exclusively on the use of hydrogen in fuel cells (in German, Brennstoffzelle). The fuel cell is an electrochemical system in which the fuel (hydrogen) reacts with air oxygen resulting in the production of electricity. Such electricity is used in electric motor to drive vehicles. For this reason, hydrogen mobility forms a sub-group of electromobility within the global context. Hydrogen powered electric vehicles are referred to as the "fuel cell electric vehicles" (FCEV) in order to be distinguished from battery electric vehicles (BEV). Technically speaking, hydrogen can also be used in combustion engines but given the lower efficiency of this approach it is currently not developed by any of the leading car manufacturers.

The use of fuel cells offers some significant advantages over battery-powered electromobility. The most important of these is the longer distance between refuelling of FCEVs (around 600 km) and the possibility of rapid refilling which is not too different from the present liquid fuel filling. An important advantage over combustion engine vehicles is the elimination of all pollutant emissions as the only product of the hydrogen and oxygen reaction in the fuel cell is clean water. It follows from the above that hydrogen drives have a chance of being applied in individual transport if the required distance between refuelling is more than 300 km or in public and freight transport (buses, light trucks), i.e. transport modes that can hardly be based on battery electric vehicles. Preference is also given to FCEVs where there is an increased requirement for air quality. The transport sector is a major producer of pollutants (dust, carbon monoxide, nitrogen oxides) and greenhouse gases [1] and the use of non-emission hydrogen technologies in transport can make a significant contribution to reducing air pollution. For example, in comparison with the valid Euro VI emission standard [2] and based on the fact that FCEV drive emissions are zero, 100 g of carbon monoxide, 10 g of total hydrocarbons (THC), (of which 6.8 g of hydrocarbons not containing methane), 6 grams of NOx and 0.5 grams of solid particles are saved in M category vehicles at a 100 km distance, respectively 50 grams of carbon monoxide, 8 grams of NOx, 17 grams of the THC + NOx sum and 0.5 grams of solid particles in comparison with a diesel engine.

Hydrogen mobility is part of a broader hydrogen-based economy that links the sector of energy and transport bringing significant benefits for both these sectors (in the field of grid energy stabilization, zero emission transport and reduced dependency on oil products import). The hydrogen economy scheme is illustrated in Figure 1.

Figure 1: Expanded hydrogen economy scheme [3]

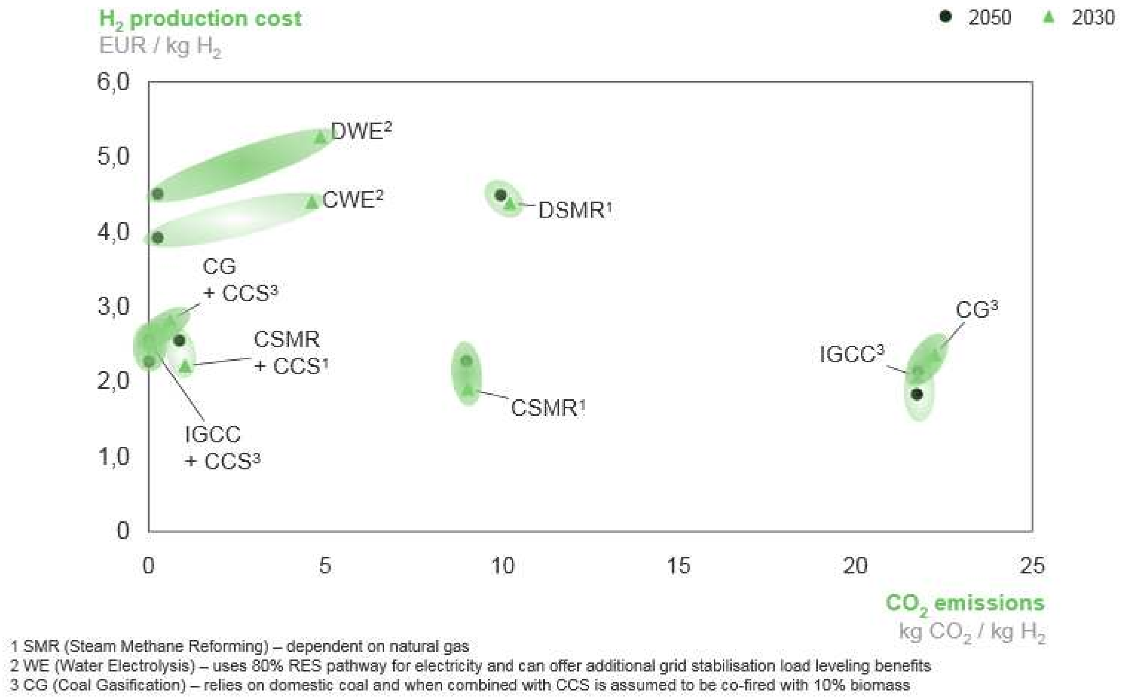


This interconnection with energy brings further potential hydrogen mobility benefits. Compared to oil or gas based transport, it makes it possible, similarly to battery-based electric mobility, to limit dependency on imported crude oil and oil products. Approximately 7 million tons of crude oil (of which 64 % from Russia) and 0.6 million tons of oil products (import and export balance) were imported to the Czech Republic in 2012 [4]. There are also significant savings in greenhouse gas emissions but this depends on the origin of hydrogen used. Vehicles powered by fuel cells are locally "tank to wheel", both in terms of pollutant emissions and carbon dioxide emissions. A positive effect over most of the other available drives is introduced by hydrogen mobility also from the "well to wheel" point of view, i.e. when including emissions produced during fuel production and distribution. According to US DOE data, the well to wheel energy intensity of hydrogen mobility is 37 % lower than petrol-fuelled combustion engine vehicles even when fossil hydrogen produced by natural gas steam reforming process is used. At the same time, carbon dioxide emissions are reduced by 44 % (from 292 g/km to 162 g/km) [5].

Hydrogen production

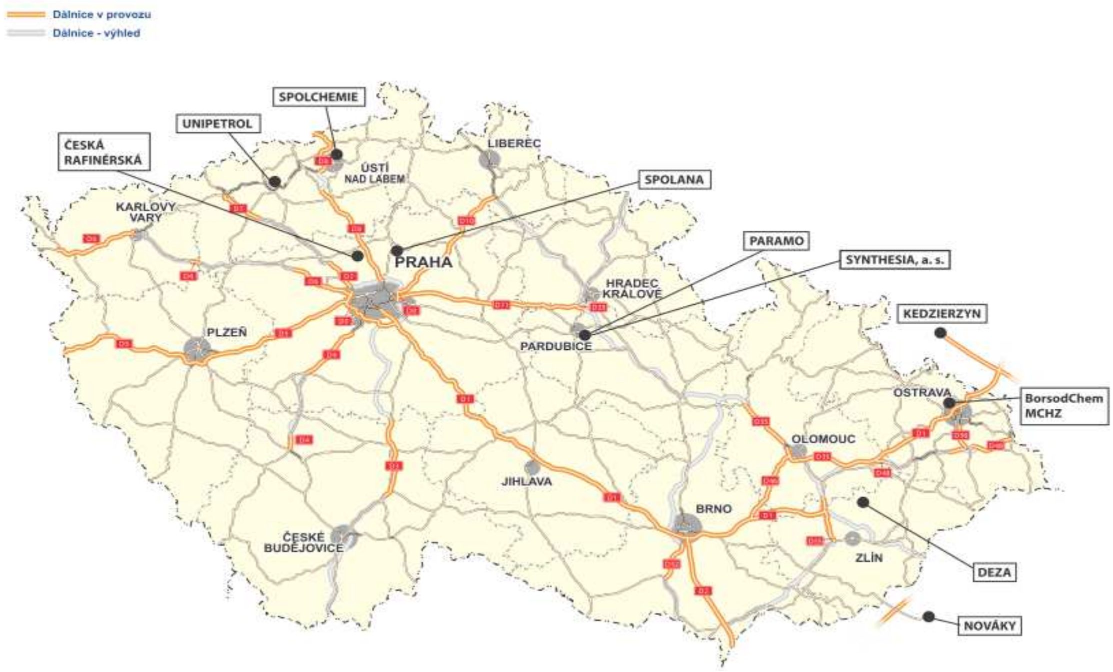
Hydrogen management (production, transport, storage) is an industrial sector that is well managed and with a long history. Coal gas which contains a considerable amount of hydrogen (and also poisonous carbon monoxide) was used in the Czech Republic from the second half of the 19th century until 1996 [6]. In terms of hydrogen production, the global production of hydrogen reached about 600 bn. m^3 (N) in 2010, equivalent to approximately 54.5 million tons/year. In recent years, an upward trend in hydrogen production has been observed by about 5 % y/y, with an even higher increase expected in the future [7]. The vast majority (96 %) of hydrogen is produced from fossil fuels, mainly by natural gas steam reforming [8]. The main advantages of these processes are considerable simplicity, long-term operating experience and the related favourable economy. On the other hand, all these processes produce a certain amount of greenhouse gases. The remaining 4 % of the annual hydrogen production is based on conventional methods, the so-called alkaline electrolysis of water. This method uses electrochemical cleavage of bonds in water molecules by means of electrical voltage. The advantage is zero CO_2 emissions in the production process itself. Total CO_2 production then depends on how the electricity is generated and "emission-free" hydrogen can be considered as hydrogen produced from electricity from nuclear energy or energy from renewable resources.

Figure 2: Expected hydrogen price between 2030 – 2050 and related CO_2 emissions from various production methods [9]



In the CR there are also about ten industrial plants producing hydrogen (either as the main product or by-product) and this hydrogen is potentially available on the market. For example, Spolchemie in Ústí nad Labem keeps free hydrogen in the amount of up to 2,000 m^3 (N)/hour (about 4 t/day, which would enable FCEV distance between refuelling of over 400 thousand km/day). Figure 3 shows the location of these producers within the Czech motorway network. Another important hydrogen producer is Unipetrol which plans to utilize the free hydrogen production capacity to supply hydrogen filling stations (HRS) built within the Benzina petrol station network [10]. The first public HRS in the Czech Republic should be established during 2018.

Figure 3: Sources of hydrogen in the CR in the motorway network [10]



In the opinion of the Czech Hydrogen Technology Platform (HYTEP), the use of free production capacities which of hydrogen produced as a by-product is an important step in the development of hydrogen mobility. The main reason is the very fast availability of this hydrogen and its relatively low price. In the next phase, i.e. after sufficient development of refuelling infrastructure and vehicle fleet, or the full utilization of the existing capacities, it will then be desirable to look for such a source of hydrogen that will make the greenhouse gas emissions as low as possible.

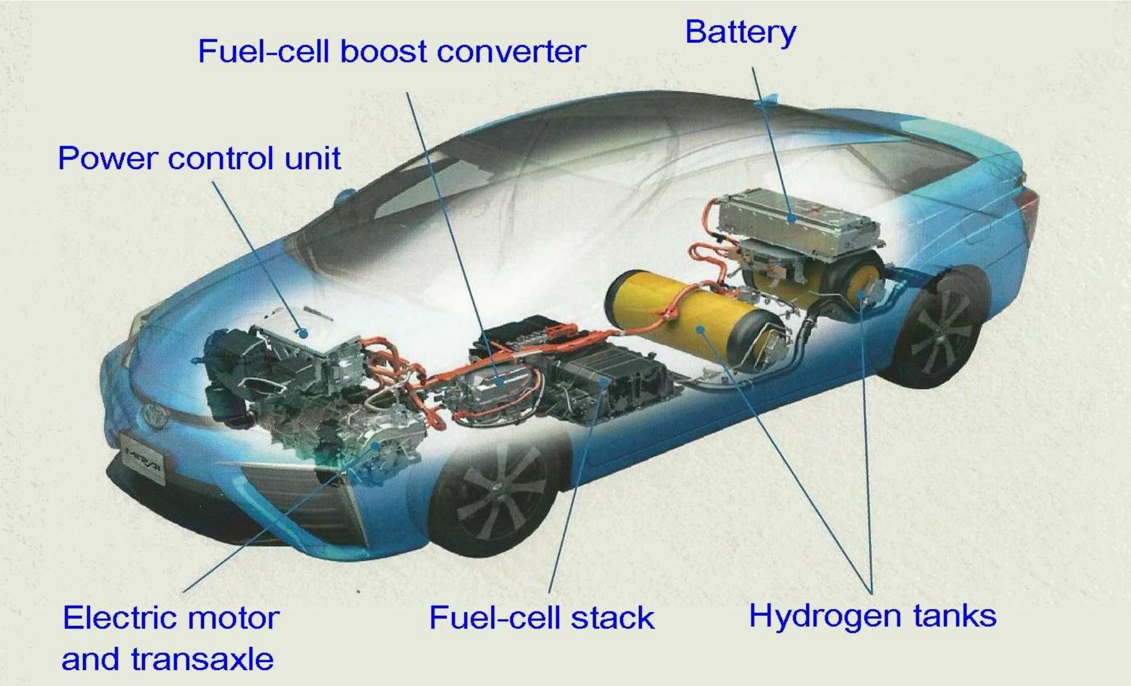
Historical development

The first fuel cell was constructed in 1839 by English physicist Sir William Grove. At that time, the fuel cell was regarded more as a laboratory curiosity. Even before that, in 1807, engineer Francois Isaac de Rivaz constructed a vehicle in Switzerland that was powered by hydrogen energy but it was used in a combustion engine. In the mid-20th century, English scientist Francis Thomas Bacon revived the interest in fuel cell technologies. Together with his colleagues he constructed an alkaline 5 kW cell (1959) that could power a welding machine. His success did not remain unanswered - Pratt & Whitney (USA) bought Bacon's license for his patent and produced fuel cells for Apollo missions, where the cells were used as a source of electricity and drinking water for astronauts. In the same year, Harry Ihrig constructed the first ever fuel cell vehicle, a 20 HP tractor. In the 1990s, several major automobile manufacturers, particularly Honda, General Motors, Mercedes-Benz, BMW, and Toyota, began to deal with hydrogen. Serial production of hydrogen-powered vehicles was first launched by the Korean automaker Hyundai [11]. This automaker has also converted the well-known SUV model ix35 to hydrogen-fuelled model. It has been clear since the 1990s that in technological terms, the electric drive receiving energy from hydrogen in fuel cells has significant positive features and can potentially be viable. The main challenge for using this type of drive has been the relatively short service life of the fuel cells, high costs and lack of refuelling infrastructure. The obstacle related to short service life of the fuel cells has been largely eliminated in recent years and the increasing number of long-term demonstration projects proves that the fuel cell service life for buses is more than 20,000 running hours [12]. For personal mobility, the multi-year FCH JU work programme requires the fuel cell service life of at least 5 thousand hours (2017) and 7 thousand running hours in 2023. Significant progress has also been made in reducing the cost of acquisition, with a 65 % reduction in the price of personal mobility between 2012 and 2017, and a 50 % reduction for buses [13]. However, the price still exceeds the purchase price of conventional vehicles. Nevertheless, the main barrier to the development is still the missing refuelling infrastructure.

Hydrogen mobility readiness

Hydrogen mobility is based on two main pillars. The first pillar is the filling station infrastructure enabling vehicle tank refuelling. The second pillar are the vehicles themselves. These include both the passenger cars (FCEV), buses (FCEB) as well as other types of vehicles and equipment such as trucks and forklifts. From the point of view of technical maturity, both these pillars of hydrogen mobility are now ready for real-life deployment.

Figure 4: Toyota Mirai [14]



From the technological point of view, the current standard is the use of filling stations capable of filling the vehicle tanks with compressed hydrogen gas up to a pressure of 700 bar (70 MPa). This pressure is presently used by the vast majority of produced passenger cars. For larger vehicles (buses, trucks, but also ships and trains), it is common to use a maximum pressure of 350 bar (35 MPa). Filling a passenger car tank to cover a distance over 500 km takes usually less than 3 minutes [11]. The main stakeholders in filling station technologies are Linde, Air Products, Giner, Air Liquide, ITM Power, McPhy and Hydrogenics.

According to the California Energy Commission data of December 2015, the cost of establishing (technology, construction, and other costs) the individual filling stations in the US ranged between USD 1-3 million. According to the same source, the potential for cheaper technologies is quantified at 50 % by 2025.

In the developed parts of the world, backbone refuelling infrastructure is gradually being established. The most active regions include Western Europe (Germany, France, Great

Britain, Scandinavian countries), East and West Coast of North America (USA and Canada) and East Asia (Japan, South Korea, and China). In January 2016, a total of 214 filling stations were in operation [15].

In Europe, 95 hydrogen filling stations are currently in operation, 50 in North America, 2 in South America, one in Australia and 67 in Asia. Of the total number, 121 stations worldwide are public.

Significant developments occurred in 2015, when 54 filling stations (48 public) were added worldwide. The others are designed to fill up buses or reserved for vehicle fleet customers. All seven new stations in North America are accessible to the public, 6 of which are located in California and one in Colorado. The greatest filling station boom is in Japan, where 28 stations have been newly opened. In Europe, 19 stations have been opened, of which 4 in Germany. This has increased the number of hydrogen filling stations in Germany to 34, of which 21 are publicly accessible [15]. These countries are working on a major change in the refuelling infrastructure.

Table 1: Number of hydrogen filling stations in individual countries (2016) [16]

Country	No.of filling stations	Country	No.of filling stations
Japan	80	China	3
USA	48	Sweden	3 (4)
Germany	34	Austria	3 (5 [17])
Great Britain	15	Canada	2
Denmark	11	Finland	2
France	10	Spain	2
Norway	6	Italy	2
South Korea	6	Czech Republic	1
Switzerland	6	Slovenia	1
Indie	4	Australia	1
Hawaii	4	Argentina	1
Belgium	4	Brazil	1

In terms of hydrogen-powered vehicles, there has been a significant shift in the autumn of 2009 when some of the leading car manufacturers (Daimler, Ford, GM/Opel, Honda, Hyundai, Kia, Renault, Nissan and Toyota) signed a Letter of Understanding [18] setting a target of achieving low-volume commercial production of fuel-cell-powered vehicles by2015. According to Daimler's statement given at the World Hydrogen Energy Conference 2012, the aforementioned automakers invested over USD 6 bn. in the FCEV development in the first three years. Following this Memorandum, some of the car makers introduced their hydrogen fuel cell car models. Some of these models are already commercially available on some global markets, others can be expected in the near future. Specifically, these models are Hyundai ix35 FC, Toyota Mirai, Honda Clarity FC. Other major automakers are now at the stage of preparing and testing their cars (Mercedes F-Cell, BMW, VW Group and others). The closest to the commercial deployment in Europe is currently Hyundai ix35 FC, which can be purchased in the German market at around CZK 1,567,160 [19]. The current fuel consumption of passenger hydrogen-powered cars is approximately 1 kg per 100 km (0.9512 kg per 100 km according to EC documents [20]).

Table 2: Serial production of hydrogen-powered cars [19, 21]

Manufacturer	Model	Distance	Output	Price (converted to CZK)*
Toyota [22]	Mirai	500 km	154 HP electromotor	1,461,650
Hyundai [11]	ix35 FC	594 km	(fuel cell 113 kWe)	1,567,160
Honda [23]	Clarity FC	589 km	136 HP electromotor	1,703,140

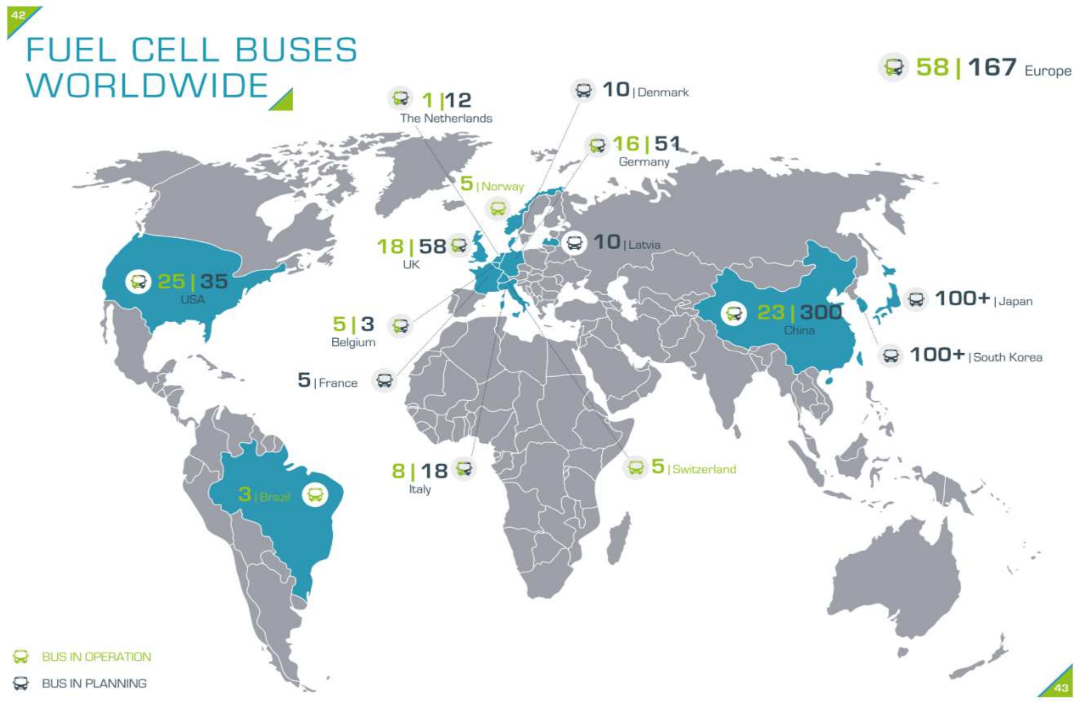
***the price depends on the specific market**

Figure 5 provides a broader overview of FCEV. In addition to the above-described commercially available models, other vehicles are also shown here. The Honda FCX Clarity models (predecessor of Honda Clarity FC), Mercedes F-Cell, the GM/Opel model and various BMW models have been tested on a long-term basis, too.

Figure 5: FCEV (various rate of readiness for market entry) [24]

More than 30 demonstration projects have been implemented in the field of fuel cell electric buses (FCEB). As part of the most important projects, more than 20 buses (High V-LO City, CHIC, Bay Area) have been purchased and operated. The most important bus integrators in these projects have been Van Hool, Daimler and Toyota, but Central European Solaris and Czech Škoda Electric are also listed. In the vast majority of cases, the fuel cells were supplied by Canadian company Ballard, but major producers include Hydrogenics and Toyota [25]. From the technological point of view, two possible approaches are currently considered for buses; they only differ in terms of the fuel cell used. According to the first approach (which is now widespread) the FCEB use fuel cells designed specifically for "heavy duty" applications. The second approach promoted, for example, by Daimler and Toyota in their cars under development, is to use the same fuel cells for both passenger cars and buses. This second approach should facilitate economies of scale given the fact that a multifold increase in the number of manufactured passenger cars compared to the number of manufactured buses can be envisaged in the near future. The FCEB price level for the European market is currently EUR 625-650 thousand (about CZK 17 million), and these prices are also the maximum threshold for the purchase of FCEB under the FCH JU Programme (2017, or 2016) [26]. The CHIC project conclusions envisage that the price could drop by about half by 2030 [27]. Figure 6 below shows completed and planned hydrogen bus projects on a global scale.

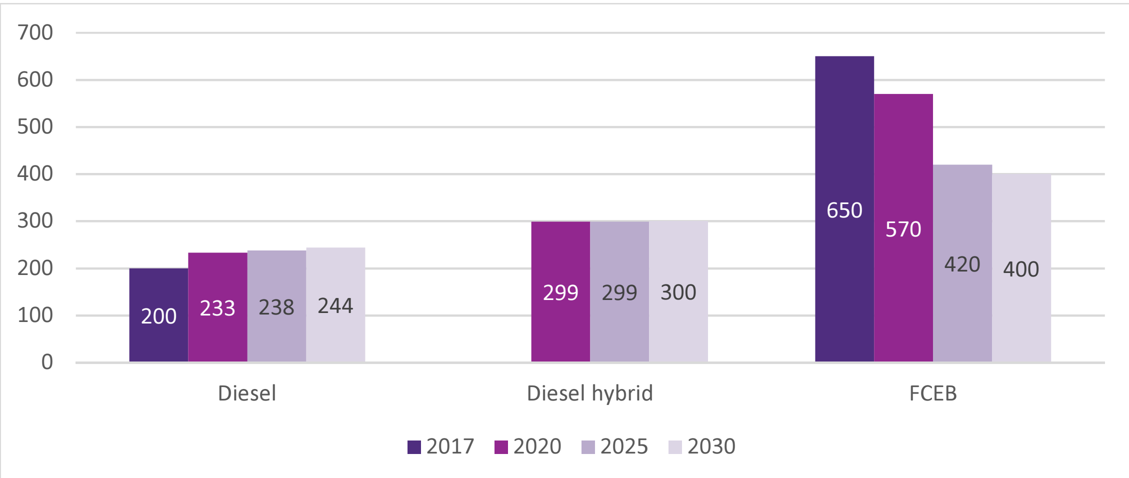
Figure 6: Current status and forecast deployment of hydrogen-powered buses [28]



Bus transport is more dependent on local conditions than private transport. A detailed analysis of the use of FCEB in Europe is provided below.

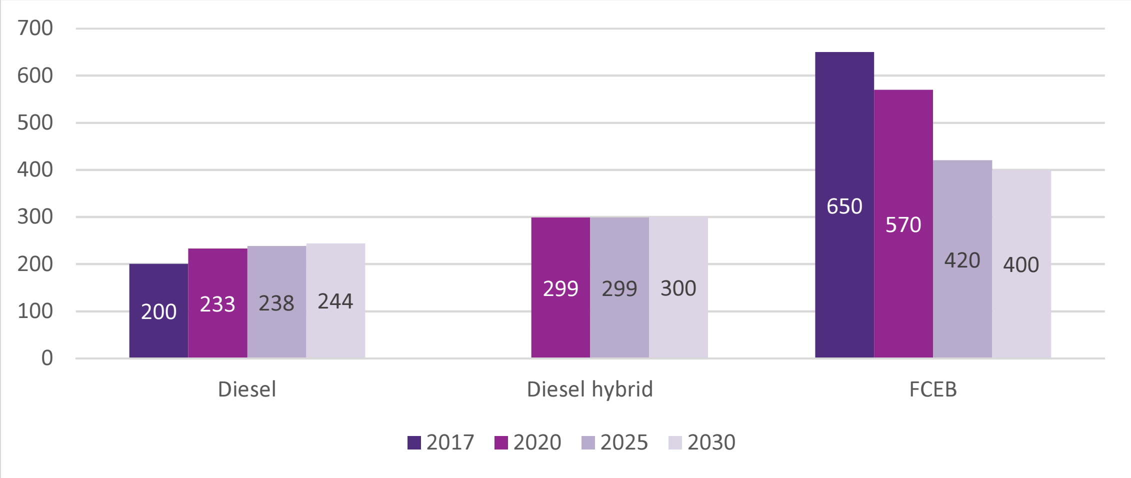
Figure 7 shows an estimated trend of the cost of FCEB acquisition comparing the present and the year 2030. If fuel cells from passenger cars (FCEV) are used, a more significant drop in the FCEB price than as shown in the graph is expected , i.e. a drop to EUR 350,000 while reaching annual sales of fuel cell vehicles at the level of 10,000 cars (expected between 2020-2025) or EUR 320,000 while reaching annual sales of 100,000 cars [29].

Figure 7: Estimated trend in the cost of standard FCEB acquisition in kEUR [29]



An important parameter for vehicle operators is the total cost of ownership (TCO) which expresses the sum of the acquisition and operating costs expressed per driven km. Figure 8 shows the total cost per kilometre for a Diesel bus, FCEB and FCEB (FCEV FC) with automotive fuel cells at the production rate of 10,000 cars and 100,000 a year. However, the above graph provides rather a comparison between the individual drives, the absolute values stated in the graph are not valid for the Czech Republic due to the different cost of labour, purchasing power and other local specifics (for example, to explain this, the estimated costs per driver are EUR 80,000 a year).

Figure 8: Total costs of ownership in EUR related to 1 driven km (model for FCH JU) [29]



The graph shows that with diesel buses the expected TCO increase is by 20 % between 2020 and 2030, the FCEB TCO should fall by almost 10 % over the same period. A further significant decrease in total costs should occur with respect to FCEB with automotive fuel cells as a result of market development. Given 100,000 vehicles (FCEV) sold annually, the costs of diesel buses should be caught up with in 2030.

The basic idea of the technical situation of FCEB in Europe can be obtained from the FCH JU 2017 Call for Proposals concerning hydrogen technologies announced on 17th January 2017. The Call sets the maximum price of a 12-meter bus to EUR 625,000 and requires the following technical parameters:

- average annual availability of FCEB fleet (up to 20 buses) at least 90 %;
- hydrogen consumption 7-9 kg/100 km (combination of SORT 1 and 2 for a 12-meter bus);
- mean distance between failures (MDBF) at least 3,500 km;
- tank-to-wheel efficiency above 42 % SORT 1 and 2;
- guaranteed fuel cell life (until general overhaul) 20,000 running hours.

4.3 Current status around the world

The current status around the world is described for the individual regions. For each region we give comments on the current status of developing the filling refuelling infrastructure and the hydrogen-powered vehicles market. In addition, strategic objectives and the methods to achieve them are described for each region.

4.3.1 Europe

From Europe's point of view, the overwhelming majority of activities are located in the European Union and the countries of the European Economic Area (especially Norway). However, unique activities can also found in other countries (e.g. Turkey and Ukraine).

The introduction of zero-emission mobility (including hydrogen mobility) in the EU is currently primarily motivated by the efforts to achieve reductions in greenhouse gas emissions from transport, which have not been reduced so far (in comparison with other sectors). This issue has become even more serious in the context of the so-called Paris Climate Change Agreement, which includes, among other things, a commitment to keep the average global temperature increase below 2° C compared to the pre-industrial revolution period. For the EU this means a commitment to reduce greenhouse gas emissions by 85-90 % by 2050.

Secondly, the strategic documents of the European Commission indicate the need to strive after reducing emissions of harmful substances. On the other hand, it is true that the issue of improving air quality in urban agglomerations and reducing the level of noise nuisance has been handled at the EU level for a long time. A crucial document in this respect is Directive 2008/50/EC on ambient air quality and cleaner air for Europe.

The main driver of hydrogen mobility in the European Union is the Fuel Cell Hydrogen Joint Undertaking (FCH JU), established by Commission Decision 559/2014. In addition to the European Commission, the Joint Undertaking includes the industrial sector (the industries are associated under the heading of Hydrogen Europe) and R&D organizations (associated under the heading of the New European Grouping on Fuel Cells and Hydrogen - N.ERGHY). Hydrogen Europe is an industrial association joining almost 100 industrial companies dealing with fuel cells and hydrogen. N.ERGHY includes 60 major research organizations in this field (list of members [30]).

Under Horizon 2020 (the period of 2014-2020), FCH JU is in charge of research support, development and implementation of hydrogen technologies with a total budget of EUR 1.33 bn. Just in 2014 and 2015, FCH JU members spent additional EUR 188 million from non-public and national resources [31]. Since 2008, (i.e. including the FP7 period) about 185 projects have been supported under the programme [32].

The FCH JU targets for 2014-2020 are defined in the document titled Multi-Annual Work Plan 2014-2020 [13]. The target performance and parameters of the announced calls are defined annually in the Annual Work Plan [26].

As regards the refuelling infrastructure, Germany has the largest number of hydrogen filling stations (34) in Europe, followed by Great Britain (14), Denmark (9), France (9) and Norway (6 stations, 5 of which are in operation, 2 more will be completed in 2017) and Netherlands (3). [33] While French stations are intended for selected vehicle fleet customers, most stations in other countries are available to the public.

Table 3: Scenario of implementing the HRS in European countries [24]

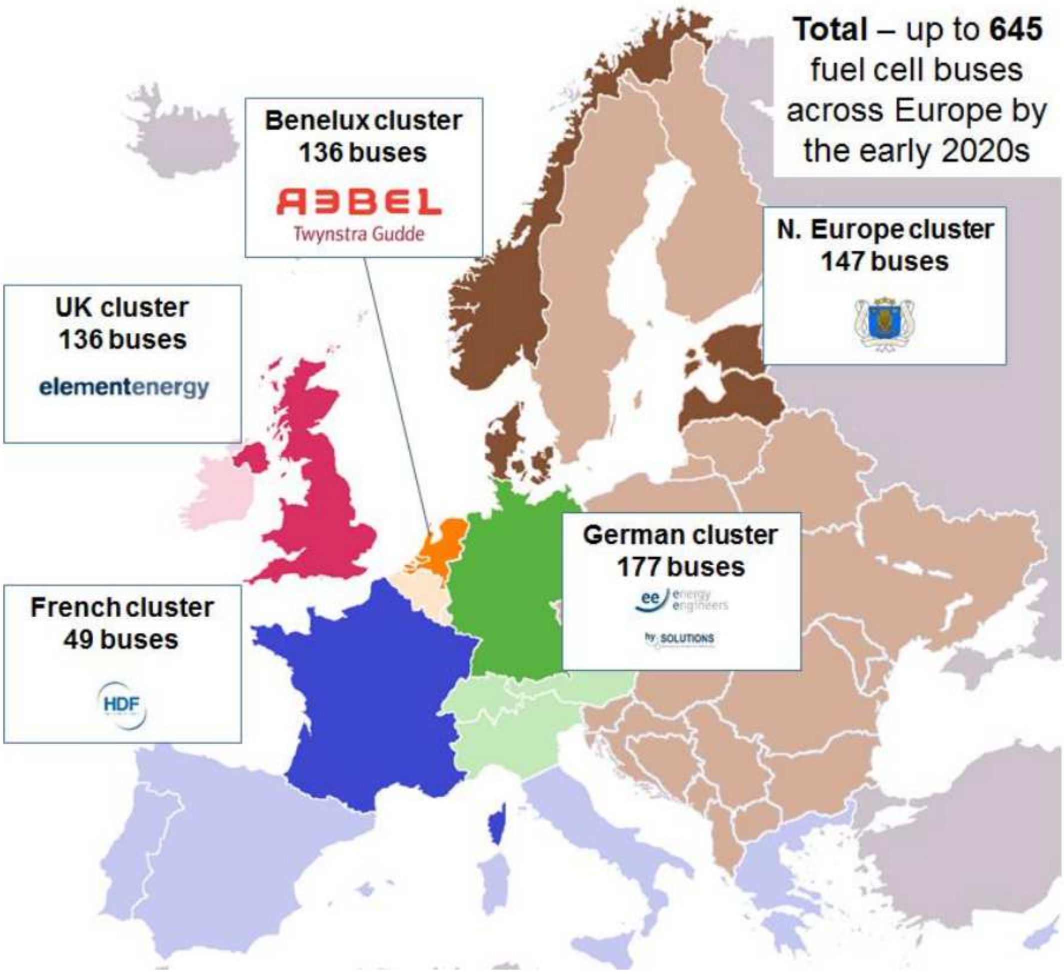
HRS	Germany	Great Britain	Norway	France	Denmark	Belgium	Sweden	Finland	Netherland	Slovenia	Poland
2015-2020	100	65	20	22	15–50	20	15	6	20	1	1
2020-2025	400	300	80	50	100–200	75	25	20	50	5-9	5
2025-2030	900	1100	200	600	500–600	150	100	26	-	-	9

Considering the Central European region, Germany is clearly the leader (34 stations), followed by Austria (5 stations in total, 3 of which 3 in operation, additional 2 planned). No filling stations are currently available in Poland, Slovakia and Hungary [16].

In the EU, the hydrogen technology support is addressed both at the level of the European Commission through FCH JU and within the national policies of the individual member states. These are often integrated projects where the establishment and development of hydrogen regions is encouraged, including both private and public transport, refuelling infrastructure and energy applications. Passenger cars are thus implemented both within FCH JU projects (e.g. Hydrogen Mobility Europe 1 and 2) as well as from national funds (mainly in NIP in Germany).

The hydrogen bus technology (FCEB) is considered an important element in the road transport decarbonization and reduction of pollutant emissions. The potential offered by hydrogen buses has mainly been demonstrated in Europe by the CHIC project but other projects (High VLOCity, HyTransit, 3EMotion) exist, too. In September 2015, FCH JU initiated a coordination platform that has led to the emergence of regional clusters. In the first phase of the hydrogen bus demonstration, 300-400 buses are planned to be deployed by 2020. As part of the joint procurement strategy for the purchase of hydrogen buses, clusters have been formed, whose members are committed to implement the following demonstration projects as shown in Figure 9 [34] (status in 2016). The Czech Republic is mentioned as an associate member of the Northern Europe cluster, whose members are Denmark, Norway, Sweden, Finland, Estonia, Lithuania, Latvia and Poland.

Figure 9: Planned hydrogen bus demonstration projects [34]



During this activity, entities interested in more than 600 FCEBs were identified and the demand for this technology exceeded the original plan. In the FCH JU 2016 Call, the maximum FCEB price was set at EUR 650 thousand, with the maximum support for a 12-meter car reaching EUR 200,000. Thus, the real cost of acquiring 1 bus was up to EUR 450 thousand (compared with EUR 200 - 250 thousand for a diesel bus) [34].

However, in terms of capex, there is a development and the FCH JU 2017 Call sets the maximum acquisition price at EUR 625 thousand.

The following section describes in brief the situation of hydrogen mobility in the individual European countries or regions. The order of importance is chosen for the Czech Republic, i.e. countries neighbouring the Czech Republic are discussed at the beginning, followed by countries and regions where significant activities can be observed.

Germany

Within the European Union, Germany is one of the most important hydrogen mobility driving forces. Given that this is also a neighbour country of the Czech Republic and its most important economic partner, this section provides a brief description of the implementation of hydrogen mobility in this country.

First attempts to transform hydrogen technology into a new commercial product were launched in Germany at the turn of the 1990s by large companies such as Dornier, Daimler, i.e. Daimler Chrysler and BMW. Since the commercial use of hydrogen technology did not materialize in the originally envisaged dimensions, these companies were forced to disconnect or suspend the planned programmes for almost 10 years.

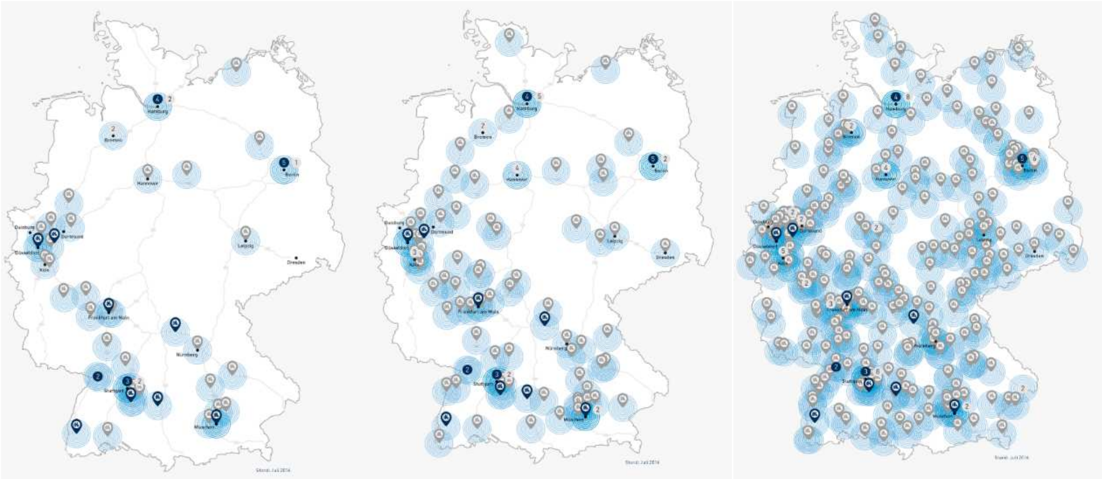
However, on the basis of a political decision to make Germany the leader in the field of transport and renewable energies from 2002, a significant change has occurred. As part of the “Energiewende” policy, a National Innovation Programme (NIP) has been set up to ensure implementation of this goal. Hydrogen technologies have become a key part of this programme. Under the NIP, a total of EUR 1.4 billion has been invested in Germany (NOW GmbH support totalled EUR 700 million) [35] while implementing more than 650 market preparation projects implemented in the form of PPPs. Under the programme it has been demonstrated that hydrogen technologies may meet the relevant requirements both in the energy sector and in the field of mobility.

This programme is followed by the NIP II programme, which, just like its predecessor, has been implemented in the form of PPPs and receives public funds of EUR 250 million for the period of 2017-2019 and another approximately EUR 1,1 bn by 2026 [36]. The role of NIP II is to introduce hydrogen technologies to the real market. Projects under NIP I and NIP II are 50 % co-funded by commercial entities [35].

An important tool for achieving the objectives of NIP I and II is the National Organization for Hydrogen and Fuel Cell Technology, Ltd. (NOW GmbH). This organization was established as a joint venture formed by four relevant German ministries: BMVI (Federal Ministry of Transport and Digital Infrastructure), BMWi (Federal Ministry of Economic Affairs and Energy), BMUB (Federal Ministry of Environment, Nature Conversation, Building and Reactor Safety) and BMBF (Federal Ministry of Education and Research.

The main task of NOW GmbH is to coordinate the implementation of NIP. It is therefore responsible for the evaluation and selection of individual projects meeting the programme strategy and oversees synergies and cooperation between individual projects. It also carries out other activities such as education, communication between industries, politicians, research centres, the public and coordination within European activities such as the Trans-European Transport Network (TEN-T). Figure 10 shows the planned development of refuelling infrastructure by 2023 in Germany. Germany is a member of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).

Figure 10: Filling station network in Germany in 2016, 2018 and 2023 [37]



Austria

Austria is an active country in terms of hydrogen mobility. Together with Germany, it is a neighbour of the Czech Republic which has included hydrogen mobility into its national policy framework. It is also a member of IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy). By the end of 2016, Austria had a total of 5 filling stations meeting the required standards under Directive 2014/94/ EU. The fuelling stations are currently being supplied by Linde acquiring hydrogen for natural gas steam reforming. In the future; however, the use of water electrolysis at the refuelling points is planned to produce hydrogen. The stations are operated by Linde and ÖMV and are designed for passenger cars (however, there is no customer in Austria at the moment). The funding of the stations was realized using a combination of private, European and national resources. The price of hydrogen at the filling stations is EUR 9.50/kg (at the consumption of 0.9512 kg of hydrogen per 100 km the price per km is about EUR 0.09), and the price reflects all costs of production, distribution and hydrogen filling (including related depreciation) and no significant change is expected in the foreseeable future. [38] Austria declares that this network covers all important agglomerations and TEN-T corridors [17]. Austria has participated in several demonstration projects, particularly in the field of development and testing of the refuelling infrastructure (Linde filling station production is located in Austria). However, Austria has not taken part in any major projects in the field of hydrogen vehicle demonstration [39].

Slovakia, Poland, Hungary

According to available information from November 2016, neither Slovakia nor Poland has included hydrogen into their national policy frameworks. Information about Hungary is not available. At present, there is no specific hydrogen technology development plan available for Slovakia or Hungary, and neither of these countries has a filling station in place. Poland has developed a plan entitled “Circumstances of the National Plan for Hydrogenation of Road Transport in Poland” under the HIT-2-CORRIDORS project. According to his project, Poland plans to build refuelling stations in the following locations: 1 - Poznań, 2 - Warsaw, 3 - Białystok, 4 - Szczecin, 5 - Lódź, 6 - Trojście, 7 - Wrocław, 8 - Katowice, 9 - Kraków [40]. Slovakia is preparing a construction project of a filling station in Kosice, which should be co-financed by the CEF Transport funds (source: HYTEP). According to the Polish Press Agency (PAP), two filling stations should be built in Poland with the help of European funding [41]. It is interesting that the Polish company Solaris has become one of the hydrogen buses manufacturers when it delivered two buses to Hamburg in 2015 [42], a delivery of trolleybuses with hydrogen extension to Latvian Riga is planned (source: HYTEP). In Hungary, activities related to hydrogen are coordinated by the Hungarian Hydrogen and Fuel Cell Association, which also participated in a project coordinated by the Czech Hydrogen Technology Platform in the framework of the Visegrad Cooperation "Strengthening of Hydrogen Competencies in Visegrad Countries in 2016" [43].

Scandinavia

In order to coordinate activities in the Scandinavian countries, the Scandinavian Hydrogen Highway Partnership (SHHP) was established in June 2016, which includes regional clusters from Norway, Sweden and Denmark. The SHHP coordinators are national platforms, i.e. Norsk Hydrogenforum, Hydrogen Sweden and Hydrogen Link (Denmark) [44]. At present, there are 18 filling stations operated in the region (5 in Norway, 4 in Sweden, 9 in Denmark).

Benelux countries

Belgium and the Netherlands have included hydrogen mobility in their national policy frameworks for alternative fuels. In terms of the existing infrastructure, Belgium now has 4 filling stations, the Netherlands has 3. By 2030, the countries have set the goal of increasing the number of stations to 150 and 200, respectively. The main motivation is to reduce greenhouse gas emissions [45]. Belgium has drawn up an implementation plan for hydrogen filling infrastructure valid until 2015 [46]. The Netherlands is a member of the IPHE.

Great Britain

In Great Britain, hydrogen mobility has also been included in the alternative fuel national framework policy. The goal was to set up 65 filling stations by 2020 and to develop additional 1,000 stations by 2030 [45]. Great Britain is a member of the IPHE.

France

In France, 14 hydrogen filling stations are currently available, additional 24 should be constructed between 2016 and 2018 The development in France is driven by Mobilité Hydrogene France, with the participation of the government in cooperation with a strong consortium of private companies whose members agreed on a transition strategy to move from isolated fleets to a nationwide hydrogen infrastructure network that should be made up of 600 HRS by 2030 [47]. France plans to focus on adequate utilization of the individual stations as part of the infrastructure development. For this purpose, it plans to support fleets of commercial vehicles, taxis, etc. France is a member of the IPHE.

Italy

Italy has been involved in several demonstration projects, mainly CHIC, 3Emotion, High V.LO City, I-Next. There are 8-10 hydrogen buses in operation here and another 15 are planned under the already-supported demonstration projects. Filling stations are available in Bolzano, Milan, Mantua, Liguria and Sicily [48].

In Italy, a national hydrogen mobility plan was launched in March 2016. In connection with this plan, a website was also launched in order to provide information to the general public on hydrogen technologies (http://www.mobilitah2.it). The plan is very ambitious and in 2020 it envisages the existence of 20 filling stations (10 for buses and 10 for private transport) and 1,000 FCEVs and 100 buses. By 2025, a total of 141 stations for private transport, 56 for buses and about 27 thousand FCEVs and 1,000 buses. The plan considers various filling station capacities with the smaller ones (around 200 kg/day) built at the early stage to cover the needs of smaller fleets and the TEN-T motorways. After 2022, stations with larger daily capacities (more than 500 kg/day) should be constructed [49].

Finland and Baltic countries

Finland, Estonia and Latvia take into account the hydrogen mobility (as opposed to Lithuania) with respect to meeting their targets concerning the introduction of alternative fuels. In Finland, an implementation plan for hydrogen as an alternative fuel was set up as part of the HIT-2-Corridors project in 2015 [24]. Its aim is to increase the number of filling stations from 2-3 in 2015 to 6 in 2020 and from 12 to 25 by 2025. The whole of Finland should be covered when reaching 20 stations. In Latvia, most activities are concentrated in the capital of Riga, which has even developed its own regional implementation plan.

4.3.2 Asia

In the Asian region, the spread of hydrogen technologies is currently concentrated in the Far East region, specifically South Korea and Japan. However, the gradual increase in this activity can also be observed in recent years in China, which, due to population size and long-term economic growth, has the potential of becoming a significant market for hydrogen mobility in the short term.

In South Korea, 7 filling stations (70 Mpa)e and 3 stations (35 Mpa) were in operation in 2016 according to the official data. A total of 80 stations by 2020 and 520 by 2030 are planned [16].

In 2015, 42 vehicles were in operation; by 2020 the number of 9,000 FCEVs should be achieved. Overall, a total of 20 % newly sold cards should be zero-emission cars by 2020. For those interested in hydrogen-powered cars, a subsidy of USD 23,000 is available [50].

The 2026 plan is to replace the current CNG buses (26,000 buses) with hydrogen buses. It is planned that more than 2,000 hydrogen buses per year should be deployed [50].

The association of industrial companies engaged in hydrogen technology has operated in South Korea since 2014. South Korea published its National Hydrogen Mobility Plan on 15th December 2016 under the title "Policy Plan on Fuel Cell Vehicle & Market Activation". In 2016, the plan was to invest over USD 5 million in hydrogen-powered vehicles and hydrogen filling stations, another USD 5 million to be invested in the hydrogen use for power generation. A total of USD 26 million has been allocated to research and development [50-52].

In Japan, 80 hydrogen filling stations are currently in operation (70 MPa) [16,53]. They are located around four metropolitan areas of Tokyo, Nagoya, Kyoto and Fukuoka. Another 5 filling stations with a pressure of 35 MPa are in service. Another 13 stations are under construction. Faster infrastructure development pace is currently hampered by security legislation. Under the law, petrol stations must be located at least four meters away from public roads but the requirements for hydrogen filling stations are stricter (at least 8 m). Due to high land prices in cities it is difficult to build the stations [54].

According to official information from August 2016, there are 909 hydrogen-powered vehicles driven on Japanese roads, the acquisition of which was supported by the Japanese government. Since 2009, there have been two forms of support in Japan. The first of these is support in the form of subsidies which were available in 2009-2012, the second is in the form of tax reliefs - this benefit is still offered. In general, the support does not apply only to FCEVs but to all vehicles with higher fuel efficiency compared to the 2015 standard. The maximum rate of support can be claimed by vehicles with efficiency above 20% compared to the above standard [55]. The support is around 3 million Yen (about CZK 650 thousand), i.e. more than 35 % of the purchase price [56].

According to the approved strategy, 40,000 vehicles should be in operation in Japan by 2020, about 200,000 vehicles by 2025 and about 800,000 by 2030 [53].

In Japan, there are currently only a few demonstration projects using hydrogen buses. Toyota Motor Corp., which has announced its entry into the hydrogen buses market in early 2017, has been the main driving force in Japan in this sector. It has also set a target of 100 buses being operated during the Tokyo Olympic Games in 2020 [57].

Japan updated its strategic plan for the introduction of hydrogen technologies and fuel cells in 2016. However, it has been active in this sector since 2000. In 2000, one of the most successful fuel cell programmes, ENE FARM, was launched. Under the project, a total of 180,000 units for heat and power generation in buildings were sold by September 2016.

The Japanese government also expects that the 2020 Tokyo Olympic Games will become a strong impetus for hydrogen technologies. The Olympic Village is planned to be constructed with a massive use of hydrogen technologies [57].

The Japanese government updated its plans for hydrogen filling stations (70 MPa) in 2016. Its goal is to open 160 stations by 2020 and double their number by 2025. In Japan, a total of USD 43 million will be spent to support research, development and deployment of hydrogen technologies this year (5/2016 - 4/2017) [53].

4.3.3 North America

In North America, hydrogen mobility activities are intensively concentrated in two local centres geographically located on the east and west coasts. Specifically, California on the west coast and states connecting Massachusetts – Virginia on the east coast.

Another important step for introducing hydrogen into transport was the announcement of the so-called Zero Emission Vehicle (ZEV) programme, i.e. a programme supporting the development of zero greenhouse gas emission transport. Countries that have joined the programme have thus adopted a set of regulations requiring mandatory development of transport and zero emission vehicles. The founding signatories of the programme were: California [58], Connecticut, Maryland, Massachusetts, New York, Rhode Island and Vermont.

Based on this programme, the states have developed the so-called Hydrogen and Fuel Cell Development Plans [59]. These plans aim to provide guidance on the introduction of hydrogen into everyday life, detailed technical information and identification of economic opportunities associated with the deployment of hydrogen technologies.

The Memorandum to this programme also outlines several specific programme points:

1. **General commitment** – consent to the objective to develop a binding hydrogen deployment plan for the transport sector and a commitment to coordinate

measures to support and ensure successful implementation of zero emission vehicle programmes.

2. **Measurable Targets** – the signatory states have agreed on a collective target, being a min. of 3.3 million zero emission vehicles on the road by 2025 and cooperation to establish hydrogen fuel cell infrastructure that will adequately support this number of vehicles.
3. **Adaptation of the existing regulations and standards** – to introduce measures ensuring readiness of related government regulations in the framework of the FCEV deployment such as building regulations and standards for the installation of charging infrastructure etc.
4. **Use in public rolling stock** - introduction of ZEV in state-owned or co-owned companies and agencies.
5. **Incentives for ZEV** – the signatory states have agree to assess the need and effectiveness of monetary incentives to reduce the initial purchase price of ZEV, tax incentives and non-monetary incentives such as access to the "HOV lane" (high-occupancy vehicle lane), toll reduction and priority parking and to set such incentives as needed.
6. **PPP (support of public and private sector partnership)** – the signatory states will cooperate with car manufacturers, electricity and hydrogen providers, fuel infrastructure operators, industrial component manufacturers, corporate fleet owners, financial institutions and others to support the growth of the ZEV market.
7. **Research and education** - the signatory states have agreed to share research and co-ordinated education and an extensive campaign to draw attention to the benefits of ZEV and to expand its use.
8. **Study and evaluation** – the signatory states have agreed to draw up a detailed study and seek to ensure its continuous evaluation and development of potential deployment strategies and infrastructure requirements for the fuel cell vehicles commercialization.

The intention behind these plans is to provide guidance and technical information and economic opportunities related to the deployment of hydrogen technologies in order to increase the environmental performance and reliability of the states' energy system.

One of the examples of ZEV programme implementation are specific steps taken in the following states. Massachusetts aims to build 18-19 filling stations by 2025 serving up to 1,867 FCEVs (1818 for public and 49 for public transport). Connecticut plans to build up to 5 filling stations for 477 FCEVs by the same year (445 for private transport and 32 for public transport). In addition to the transport objectives, both countries have also set targets for the introduction of fuel cells into the energy sector where they plan to deploy up to 312 MW, respectively 175 MW, of installed capacity [60].

In terms of the filling infrastructure, a total of 51 filling stations have been established in California. As noted above, the cost of the individual filling stations in the US ranges between USD 1 - 3 million. The difference in prices is mainly due to the maximum daily filling capacity (60-350 kg/day) and the method of supplying the station with hydrogen. The highest number of US stations has a capacity of 180 kg/day stations, which are supplied with compressed hydrogen transported in trailers. Stations supplied through electrolytic production of hydrogen directly at the point of consumption are more demanding in terms of investments and the building costs are at the upper limit of the above range. In most cases, the construction of the stations was subsidized; the California Energy Commission's support rate was 70-85 %, exceptionally up to 100 % of the capex (West Sacramento - South River, Yolo). Operation of some of these stations is also subsidised. In total, USD 80.9 million was allocated for the support of this infrastructure by the end of 2015, and another USD 9.9 million was allocated for operation support. Non-public sources were used to invest USD 35 million in the construction of the filling infrastructure [61].

4.3.4 Other regions around the world

Hydrogen infrastructure activities are limited primarily to the regions listed above.

As regards other regions, certain activities can be found in Australia where one filling station is currently in operation in Sydney and another project is in the pipeline in the capital of Canberra. In 2008, the Australian Association for Hydrogen Energy (AAHE) was established in Australia.

Certain activities also take place in South America, where there are currently two filling stations in Brazil, Sao Paulo and Santa Cruz, Argentina, Patagonia. Interestingly, Mexico City plans to ban the entry for diesel cars to the city centre by 2025.

4.3.5 Evaluation of the current status worldwide

As indicated by the description in this chapter, the global development of hydrogen mobility is localized into three major centres being Europe, East Asia (Japan, Korea) and North America (primarily USA). The development in these regions is very different and is based on the economic and political context in these countries. There is also a slight difference in the motivation of the individual regions to introduce hydrogen mobility.

The region where hydrogen mobility is developing is Europe (more specifically, the EU and Norway). The main driving force in this region is the political representation, namely the European Commission (EC) and the governments of active member countries (mainly Germany, Great Britain). Given the fact that EC has given the member countries a relatively free hand in the framework of Directive 2014/94/EU and other documents, the approach to hydrogen mobility varies considerably between these countries. The EC's most important motivation for the introduction of hydrogen mobility is obviously the effort to reduce greenhouse gas emissions, improve air quality and increase the competitiveness of European industries in other regions. In Europe, the centre of hydrogen mobility can be seen in Germany, followed by its neighbours and other countries (Benelux countries, Austria, France, Scandinavia). The UK is somehow isolated due to its geographical location, where development is also taking place.

Germany is a very specific case is where the intention to develop hydrogen mobility is supported by a well-developed government strategy and the presence of a strong coordinator. Germany also allocates funds to support hydrogen technologies (EUR 1.35 billion for NIP II 2017-2026) at a level almost comparable to the pan-European support under FCH JU (EUR 1.33 billion for 2014-2020).

As regards the Czech Republic, the context of the neighbouring countries (and also V4) is of key importance. In this respect, it is clear that both Germany and Austria have decided to include hydrogen mobility among the basic pillars of future transport within their countries. The situation in Slovakia and Hungary is ambiguous. This is also the case of Poland where the government presents the non-inclusion of hydrogen mobility in the alternative fuel agenda; however, a national plan for hydrogen infrastructure development has been developed.

In the technologically advanced countries of East Asia, the hydrogen technology development leader is the industrial sector and in the field of hydrogen mobility it is logically primarily the automotive industry. Motivation in these countries is based on three pillars: improving air quality in large urban agglomerations, reducing greenhouse gas emissions and gaining technological edge in modern hydrogen mobility technologies to increase competitiveness. Government support is particularly important in Japan where the subsidy mechanism has facilitated the kick-start of the FCEV market. An interesting approach is the integration of hydrogen mobility and other hydrogen technologies into the preparation for the 2020 Tokyo Olympic Games where this specific goal helps achieve the planned results.

The US situation is quite different. The main hydrogen mobility development driver is not the technological companies directly involved in hydrogen technologies and related disciplines but business entities generally seeking efficient and economic lines of business (for example, forklift cart projects). What is very important in otherwise unregulated US environment is political activity, and the announced ZEV programme has resulted in a very effective development of zero-emission mobility including hydrogen mobility. In terms of motivation for deployment, there are some differences in different states, for example, in California there is clear effort to improve air quality and reduce greenhouse gas emissions.

4.3.6 Current international hydrogen initiative

At the World Economic Forum in Davos, a consortium of 13 companies announced their intention to join forces in promoting hydrogen as a clean and environmentally friendly fuel of the future in transport.

Car manufacturers and oil industry want to promote hydrogen drive as an alternative to electromobiles. The group of these companies formed the so-called Hydrogen Council, which aims to support the development of hydrogen technologies in transport, both in terms of investment and commercialization. These investments should now rise to about EUR 1.4 billion/year.

This consortium of automotive and energy companies consists of Toyota, Daimler, BMW Group, Honda, Hyundai Motor and Kawasaki, the oil and gas companies are represented by The Linde Group, Anglo American, Total, ENGIE, Air Liquide, Alstom and Royal Dutch Shell.

The aim of this consortium is to convince other companies as well as regulators and the public that hydrogen is vital for survival. According to Air Liquide CEO, Benoit Poiter, subsidies for the oil and gas industries play a major role in developing new solutions as switching to cleaner fuels is only possible with appropriate support from politicians and government programmes. At the same time, it is necessary to provide the necessary background and invest in a large infrastructure. Transport is accountable for more than a quarter of all greenhouse gases and cleaner alternatives to oil and fossil fuels are beneficial. Hydrogen, as a clean source of energy producing no CO_2 at the point of use, is a significant improvement for the future.

The cornerstone of Toyota’s 90 % reduction in carbon dioxide emissions by 2050 is fuel cell vehicles. This automaker believes that it is easier to persuade customers to use hybrid vehicles or fuel cell vehicles rather than electric battery vehicles that generally show a shorter refuelling distance and longer charging time compared to petrol or hydrogen refuelling.

4.4 Czech Republic

The Czech Republic is the first country of the former Eastern Bloc that became involved in the development and demonstration of hydrogen technologies in transport. In 2009, a prototype of the TriHyBus hydrogen fuel cell hybrid bus developed by a consortium led by UJV Řež, a. a. (Škoda Electric, Proton Motor and others) was introduced. As part of a project supported by the Ministry of Transport of the CR, a hydrogen filling station in Neratovice has been established. It is a non-public filling station with a maximum filling pressure of 35 MPa. This station is supplied with hydrogen from natural gas steam reforming, which is delivered by trucks (hydrogen compressed in several sections of pressure cylinders). Both these pilot facilities, the hydrogen bus and the filling station, are still in existence and a decision was made in 2016 to continue their operation at least until 2018.

Figure 11: Hydrogen filling station in Neratovice

Relevant projects include a series of projects carried out at the Ostrava Mining University, VSB TUO (HydrogenIX, Jeep Hydrogene and others) that started in 2005 and demonstrated the ability of the Czech research and development sector to become engaged in the development and demonstration of hydrogen-fuelled vehicles. The LVT hydrogen technology laboratory was established at the VSB in Ostrava, which is unique from the point of view of its existence and potential as a basic research infrastructure of H2 technologies and enabling education which is unique in this field in the Czech Republic. More information can be found on the ENET website or sub-section related to the laboratory itself. In 2013, as part of the Nuclear Research Institute in Řež project, the possibility of producing "green" hydrogen using renewable energies was demonstrated as part of the system balancing photovoltaic power plant output.

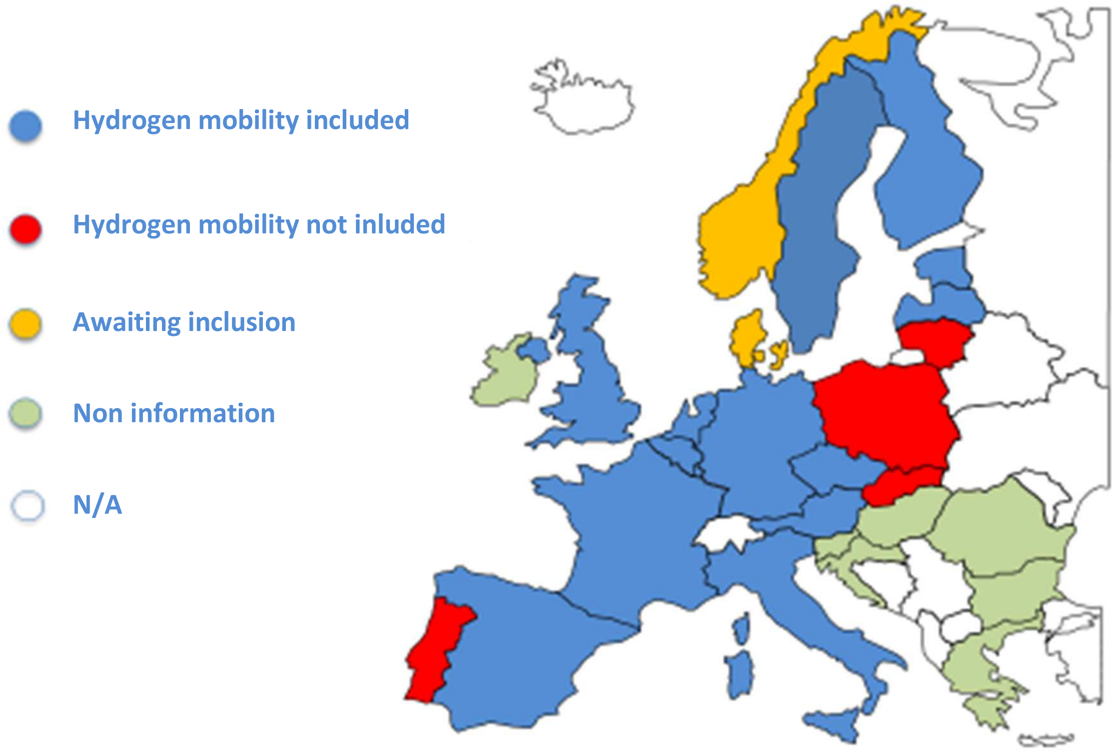
At present, several projects at various stages of development have been identified in the Czech Republic, listed as follows:

- Unipetrol has declared its interest in building a hydrogen filling station within the Benzina network;
- the town of Trutnov has been involved in the FCH JU activity aimed at supporting the implementation of hydrogen technologies in the region;
- inclusion of hydrogen technologies in the strategic plans of other self-governing units in the Krkonoše region is under discussion (regions, municipalities);
- Bateson plus prepares the SCEC Trutnov (Poříčí u Trutnova) project - energy storage and hydrogen mobility;
- Škoda Electric has been involved in the implementation of the TriHyBus prototype and is ready to participate in the commercial production of hydrogen fuel cell buses;
- SOR plans to test a fuel cell-based electric bus with extended refuelling distance,
- Arriva is involved in the TriHyBus prototype testing and plans to participate in the project planned in Trutnov;
- United Hydrogen Group, in cooperation with Q Park Měšice, plans to build a filling station for a fleet of fuel cell forklifts.

Legislative framework in the CR and EU

A key document in the field of alternative fuels is DIRECTIVE 2014/94/ EU OF THE EUROPEAN PARLIAMENT AND COUNCIL of 22nd October 2014, which the member states were required to implement by 18th November 2016.
In particular, the hydrogen mobility directive defines that member states that decide to include publicly available hydrogen filling stations in their national policy framework should ensure that an adequate number of filling stations will be available by 31st December 2025. On the basis of the national policy frameworks, FCH JU has assessed the expected involvement of the individual states in the implementation of hydrogen mobility. The status as of 17th November 2016 is shown in Figure 12 below.

Figure 12: Inclusion of hydrogen mobility in national policy frameworks (as of 17th November 2016) [62]



Annex II to the Directive also sets out the technical requirements for hydrogen filling stations, purity of hydrogen emission, fuel filling algorithms and fittings (filling end pieces). Technical requirements are specified with references to international standards (as listed below).

As regards European legislation, one of the key documents is the European Commission's Communication on a strategy for the development of low-emission mobility as a response to increasing greenhouse gas emissions from transport, which is in line with the White Paper, the Paris Agreement and Agenda 2030. This document presents the crucial strategic points for reducing emissions while maintaining the efficiency of transport system while using alternative resources and supporting low and zero emission means of transport. In terms of hydrogen mobility, this strategy is key to establishing the European regulatory framework and changes needed to facilitate the transition to low-emission mobility (establishment of infrastructure, investments in technological development, pricing policy in the sector) [63].

Related EU legislation

In terms of hydrogen mobility, the legislation below is the most relevant:

- DIRECTIVE 2007/46/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.

This directive aims to harmonize and specify through regulatory acts. It defines the technical requirements applicable to systems, components and technical units and vehicles and defines provisions related to the sale and installation of vehicle equipment approved in accordance with this Directive and their operation. The main objective of this vehicle approval legislation is to ensure that new vehicles, components and technical units introduced to the market provide a high level of safety and environmental protection. The Directive also defines the level of consumer protection and information to be provided to the vehicle end-users by the manufacturers of hybrid vehicles.

- REGULATION (EC) No 79/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the type-approval of hydrogen powered motor vehicles and amending Directive 2007/46/EC.

EC Directive 79/2009 amends EC Directive 46/2007 on the legislative regulation of the European Commission's competences related to the type approval of hydrogen powered vehicles. Furthermore, the Directive extends the EC's competences with respect to the specification of requirements and testing procedures concerning new forms of hydrogen storage and use, additional hydrogen structural components and the drive system. The Commission is also empowered to establish specific procedures, tests and requirements for protection in case of hydrogen powered vehicle road crash and to establish safety requirements for the integrated system. The Directive also defines new requirements for hydrogen powered vehicle manufacturers, in particular those concerning vehicle safety and technical parameters.

Technical ISO standards

Table 4: ISO standard (a total of 18 standards under ISO/TC 197 Hydrogen Technologies) [64]

Standard	Impact	Related
ISO 14687-2:2012 Hydrogen fuel -- Product specification -- Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles	Defines the quantitative requirements for hydrogen fuel	Decree133/2010 Coll., 2014/94/EU
ISO/TS 19880-1:2016 Gaseous hydrogen -- Fuelling stations -- Part 1: General requirements	Specifies characteristics of public and non-public hydrogen fuelling stations	2014/94/EU Act 183/2006 Coll.
ISO 17268:2012 Gaseous hydrogen land vehicle refuelling connection devices	Defines technical requirements for refuelling connection devices	ISO/TS 19880-1:2016
ISO/TS 20100	Specifies characteristics of public and non-public hydrogen fuelling stations	Replaced by ISO/TS 19880-1:2016

National standards

Table 5: National standards

Standard	Impact	Related
ČSN 07 8304 – Pressure vessels for gases	Specifies requirements for periodical equipment inspections	Decree 18/1979 Coll.
ČSN 38 6405 – Gas equipment, operating principles		Decree 18/1979 Coll.
ČSN 69 0012 – Stable pressure vessels		Decree 18/1979 Coll.
ČSN P ISO/TS 19880-1 Gaseous hydrogen – Filling stations – Part 1: General requirements	Specifies requirements for public and non-public hydrogen fuelling stations	Original taken over ISO/TS 19880-1:2016, issued as of 1. 3. 2017 valid from 1. 4. 2017
ČSN 73 6060 – Fuel filling stations	Contains technical standards to be met by a hydrogen filling station	

Czech legislation

- **Act No. 311/2006 Coll. on fuels and filling stations and amending some related Acts;**

Act No. 311/2006 Coll. on fuel reflects the relevant European Community regulations and specifies the conditions for fuel sale and dispensing, registration of fuel distributors, registration of filling stations and requirements for the composition and quality of fuels (i.e. any fuels intended to drive a vehicle). The Act specifies in detail the necessary conditions for a fuel distributor registration including the actual process of registration and operation of the filling station.

Recently adopted Act No. 542/2016 Coll. amending valid Act No. 311/2006 Coll. on fuels and fuel filling stations, the subject of which is partial transposition of the directive 2014/94, contains the definition of alternative fuels where hydrogen belongs to. Moreover, there are also stated obligations for operators and owners of the filling and charging stations. This Act was published in the Journal of Laws on 22nd May 2017.

- **Decree No. 133/2010 Coll. on requirements for fuel, the method of monitoring the composition and quality of fuel and its registration;**

Decree No. 133/2010 Coll. amends Section 11 of Act No. 311/2006 Coll. on fuel. The decree specifies requirements for fuel quality, monitoring, composition and quality of fuels and fuel registration. In addition to conventional fuels (motor oils, diesel, compressed gas) it also covers alternative fuels such as hydrogen. The decree stipulates the quality parameters necessary for distribution of these fuels, quality control methods related to the fuels, their marking and registration.

- **Draft decree amending decree No. 268/2009 Coll. on technical requirements for buildings, as amended by Decree No. 20/2012 Coll.**

Section 48a, Technical Specification for Recharging Stations and Filling Stations, which defines technical conditions for the technical requirements for buildings has been added to the Directive, and hydrogen filling stations can therefore be constructed according to this directive and related technical standards.

Other legislation

- **183/2006 Coll. Building Act**

Act 183/2006 Coll., the Building Act, specifies the comprehensive process of planning and construction proceedings concerning the location of buildings, including necessary conditions to be met by a building or civil structure in order to receive a construction permit for the construction site. The specific rules for the application of this Act with respect to filling stations (the decision on construction) are then laid down under Section 5 and 2 (d) of Act No. 311/2006 Coll.

- **Decree 18/1979 Coll. of the Czech Office for Occupational Safety and the Czech Mining Authority of 22nd January 1979, which designates dedicated pressure equipment and sets certain conditions for their safety (as amended by 393/2003 Coll.).**

Decree No. 18/1979 Coll. defines the range of types of pressure equipment and sets certain conditions to ensure their safety. It specifies individual types of pressure equipment, authorisations to install such equipment and determines the necessary range of tests and inspection tests for such equipment. The decree furthermore regulates the qualification of inspection technicians and the necessary scope of tests to receive this classification.

4.5 Examples of best practice

This section of the document focuses on the study of know-how gained from interesting, and so far successful hydrogen mobility implementations. Experience from these projects offers interesting conclusions that could be applied in hydrogen integration in the Czech Republic. It is premature to draw concrete conclusions based on this information but these conclusions can indicate the direction of successful hydrogen integration amongst current modes of transport.

This section is dedicated to 6 sub-projects in different phases of implementation. The effort is to identify such projects that already bring some results, but they should also be geographically close and have similar initial conditions as the Czech Republic. The provided examples are projects from Germany and Western Europe.

On the other hand, partly "exotic projects" from the US have been selected, specifically from California, which may seem useless to us. However, these projects can indicate partial directions of development that can support our main chosen orientation.

4.5.1 Bee Zero, Munich

From a global perspective, the Bee Zero Project is unique. For the very first time there are 50 hydrogen-powered passenger cars available in one place. The high demonstration potential of the project is ensured by the use of cars in a modern way, i.e. in the form of car-sharing.

Intention

The project intention is to demonstrate the readiness of hydrogen mobility and to implement a demonstration project that will not be disadvantaged by inadequate refuelling infrastructure. The chosen car-sharing model in the urban environment allows for refuelling even with a limited number of filling stations (one filling station is sufficient). The project is situated in the centre of the Bavarian metropolis of Munich, which ensures sufficient visibility of the project and justifies the need for zero emission transport.

Compared to similar projects where car-sharing is provided by electric vehicles, the Bee Zero project offers a significantly longer refuelling distance (600 km) and resulting possibility to leave the city boundaries and go on a journey to the Alps or Salzburg. The real-life phase has been running since the summer of 2016. The project is led by Linde which is based in Munich.

The project consists of 50 Hyundai ix35 FC vehicles that are provided in the form of car-sharing. The vehicles can be used at three price levels:

- Bee a pioneer (6 hours, 100 km) at 49 EUR;
- Bee by the lake (12 hours, 150 km) at 79 EUR;
- Bee an adventurer (24 hours, 200 km) at 99 EUR.

The vehicles are filled up by the staff at the newly established filling station Total (Detmoldstrasse 1) in Munich. The vehicles can be booked via a smart phone application and detailed information is available at https://beezero.com/.

4.5.2 CHIC project

The aim of the CHIC (Clean Hydrogen in European Cities) project which was implemented between 2010 and 2016, was to demonstrate that hydrogen-powered buses can provide a functional solution to public transport decarbonising while improving air quality and reducing noise nuisance.

A total of 7 European cities were involved in the project along with the Canadian city of Whistler (between 2010 and 2014) in relation to the Winter Olympics.

Table 6: List of participating cities

City	London	Aargau	Bolzano	Oslo	Berlin	Hamburg	Cologne	Milan	Whistler (Canada)
Number of buses	8	5	5	5	4	4	4	3	20

A total of 54 buses powered by hydrogen fuel cells of different concepts and by different manufacturers were operated during the project. The produced hydrogen originated primarily from renewable resources but, when necessary, it was also supplied through industrial steam reforming.

The project involved over 20 companies. The consortium consisted of companies engaged in the production and distribution of gas (Air Liquide, Air Products, Linde), vehicle manufacturers (Daimler, Wrightbus), energy companies (Vattenfall), research and consulting companies in close cooperation with public transport operators in the participating cities (e.g. Hochbahn).

The total project cost amounted to EUR 81.8 million and the cost was covered from various sources. An important source of funding was FCH JU contributing EUR 25.88 million. [28]

Most significant project outcomes

- the buses reached a distance between refuelling comparable to the existing solution (diesel), with 350 km distance to empty;
- filling times under 10 minutes;
- the average hydrogen consumption was 9 kg per 100 km for a 12-meter bus. Hydrogen drive was evaluated as being 26 % more fuel efficient (9 kg of hydrogen

corresponds to ca. 30 litres of diesel oil, the average consumption of diesel buses is set at 40.9 litres per 100 km);
- CO_2 emissions were reduced by 85 %, 6,800 t of carbon dioxide equivalent (LCA) was saved;
- 4.3 million litres of diesel oil were saved;
- surveys showed a significant increase in the support for zero-emission technologies in the participating cities;
- in total, over 9 million kilometres were travelled in about 500,000 running hours;
- the possibility of deploying buses up to 20 hours a day has been demonstrated

4.5.3 Hamburg

The main hydrogen technology driver in the city of Hamburg is hySOLUTIONS, which is jointly owned by HOCHBAHN AG (61 %), Vattenfall Europe Innovation GmbH (25 %), Germanischer Lloyd SE (6 %) and others. The Land Senat took a decision under which this company was given a coordinating role in the field of electromobility and hydrogen technologies.

Context

- Hamburg is the second largest city in Germany;
- the city's growth and European emission limits do not make it possible to maintain the current status;
- emission targets (CO_2): -40 % by 2020, -80 % by 2050;
- use of wind energy - good conditions, strong technological base.

Long-term strategy

The City of Hamburg had tested various types of public transport vehicle drives for a long time (hybrid, battery and hydrogen buses). Based on this experience, a decision was made not to purchase other than zero-emission means of public transport after 2020.

Hamburg's vision is to become a hydrogen technology link between Scandinavia and Central Europe. To this end, 5 filling stations were built by 2016. Hydrogen drives have been tested since 2003 (HyFLEET: CUTE project - 9 buses), since 2011 and 2014 there has been the next bus generation in place. Hamburg is involved in a large number of demonstration projects covering the full range of hydrogen technologies.

From the practical point of view, Hamburg has tried to compare different alternative drives by introducing "Innovation line" No. 109. This line with a total length of 10 km is operated between the main railway station and Alsterdorf station using exclusively innovative drives (hybrid drive, BEV and FCEV). This line enables direct comparison of each of the drive types. Localization of this line in a relatively busy part of the city has resulted in significant promotion of alternative drives in bus transport.

Hamburg in the CHIC project

- 4 hydrogen buses (12 meter long);
- double shifts - up to 16 hours a day;
- 80 % hydrogen produced on-site using renewable energies;
- since April 2012, almost 500,000 km travelled;
- average consumption of 8 kg of hydrogen per 100 km;

- replacing 171,000 l of diesel oil.

4.5.4 Hydrogen Mobility Europe projects

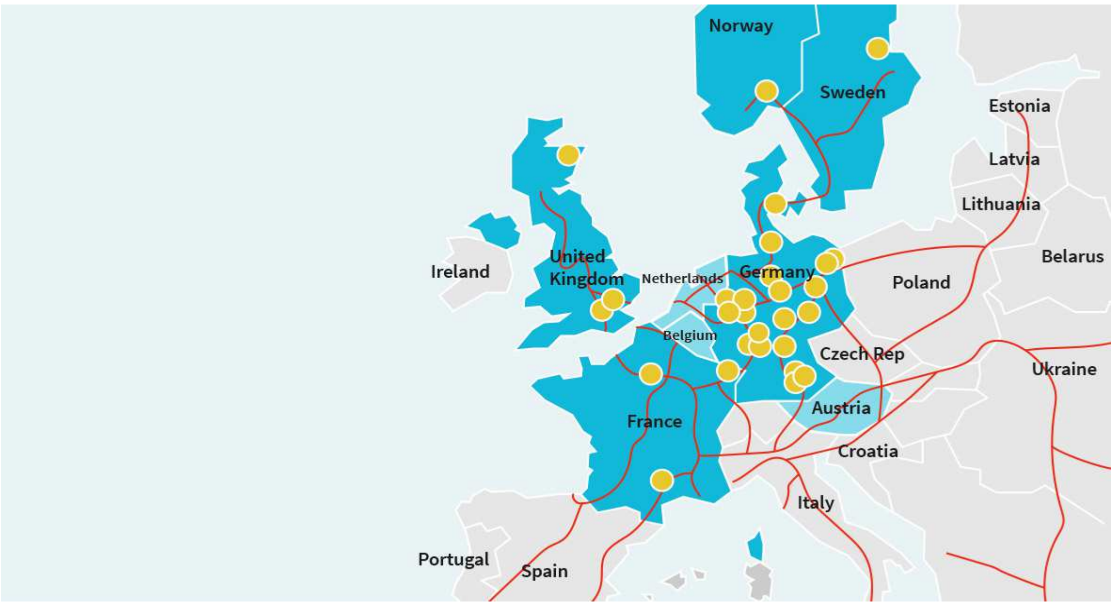
Important projects aimed at establishing hydrogen mobility in Europe are the Hydrogen Mobility Europe I and II projects. Both of them are primarily co-financed by FCH JU. In addition to European funds and private co-financing, national budgets are involved in its implementation in individual regions. The basic project idea is to construct dozens of filling stations located along the TEN-T backbone network and to ensure sales of over 1,000 hydrogen-powered vehicles of different types thanks to these filling stations.

Table 7: Hydrogen Mobility Europe projects

Project title	Hydrogen Mobility Europe	Hydrogen Mobility Europe 2
Coordinator	ELEMENT ENERGY LIMITED, UK	ELEMENT ENERGY, UK
Number of partners	26	37
Total budget	63 mil. EUR	106 mil. EUR
Duration	2015–2020	2016-2022
Project target	• 29 filling stations • 200 passenger cars • 125 utility vehicles	• 20 filling stations • More than 1,000 hydrogen fuelled vehicles (passenger and car utility vehicles and light trucks)
Source	[65]	[66, 67]

Engagement of EU countries in the project is shown in Figure 13.

Figure 13: H2ME project localisation [67]



4.5.5 Hydrogen-powered forklift carts – USA

One of the first "early bird" applications with a significant impact on the economy of operation and meeting increasingly stringent environmental standards was the forklift cart segment.

Forklift carts are special vehicles moving products around warehouses. Due to the size of the warehouses run by such retail giants as Walmart or Whole Foods, it is obvious how useful and necessary this assistant is and how many of them are needed in normal operation. At a time when efficiency and costs are the most carefully watched business figures it is obvious that streamlining this part of operation is more than vital. The main benefits compared to battery-powered forklift carts are, as in the case of passenger cars, longer distance covered and fast filling in less than 3 minutes. This saves storage space allocated for replacement batteries.

Examples of US corporations already benefiting from hydrogen technologies:

1. **Nestle Waters** - after comparing the OPEX and impacts on labour productivity gains, Nestlé has been converting its forklift cart fleet to fuel cell drives since 2008.
2. **GM and FedEx -** the primary objective of a joint pilot project with Hydrogenics was to validate the real service and operating expenses related to this new technology. The successful outcomes surpassed the original expectations and fuel cells have now become a recognized standard.
3. **Walmart** - After a pilot project and its evaluation, Walmart is going to save USD 2 million over seven years and will reduce greenhouse gas emissions by 530 t a year by using hydrogen fuel cell technology.
4. **Whole Foods** –saving the time lost by replacing and recharging batteries will earn Whole Foods 3,750 hours a year.
5. **Central Grocers** - Central Grocers in the Chicago area has purchased 140 hydrogen fuel cells for forklift carts and plans to buy another 80 by the end of 2017.
6. **Coca-Cola** - Coca-Cola‘s second largest bottle factory in the US uses fuel-cell forklift carts. Since 2010, it has worked on a complete transition to fuel cell forklift carts.

4.5.6 California

The primary reason for introducing hydrogen into transport in California was the interest in massive GHG emission reduction. The hydrogen implementation project was designed under the motto "Go where you want to go“ and it focused on establishing a comprehensive infrastructure so that the entire state can be crossed from the north, starting at Reno, through the capital of Sacramento, through the multicultural San Francisco down to the southernmost part of the state to Los Angeles [68].

Similarly to other regions, hydrogen powered passenger cars as well as buses are tested in California. A detailed study of operating hydrogen powered buses (FCEB) has concluded that any bus put into service in the United States could reduce the amount of carbon dioxide released to the atmosphere by 100 t a year and reduce the consumption by 9,000 litres of fuel a year over the lifetime of the vehicle. For buses running on hydrogen fuel, the economic savings exceed USD 37,000 per vehicle/year. As of 15th December 2016, 25 fuel cell-powered buses were in operation in California and another 46 were in the process of completion and putting into service [69].

Experience gained:

- Hydrogen prices range from USD 12.85 to USD 16/kg, the average price is USD 13.99/kg.
- The cost of FCEV fuel to cover one kilometre is CZK 1.89/km compared to CZK 2.04/km for conventional vehicles.

- the US Department of Energy has set a target value of the fuel cell lifetime to 5,000 hours for passenger car and 20,000 hours for buses.
- The FCEV has shown a distance to refuelling comparable to the present vehicles.
- The NREL has collected data from service stations and filling stations since 2011. Using a sample of about 20,000 records it has concluded that 50 % filling takes less than 5 minutes and 20 % filling takes less than 3 minutes [70, 71]

Types of support:

- High-Occupancy Vehicle Lanes can be used by the FCEVs even with a single person in the car and these vehicles can also park in city centres where conventional vehicles are not allowed access [72].
- The Centre for Sustainable Energy California Air Resources Board offers USD 5,000 (approximately CZK 125,000) to purchase or lease a new FCEV [73]. This support is provided within the Clean Vehicle Rebate Project (CVRP).

4.5.7 Evaluation of best practice examples

The selected "best practice" projects are various types of projects in terms of their content (FCEV, FCEB and others) and their complexity and scope (individual project, city level, country level). Examples of long-term strategies are provided along with ongoing as well as already successful projects. The main objective of this overview was to provide examples of successful implementation for different types of projects that can be employed when various projects are implemented by various entities (business, public administration, regions).

The Bee Zero project thus shows how a fleet of passenger cars can be operated with a minimum investment in the infrastructure (one filling station). The advantage of the car sharing approach is above all the high demonstration effect, as the car can be tested by anyone interested, including foreign visitors.

The CHIC project has demonstrated sufficient maturity of hydrogen drives for buses. Different bus concepts have been tested in regions with different conditions and a set of documents providing operational details, including FCEB implementation "guidelines" [74] has been developed. The project conclusions include mainly significant savings in primary energy and carbon dioxide emissions.

The next section analyses in brief the hydrogen mobility approach adopted in Hamburg. It outlines a strategy for dealing with public transport and hydrogen filling infrastructure implementation. The project outcomes are particularly relevant for larger cities and include demonstration of the possibility of producing most of hydrogen by using renewable energies while achieving significant fossil fuels savings and greenhouse gases and pollutant emission reduction.

The Hydrogen Mobility Europe projects aim to start establishing primary hydrogen regions and contribute to covering Europe with filling infrastructure. They are examples of projects involving more than one region and a large number of various partners.

The last section describes the successful project of forklift carts which have been applied since 2008 by large corporations. Even in this case there is a significant reduction in greenhouse gas emissions and users of hydrogen-powered fork-lift carts benefit from OPEX savings.

The last section outlines the situation in California, i.e. the state-level project (strategy). It is obvious that California has now a well-proven combined support system where financial support is complemented by non-financial instruments that increase attractiveness of alternative drives (parking in centres, possibility of driving in high-occupancy lanes). This example also shows that the costs of fuel (hydrogen) can be lower in some cases compared to conventional fuels.

4.6 SWOT analysis

The developed SWOT analysis aims to highlight the main factors influencing the potential development of hydrogen mobility considering the conditions and specifics of the Czech Republic. The list of influencing factors is not exhaustive, further additions and specifications will result from follow-up work related to market readiness, potential development modelling, market research and joint work with the expert group. The objective is to focus on potential threats and steps to be taken to eliminate these threats along with the proposed support and development of potential opportunities, the use of which should be the main driver in hydrogen mobility.

Below we provide the standard four-quadrant format listing strengths/weaknesses, and opportunities/threats. In addition, all points from the SWOT analysis are then analysed and explanations of the individual points are provided and, where necessary, the primary impact is defined, with the final formulation of the recommendations on hydrogen mobility in the Czech Republic

It must be added that the presented SWOT analysis and the specific points reflect the current status at the time of the study and the specific points may change over time.

Table 8: SWOT matrix

#	Strengths	#	Weaknesses
S1	Innovative technologies (use of hydrogen technology)	W1	New technology accompanied by mistrust
S2	Zero NOx, SO2, CO and THC emissions demonstrated during operation	W2	Legislation not supportive of market formation
S3	Reduced GHG emissions (well-to-wheel)	W3	High price of serially-manufactured vehicles
S4	Inexhaustible sources of hydrogen production around the world	W4	Non-existence of hydrogen fuelled vehicle market
S5	Filling time comparable to conventional fuels	W5	Non-existence of filling station market
S6	Complementary to standard petrol stations	W6	Non-existence of services related to the purchase and operation of hydrogen fuelled cars (insurance, leasing)
S7	Hydrogen as standard commodity (technical gas)	W7	Missing filling station network in the CR
S8	Real experience with non-public filling station operation (Neratovice)	W8	Insufficient service coverage
S9	Accepted distance to empty (relation to survey)	W9	Lower public awareness of the CR strategy in the field of hydrogen development
S10	Good hydrogen vehicle driving dynamics (electromotor)	W10	Long car fleet replacement cycle in the CR (potential replacement for hydrogen fuelled vehicles)
S11	Noiseless motors	W11	Filling at the filling station by trained staff

S12	More types of sources of production (oil, natural gas, electricity– electrolysis, chemical waste treatment)	W12	Public awareness of inadequate distance to empty
S13	Existence of international standards for the individual elements of hydrogen mobility		
#	**Opportunities**	**#**	**Threats**
O1	Production of hydrogen as a by-product (at low cost)	T1	Public prejudice against operation safety, negative awareness
O2	Possible of strong positive PR for the Czech Republic and local authorities	T2	Lack of public awareness of the safety context
O3	Involvement of the education system (universities) in the development	T3	Uncertain interest (lack of knowledge of market opportunities)
O4	Instrument to fulfil the Czech Republic's emission obligations towards the EU	T4	The business case of infrastructure construction will be negative for a long time
O5	OPEX savings in public transport and other vehicles operating in one locality	T5	Lack of support for the development of hydrogen mobility (financial)
O6	Similar situation to electromobility and CNG several years ago	T6	Hydrogen market price
O7	Use of international best practices	T7	Unpredictability of hydrogen prices in the coming years
O8	Interest in hydrogen technology on the supply, demand and investors side	T8	Lobbying by the existing market (oil, electricity, conventional vehicle manufacturers, service station operators)
O9	Excess hydrogen in the chemical industry	T9	Poor strategic decisions (investments in individual stations vs. comprehensive market investments)
O10	Existence of international standards for individual elements of hydrogen mobility	T10	Inadequate infrastructure
O11	New labour market	T11	Technological rapid progress in competing technologies
O12	Carmakers in the CR focused on standard vehicles have hydrogen mobility development visions in place	T12	Competitive low-emission mode of transport – electromobility - has a 10-year lead over hydrogen mobility
O13	Connection to German-Austrian infrastructure (interconnection within TEN-T networks)	T13	Threats to jobs at existing petrol stations and reduction in the number of petrol stations in the Czech Republic
O14	Expansion of hydrogen mobility into other transport and industrial sectors	T14	Unclear or prohibitive legislative environment for the practical use of hydrogen drive (e.g. parking restrictions in enclosed spaces (garages))
O15	Competitive advantage for the Czech industry	T15	Insufficient speed of introducing this technology
O16	Hydrogen production is not related to existing raw material resources	T16	Lack of qualified staff/experts to start up the industry
O17	Stabilization element for the energy system (in the future)		
O18	Hydrogen as a zero-emission resource in improving the environment		

The tables below show all the above points from the SWOT analysis giving details with explanations of the individual points. Wherever necessary, the basic impact is defined.

Table 9: Strengths

#	Aspect	Commentary
S1	Innovative technologies (use of hydrogen technology)	Modern technology
S2	Zero NOx, SO2, CO and THC emissions demonstrated during operation	Major positive impact on air quality, benefits for cities, positive impact on human health
S3	Reduced GHG emissions (well-to-wheel)	Reduction in greenhouse gas emissions thanks to the high efficiency of fuel cells and electric drive
S4	Inexhaustible sources of hydrogen production around the world	Hydrogen can be produced from a variety of sources (hydrocarbons, water). In case of production from water, it is a closed cycle
S5	Filling time comparable to conventional fuels	Filling time 3 – 5 minutes
S6	Complementary to standard petrol stations	CAPEX as well as OPEX when building at existing petrol stations
S7	Hydrogen as standard commodity (technical gas)	Existence of hydrogen market, basic logistics resolved
S8	Real experience with non-public filling station operation (Neratovice)	Activity managed in technical, legislative and organisational terms
S9	Accepted distance to empty (relation to survey)	The conducted survey shows that a distance to empty over 500 km is acceptable (sufficient) to the general public (see the survey results)
S10	Good hydrogen vehicle driving dynamics (electromotor)	Electric motor ensures good FCEV driving dynamics, it is smoother, more accurate there is no need to wait for the motor to "warm up"
S11	Noiseless motors	Reduction in noise nuisance (especially in cities and while using buses)
S12	More types of sources of production (oil, natural gas, electricity– electrolysis, chemical waste treatment)	Limited dependence of the transport sector on a particular raw material and its import. No dependence on a single market, diversity, reduced risk of a high increase in fuel prices
S13	Existence of international standards for the individual elements of hydrogen mobility	International standards for important elements of hydrogen mobility are applied, including a uniform filling interface as well as requirements for public filling stations, filling speed and the minimum capacity.

Table 10: Weaknesses

#	Aspect	Commentary
W1	New technology accompanied by mistrust	Necessity to overcome initial mistrust and high demands when the public may reject new technologies for certain reasons
W2	Legislation not supportive of market formation	At present, there are legislative constraints that hamper potential market development - a form of uncertainty, legislation needs to be adapted to allow for faster development
W3	High price of serially-manufactured vehicles	The FCEV and FCEB prices are much higher than prices of conventional vehicles in the same category
W4	Non-existence of hydrogen fuelled vehicle market	Market starts being formed only in the most economically advanced countries, i.e. where filling infrastructure is available. Logically, there is no market in the Czech Republic yet
W5	Non-existence of filling station market	High costs of filling stations, limited competition. In the Czech Republic, there are not conditions for construction yet, which can get changed on the basis on this analysis
W6	Non-existence of services related to the purchase and operation of hydrogen fuelled cars (insurance, leasing)	Products to operate the vehicle are not available now. It takes some time for the market to adapt
W7	Missing filling station network in the CR	Significant weakness - inability to use the vehicle as needed
W8	Insufficient service coverage	Problematic service provision before a sufficient number of vehicles is achieved (less serious problem for fleets operated in one location - bus, taxi etc.)
W9	Lower public awareness of the CR strategy in the field of hydrogen development	The public has little information about this potential fuel type
W10	Long vehicle fleet replacement cycle in the CR (potential replacement for hydrogen fuelled vehicles)	The vehicle fleet replacement cycle in the Czech Republic is slow. Experience in the Czech Republic shows slow rate of replacing old vehicles for new one. FCEV will find its way to replace the existing vehicles relatively slowly
W11	Filling at the filling station by trained staff	Only trained staff can fill up the vehicle with hydrogen (under the law)
W12	Public awareness of inadequate distance to empty	Shorter distance to empty than conventional vehicles meaning lower driving comfort - a dense filling station network is a must

Table 11: Opportunities

#	Aspect	Commentary
O1	Production of hydrogen as a by-product (at low cost)	Using hydrogen as a by-product from the chemical industry creates a potential for a significant reduction in fuel costs
O2	Possible of strong positive PR for the Czech Republic and local authorities	Hydrogen mobility is considered as a highly prestigious field, the application may help raise the prestige of the Czech Republic in the world
O3	Involvement of the education system (universities) in the development	Potential development of higher education if involved in the hydrogen market
O4	Instrument to fulfil the Czech Republic's emission obligations towards the EU	Reduction of greenhouse gas emissions. Achieving emission commitments without introducing innovative technologies would be very difficult
O5	OPEX savings in public transport and other vehicles operating in one locality	OPEX (fuel, service) may be lower due to the concentration of vehicles in a single area
O6	Similar situation to electromobility and CNG several years ago	Possibility of using experience with the development of other alternative fuels in the Czech Republic and internationally
O7	Use of international best practices	Possibility of using experience of more advanced countries
O8	Interest in hydrogen technology on the supply, demand and investors side	Potentially interesting business opportunity
O9	Excess hydrogen in the chemical industry	Excess hydrogen in the chemical industry offers the possibility of using surpluses in other sectors
O10	Existence of international standards for individual elements of hydrogen mobility	Applicability of international standards in the context of hydrogen mobility, which are not currently included in the Czech law
O11	New labour market	New sector offering new jobs
O12	Carmakers in the CR focused on standard vehicles have hydrogen mobility development visions in place	Involvement of industries (not only automotive) in CR, potential for increased exports, employment etc
O13	Connection to German-Austrian infrastructure (interconnection within TEN-T networks)	The Czech Republic's geographic position allows for the construction of transit points (filling stations) for hydrogen fuelled vehicles. The filling stations can be used by foreign customers, tourism support
O14	Expansion of hydrogen mobility into other transport and industrial sectors	In terms of the amount of produced emissions, the railway segment is a significant source of pollution (non-electrified lines), the emissions of which are not currently regulated, but the regulation is under preparation
O15	Competitive advantage for the Czech industry	Hydrogen filling infrastructure and development of hydrogen mobility may allow the Czech industry to develop business based on hydrogen technologies (Škoda Electric, Škoda Auto, SOR and others)
O16	Hydrogen production is not related to existing raw material resources	Water does not depend on raw materials such as oil and gas.
O17	Stabilization element for the energy system (in the future)	Hydrogen can serve as a backup source for the implementation of island or local systems (accumulation)
O18	Hydrogen as a zero-emission resource in improving the environment	Use of zero-emission sources in transport and potentially in power generation to ensure environmental improvement (or at least maintain the current status)

Table 12: Threats

#	Aspect	Commentary
T1	Public prejudice against operation safety, negative awareness	The lack of public awareness inclines towards uncertainties associated with the new sector. It is necessary to ensure positive PR to the public
T2	Lack of public awareness of the safety context	Low level of knowledge, historical negative experience
T3	Uncertain interest (lack of knowledge of market opportunities)	With the absence of knowledge about the technology and its benefits by the public, the expected development may not materialise even if the filling infrastructure is developed along with vehicles offer
T4	The business case of infrastructure construction will be negative for a long time	If infrastructure investment support is not properly set, the segment sustainability cannot be expected.
T5	Lack of support for the development of hydrogen mobility (financial)	Without support, the market will be formed very slowly, i.e. investments will only be offered once certain profitability is guaranteed
T6	Hydrogen market price	Uncertainty of hydrogen prices in case of market development. At present, the price is low but it can grow due to a potential shortage
T7	Unpredictability of hydrogen prices in the coming years	The hydrogen market price may become unstable with rising demand
T8	Lobbying by the existing market (oil, electricity, conventional vehicle manufacturers, service station operators)	Conservative approach of current main stakeholders
T9	Poor strategic decisions (investments in individual stations vs. comprehensive market investments)	When establishing the network, it is necessary to take a decision whether to build connections to neighbouring countries – along the main motorways or whether to focus, wherever appropriate, on local development in individual cities
T10	Inadequate infrastructure	Insufficient infrastructure will hinder development in related areas
T11	Technological rapid progress in competing technologies	At present, electromobility is not able to provide sufficient travel comfort for long journeys. If there is massive technological process, this disadvantage can be eliminated
T12	Competitive low-emission mode of transport – electromobility - has a 10-year lead	Difficult application among other alternatives due to a certain delay
T13	Threats to jobs at existing petrol stations and reduction in tthe number of petrol stations in the Czech Republic	The construction of hydrogen infrastructure would cause a drop in the number of petrol stations (as there is no need for as many hydrogen stations)
T14	Unclear or prohibitive legislative environment for the practical use of hydrogen drive (e.g. parking restrictions in enclosed spaces (garages))	The legislative framework may slow down deployment of this technology. E.g. in Japan, unjustifiably stringent safety requirements halted the development of filling infrastructure in cities. Similarly, the entry of CNG-driven vehicles into underground parking facilities is restricted in the CR although there are no relevant reasons for that.
T15	Insufficient speed of introducing this technology	Given that this is a competitive sector for electromobility, it is necessary to proceed relatively quickly so that electromobility will not cover the whole new alternative fuels market in the meantime
T16	Lack of qualified staff/experts to start up the industry	The new sector requires involvement of professionals and skilled labour in its development. The lack of qualified manpower, may slow down the development.

5 Survey of the current situation of hydrogen mobility

The analysis of the current situation of the hydrogen mobility in the Czech Republic includes primary data collection using public questionnaire on the sample of potential customers/buyers of personal cars and in-depth interviews with the representatives of the public transport providers in the Czech Republic. The goal of such research is the identification of the key subjects on the supply side who use hydrogen as strategic fuel for the means of transport (the personal car producers and producers of other means of transport). Furthermore, the subjects to be identified are those who produce hydrogen and ensure its infrastructure, mainly the filling stations and firms that sell and produce the hydrogen. On the demand side, among the key subjects, potential customers can be included. The potential customers can be represented by individuals or by the companies such as the public transport providers in the Czech Republic. Another distinct topic is then the evaluation of the hydrogen mobility attractiveness for the potential investors.

The quantitative part of the research was carried out in the form of questionnaire. The topic of this research was the Hydrogen propulsion usability in the transport in the Czech Republic. The research was undertaken since 9th January, 2017 till 31st March, 2017. The questionnaire was created on the Survey Monkey website and it consisted of 17 open and closed questions. In total, 652 respondents participated in the questionnaire and it was mainly distributed through social networks with the help of Ministry of Transport, Ministry of Industry and Trade and Ministry of the Environment. The complete list of the questions included in the questionnaire can be found in the appendix 1 in this document.

The qualitative part of the research on the other hand was realized through the in-depth interviews. They took place from 6th March, 2017 till 11th May, 2017. The questions were related to the usability of the hydrogen propulsion in the transport in the Czech Republic. More specifically, the questions were devoted to various areas such as the description of the current and future state of hydrogen, the prediction of its evolution in the transport, the comparison between the hydrogen and electricity usage, the investment into hydrogen, the prices of hydrogen, hydrogen vehicles or hydrogen filling stations, the riskiness on the market and potential definition of the appropriate support. The complete list of the questions used can be found in appendix 2 in this document. In total, 12 respondents from various areas ranging from the representatives of the hydrogen production, automobile industry, public transport services, the cities or potential investors participated in these in-depth interviews. Below, the list of respective respondents who took part in the in-depth interview can be found.

Production of hydrogen and components for its usability

- Zbyněk Brada (Head of Marketing Communications, Linde Gas)
- Tomáš Herink (Research director, Unipetrol, a. s.)
- Jiří Pohl (Senior Engineering, Siemens)
- Zdeněk Vomočil (Technical director, Vítkovice)

Science and Research

- Daniel Minařík (Head of the Laboratory of Hydrogen Technologies, VŠB-TU Ostrava)

Car companies

- Lukáš Folbrecht (SR – Coordinator of external relations, Škoda Auto, a. s.)
- Martin Peleška (Czech Country Director, Toyota CENTRAL EUROPE – Czech s. r. o.)
- Jan Vodstrčil (Homologation and Product Safety Manager, Iveco Czech Republic, a. s.)
- Representative from Hyundai Motor Manufacturing Czech s.r.o.showed interest in the interview, however subsequently no necessary documents were delivered from the company and the interview was not carried out at their request

Transport companies

- Martin Chovanec (Technical and Investment Deputy, DP Ostrava)
- Tomáš Jílek (Member of the Supervisory Board, ICT Operator, Hlavní město Praha)

Cities

- Věra Palkovská (Mayor of the city, Město Třinec)

Investors

- Aleš Barabas (Member of the Board, UniCredit Bank)
- Karel Mourek (Member of the Board, Česká spořitelna)

5.1 Executive summary

The attitude towards **hydrogen usability in the transport sector** is quite favourable when it comes to the **potential customers** from the **broad public**. One of the assumed hypotheses that the public will not be informed about its usability and will have prejudices towards the new rising technology or at least will be afraid of its safety in the automobile transport thus fails to be confirmed. The **important reason** why the hydrogen technology is positively accepted by the broad public is due to its **environmentally friendly nature**. From the respondents´ point of view, its environmental benefit can be seen in the decline of the overall noise and emissions. The undertaken survey, however, confirmed that the **vision of such environmental benefits** will not be **sufficient in the future for the public** to consider this option of automobile transport and incentives such as **donations, tax benefits or privileged parking** would be needed. **High purchasing costs** of new car and **insufficient infrastructure of the filling stations** rank among the main concerns from this type of transport. These findings from the survey were also confirmed by the perception of the project team, the ministry since the premise of the necessary additional incentives was perceived from the beginning and it will be further elaborated in the next chapter of this document.

In contrast to the customers´ point of view, **the experts´ opinion** is **not that influenced** by the topic´s **publicity in the media**. The current state of the hydrogen technology in the Czech Republic is on the one hand described as being at its earliest stage by the experts but on the other hand as being ready for further usage. From the evolution point of view, **hydrogen car builds on the battery electric car concept** whereas in the near future the hydrogen could be used as the **extender of the driving distance**. The question of long term horizon will depend on the evolution of electrochemical sources with the direct impact on the driving distance and duration of electric car´s battery.

It is not widespread among the broad public that the hydrogen and electric vehicles are more or less interchangeable regarding their motor structure. According to many respondents from the in-depth interviews, the **future evolution is not a battle between electric and hydrogen vehicles** but it is rather perceived as two alternative ways of propulsion which can be in mutual synergy. Current support of the electric transport can thus simultaneously help the development of hydrogen transport.

In addition, it is necessary for the **Czech Republic** to join some energy platform since there are not **ideal conditions** for the renewable resources. Moreover, hydrogen should be seen as a strategic source in this platform (storage of electricity, alternative fuel, etc.) in order to represent valuable source for the Czech Republic that could be distributed beyond its borders. The views are that the **location of the Czech Republic** between **Germany and Austria and their TEN-T networks**, countries that already started to build and are in possession of the filling stations, could **represent strategic connection** between the South and North of Europe.

In the near future, the respondents mainly see the potential of hydrogen usability in the **bus transport** where the technology is **perfectly developed** and **available**. The economic feature has to be always remembered. There is a general consent that various forms of **island hydrogen operations can be interesting from the low-emission point of view and gradually also from the operating cost savings**. In addition, hydrogen transport will be firstly operated only on a local basis before operating national wide, which can be apart from bus services represented by other communal organizations such as post services. In general, these operations should be thought of as pilot operations, respectively as a precursor of nationwide use where the life cycle of hydrogen technology in the Czech Republic will be tested.

One of the main factors which is going to play major role in the hydrogen transport is its strong PR and it should be thus directed towards the majority of the population and mainly towards the rich who should therefore consider this type of transport as being trendy. Similarly, it was the case of electromobility.

Regarding, the hydrogen transport development, majority of the respondents are in agreement that the most complex problem represents the question whether to **start building infrastructure of filling stations or to start with the production of new automobiles** as these two go hand in hand and are meaningless without each other. The state support should be primarily directed into the infrastructure development rather than providing the support to development. As subsequent support of hydrogen car production makes sense only for the end customers (thus not for the manufacturers and car dealers).

The necessary step in the future is thus the development of **national government strategy (respectively, extension of the NAP CM document in the context of general update and in particular update of the hydrogen chapter)** which should include **support of the hydrogen technology usage**. There exists consent among the respondents over the areas towards which the support should be directed. There are three distinct areas considered - the legislation one, the environmental one and the infrastructure one. In the **legislation area**, the support should be inherent in various tax benefits for the purchase of hydrogen cars or buses. In the **environmental** area, the support could be directed towards the entrance into the cities or the parking. Lastly, regarding the **infrastructure** area, the support could lie in the construction of filling stations.

5.2 Outputs from the questionnaire

The questionnaire consisted of 17 questions. It was completed by 652 respondents in total. The number of answers to each question however slightly differs since it was not obligatory to answer each question in the questionnaire. The reason for such approach was to get as much completed questionnaires back as possible.

Graphical representation of the results

1. **Did you know that hydrogen cars are already produced and used in the regular traffic?**

Figure 14: Evaluation of question No. 1

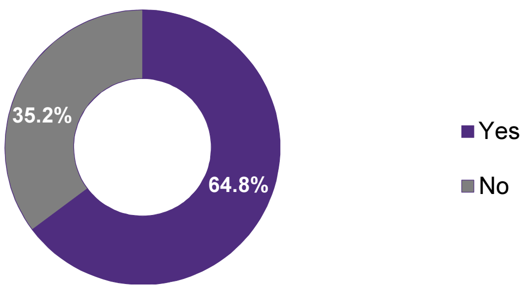


Table 13: Evaluation of question No. 1

Answers	in %	Number
Yes	64.8 %	421
No	35.2 %	229
Total		**650**

2. Would you feel motivated by the environmentally friendly nature of the hydrogen car if you were thinking about buying it (0% emission)?

Figure 15: Evaluation of question No. 2

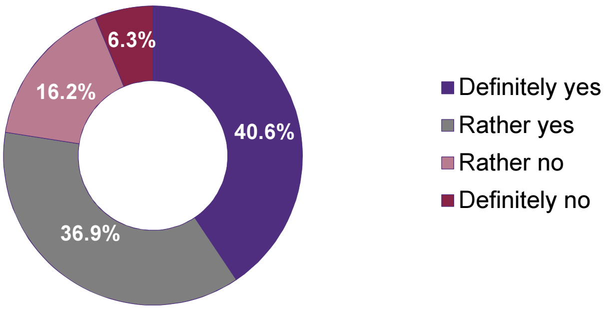


Table 14: Evaluation of question No. 2

Answers	in %	Number
Definitely yes	40.6 %	263
Rather yes	36.9 %	239
Rather no	16.2 %	105
Definitely no	6.3 %	41
Total		**648**

3. Would you be willing to purchase hydrogen car with the following purchasing costs:

Figure 16: Evaluation of question No. 3

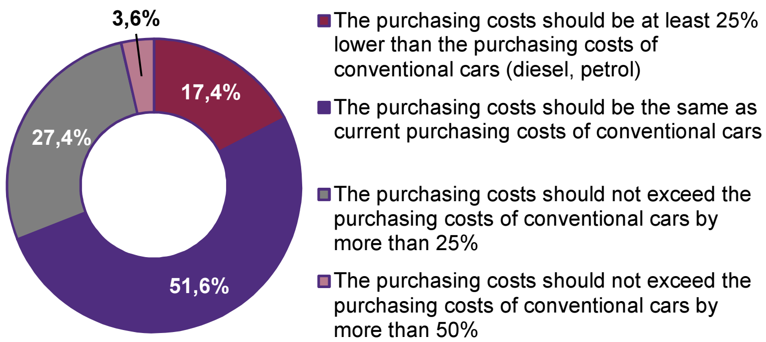


Table 15: Evaluation of question No. 3

Answers	in %	Number
The purchasing costs should be lower by at least 25 % than the purchasing costs of conventional cars (diesel, petrol).	17.4 %	112
The purchasing costs should be the same as current purchasing costs of conventional cars.	51.6 %	332
The purchasing costs should not exceed the purchasing costs of conventional cars by more than 25 %.	27.4 %	176
The purchasing costs should not exceed the purchasing costs of conventional cars by more than 50 %.	3.6 %	23
Total		**643**

4. Would you be willing to purchase hydrogen car with the following operating costs:

Figure 17: Evaluation of question No. 4

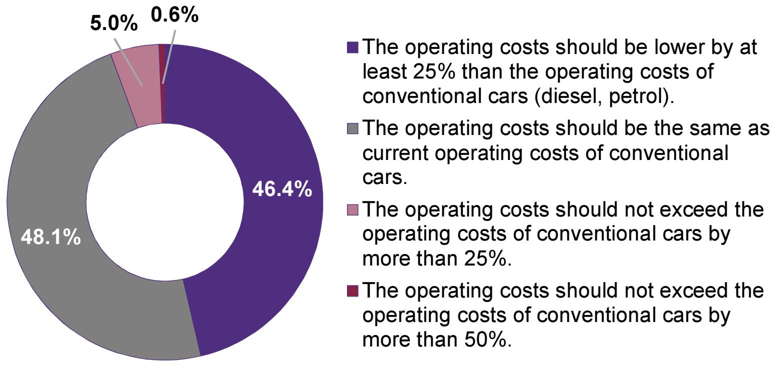


Table 16: Evaluation of question No. 4

Answers	in %	Number
The operating costs should be lower by at least 25 % than the operating costs of conventional cars (diesel, petrol).	46.4 %	299
The operating costs should be the same as current operating costs of conventional cars.	48.1 %	310
The operating costs should not exceed the operating costs of conventional cars by more than 25 %.	5.0 %	32
The operating costs should not exceed the operating costs of conventional cars by more than 50 %.	0.6 %	4
Total		**645**

5. Would you feel motivated to purchase a hydrogen car if you were to get a financial subsidy from state or a producer?

Figure 18: Evaluation of question No. 5

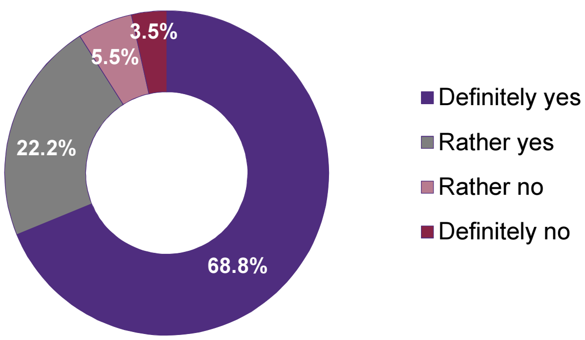


Table 17: Evaluation of question No. 5

Answers	in %	Number
Definitely yes	68.8 %	447
Rather yes	22.2 %	144
Rather no	5.5 %	36
Definitely no	3.5 %	23
Total		**650**

6. What minimum driving distance would you tolerate in case of a hydrogen car?

Figure 19: Evaluation of question No. 6

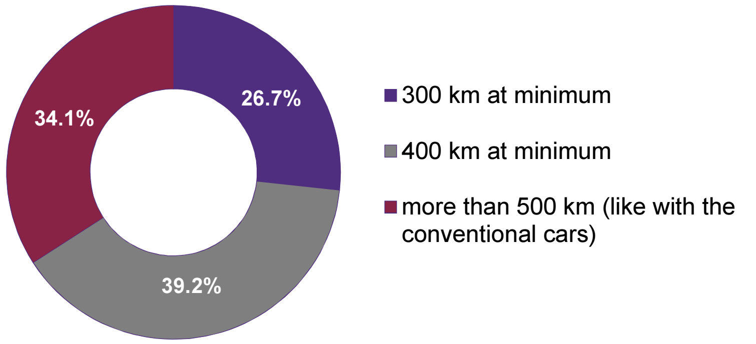


Table 18: Evaluation of question No. 6

Answers	in %	Number
300 km at minimum	26.7 %	173
400 km at minimum	39.2 %	254
More than 500 km (like with the conventional cars)	34.1 %	221
Total		**648**

7. What approximate refuelling period would you be willing to tolerate in case of a hydrogen car?

Figure 20: Evaluation of question No. 7

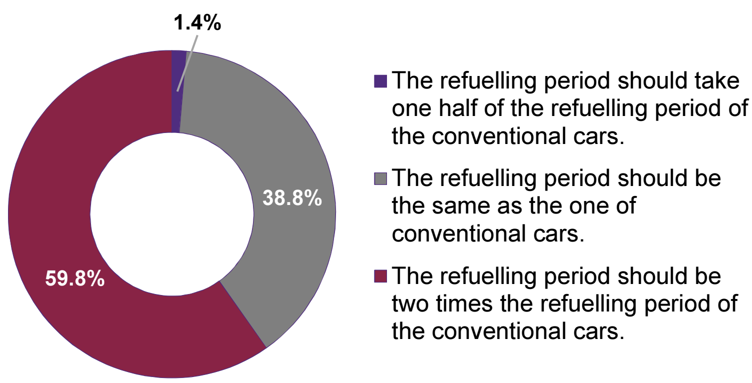


Table 19: Evaluation of question No. 7

Answers	in %	Number
The refuelling period should take one half of the refuelling period of the conventional cars.	1.4 %	9
The refuelling period should be the same as the one of conventional cars.	38.8 %	252
The refuelling period should be two times the refuelling period of the conventional cars.	59.8 %	389
Total		**650**

8. Do you think that hydrogen cars are safe?

Figure 21: Evaluation of question No. 8

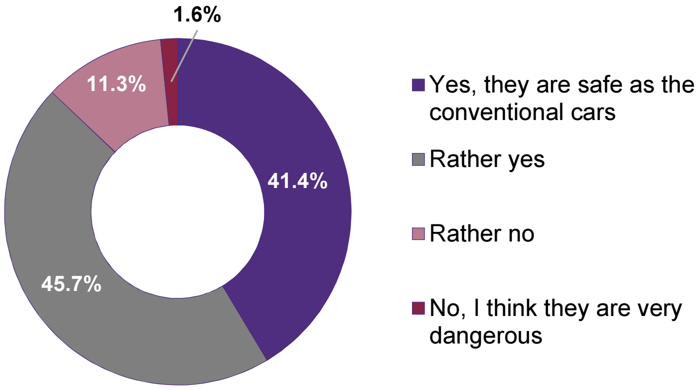


Table 20: Evaluation of question No. 8

Answers	in %	Number
Yes, they are safe as the conventional cars	41.4 %	267
Rather yes	45.7 %	295
Rather no	11.3 %	73
No, I think they are very dangerous	1.6 %	10
Total		**645**

9. What do you fear the most if you should buy a hydrogen car? (you can choose more options)

Figure 22: Evaluation of question No. 9

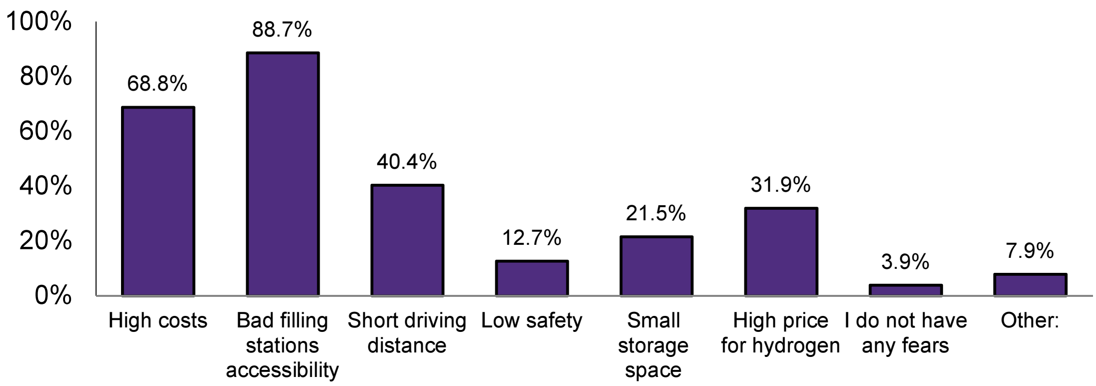


Table 21: Evaluation of question No. 9

Answers	in %	Number
High costs (purchasing, operating, ...)	68.8 %	446
Bad filling stations accessibility	88.7 %	575
Short driving distance	40.4 %	262
Low safety	12.7 %	82
Small storage space	21.5 %	139
High price for hydrogen	31.9 %	207
I do not have any fears	3.9 %	25
Other*	7.9 %	51
Total		**650**

*The respondents mentioned following fears in the category **"Other"**:

- If the whole cycle together with the mining and production process of hydrogen and the motor´s creation is considered, it is in fact harmful to the environment,
- hydrogen volatility, problems with storage capacity, leakage into the atmosphere, parking house limitations,
- the operation is only in its pilot stage, unchecked service life, disturbance,
- fears from donations in somebody´s favour/donations seen as programs for supporting thieves.

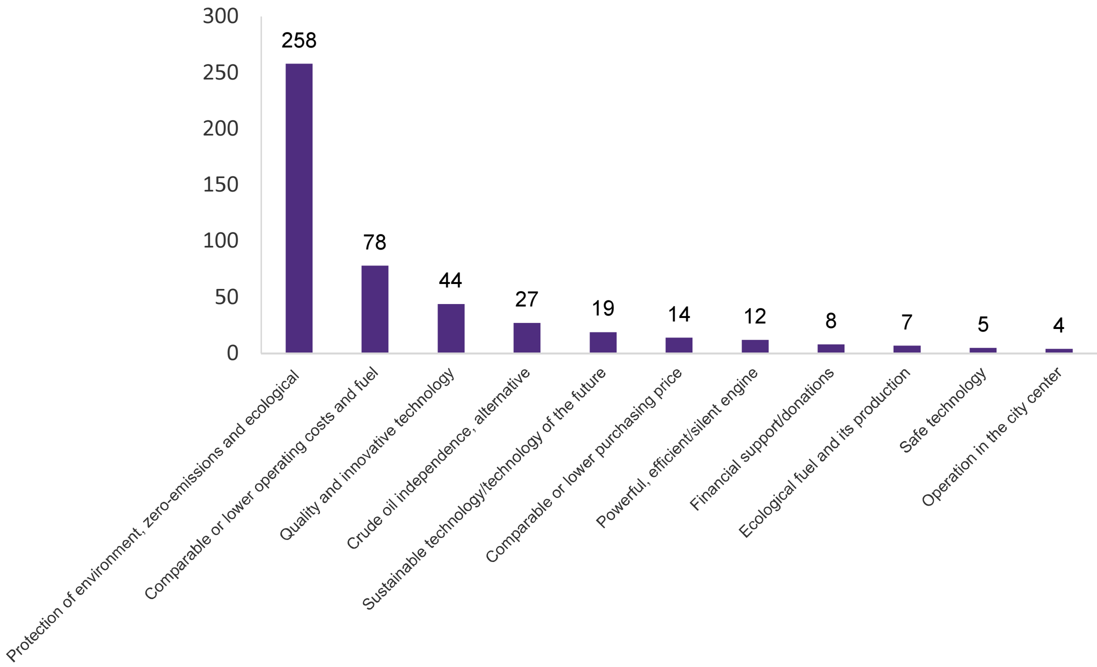
10. Name the most crucial reasons why you would.... the hydrogen car: (open question)

Table 22: Evaluation of question No. 10

Answers	in %	Number
Purchase	92.4 %	413
Not purchase	87.5 %	391
Total		**447**

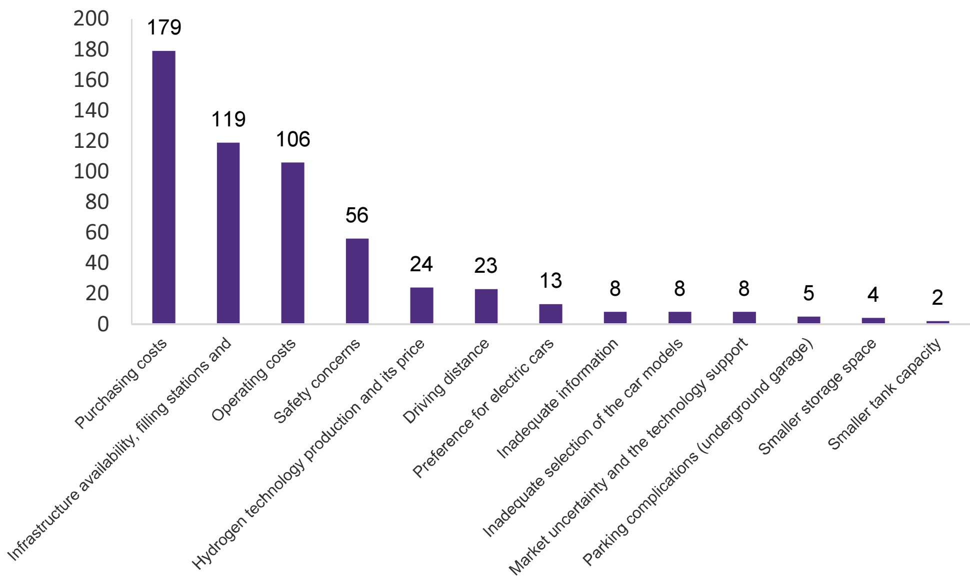
a) The most crucial reasons FOR purchasing hydrogen cars

Figure 23: Evaluation of question No. 10 - The most crucial reasons FOR purchasing hydrogen cars



b) The most crucial reasons AGAINST purchasing hydrogen cars

Figure 24: Evaluation of question No. 10 - The most crucial reasons AGAINST purchasing hydrogen cars



11. How old are you?

Figure 25: Evaluation of question No. 11

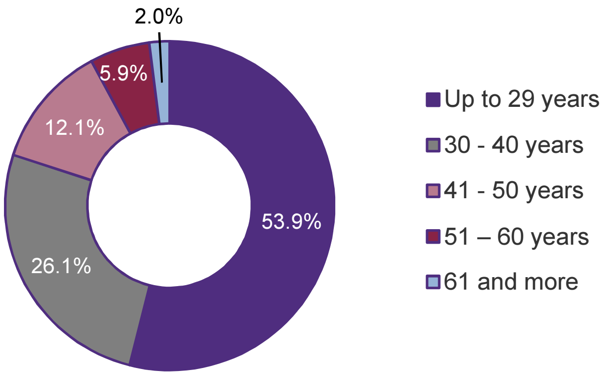


Table 23: Evaluation of question No. 11

Answers	in %	Number
Up to 29 years	53.9 %	347
30 – 40 years	26.1 %	168
41 – 50 years	12.1 %	78
51 – 60 years	5.9 %	38
61 years and more	2.0 %	13
Total		**644**

12. What sex are you?

Figure 26: Evaluation of question No. 12

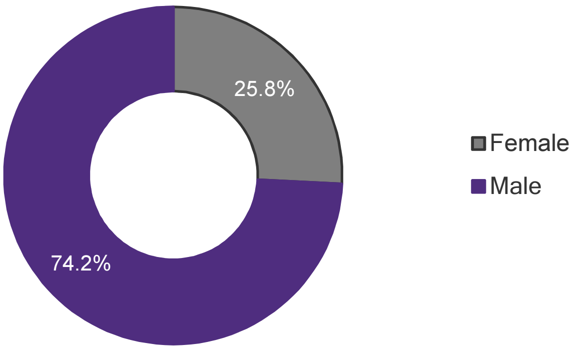


Table 24: Evaluation of question No. 12

Answers	in %	Number
Female	25.8 %	166
Male	74.2 %	477
Total		**643**

13. What kind of car do you drive?

Figure 27: Evaluation of question No. 13

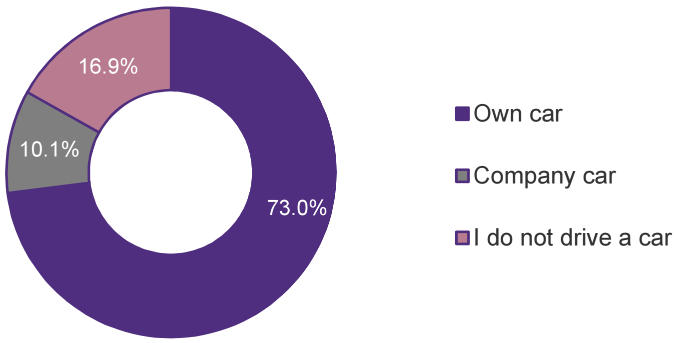


Table 25: Evaluation of question No. 13

Answers	in %	Number
Own car	73.0 %	470
Company car	10.1 %	65
I do not drive a car	16.9 %	109
Total		**644**

14. In case you drive a car, which type of fuel do you use?

Figure 28: Evaluation of question No. 14

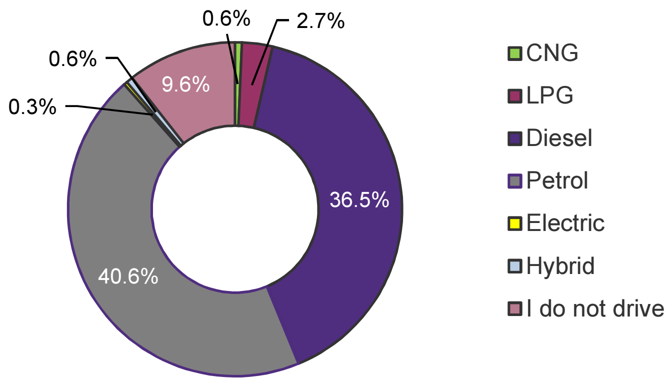


Table 26: Evaluation of question No. 14

Answers	in %	Number
CNG	0.6 %	4
LPG	2.7 %	17
Diesel	36.5 %	228
Petrol	40.6 %	254
Electric	0.3 %	2
Hybrid	0.6 %	4
I do not drive	9.6 %	60
Total		**625**

15. How many kilometres on average do you drive per year?

Figure 29: Evaluation of question No. 15

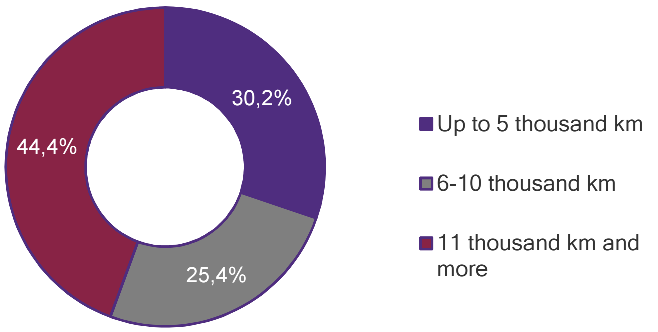


Table 27: Evaluation of question No. 15

Answers	in %	Number
Up to 5 thousand km	30.2 %	188
6-10 thousand km	25.4 %	158
11 thousand km and more	44.4 %	276
Total		**622**

16. In which region do you live?

Figure 30: Evaluation of question No. 16

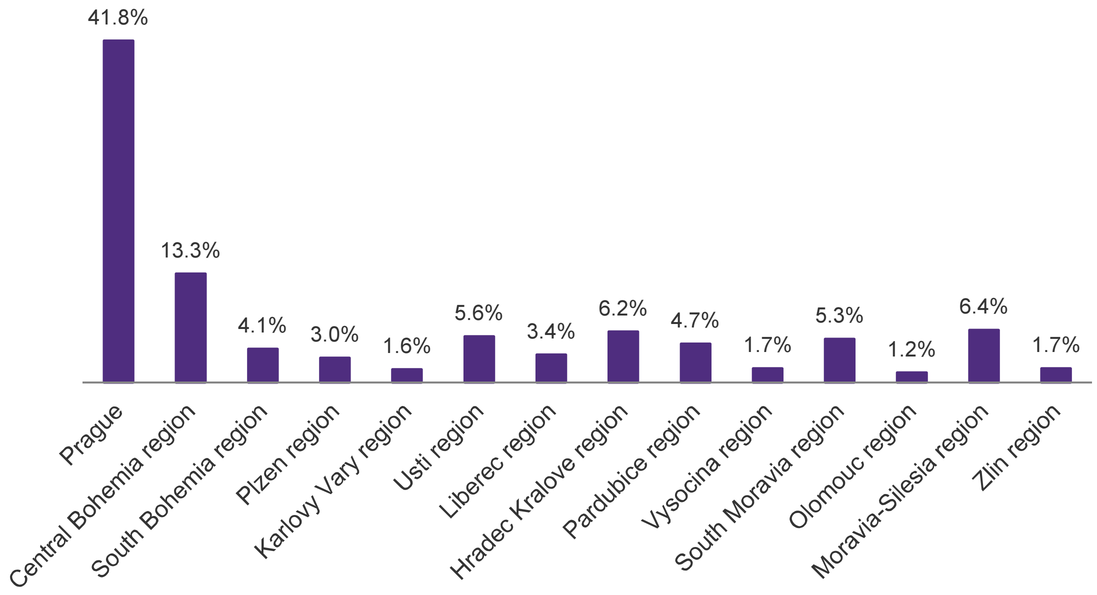


Table 28: Evaluation of question No. 16

Answers	in %	Number
Prague	41.8 %	268
Central Bohemia region	13.3 %	85
South Bohemia region	4.1 %	26
Plzen region	3.0 %	19
Karlovy Vary region	1.6 %	10
Usti region	5.6 %	36
Liberec region	3.4 %	22
Hradec Kralove region	6.2 %	40
Pardubice region	4.7 %	30
Vysocina region	1.7 %	11
South Moravia region	5.3 %	34
Olomouc region	1.2 %	8
Moravia-Silesia region	6.4 %	41
Zlin region	1.7 %	11
Total		**641**

17. What is your highest level of education?

Figure 31: Evaluation of question No. 17

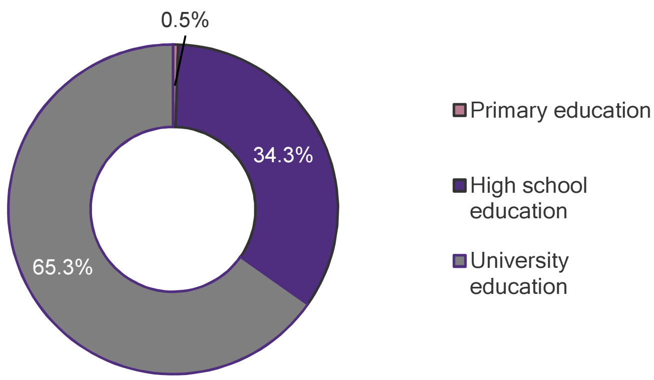


Table 29: Evaluation of question No. 17

Answers	in %	Number
Primary education	0.5 %	3
High school education	34.3 %	221
University education	65.3 %	421
Total		**645**

5.3 Outputs from in-depth interviews

In total, 13 in-depth interviews were carried out. The topics for the questions regarding hydrogen mobility were pre-selected in advance. The in-depth interviews were authorized and revised by each respondent.

5.3.1 Production of hydrogen and components for its usability

5.3.1.1 Zbyněk Brada

Table 30: Record of the interview: Zbyněk Brada

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Ing. Zbyněk Brada	Head of Marketing Communications	Linde Gas a.s.

Record of the in-depth interview

According to Zbyněk Brada hydrogen is perceived as a technical gas. Linde company has a developing centre for hydrogen technology in Austria. The speed of hydrogen mobility is rising quickly as it functions very well in many foreign cities, for example in bus transport which is powered by hydrogen. In addition, it is also used by private companies for their own transportation with own filling stations being located inside the company´s area (for the driving distance of 350 km). He sees the future of hydrogen usability not only in the automobile transport but also in the air, ship transport and eventually it can be also used for the storage of electricity.

According to Zbyněk Brada, in terms of the current state and hydrogen usability in transport, all is managed well technologically as the infrastructure functions and the hydrogen cars are used for driving. The willingness of producers to move onto hydrogen technology is however very low. In the near future, he sees the potential in the bus transport where the technology is nowadays perfectly managed. It already functions like this abroad. Simultaneously, it is important to receive support from the EU and most importantly from the state. It is necessary to produce cars that will be attractive for customers by their appearance (fans of hydrogen technologies, richer clientele). He also sees the hydrogen usability in the island technology – post services, municipal waste collection, etc.

According to Zbyněk Brada the hydrogen mobility will find its use in the near future mainly in the bus transportation. He thinks that the first pilot programs could be realized in approximately 2020 and greater expansion of the hydrogen mobility could happen in 2030. He anticipates that the key milestones which would approximate the current state to the future one lie in the creation of at least two filling stations which would connect the Czech Republic with Germany or would be an important connection on the Prague-Ostrava corridor. Nowadays, the legislation is also not rigorously specified regarding the hydrogen mobility, for example in terms of fire protection, offset distance between stands in the filling stations, the need of qualified workers for the hydrogen filling, etc. Security technicians are afraid of the consequences, they are not willing to participate in this process. It is thus necessary for each country to have its own legislation with specific regulation in which the rules are clearly defined for this area.

When compared to electric vehicles, hydrogen cars do not stand very well, the electric mobility is a bit far in the evolution nowadays. In the Czech Republic, electric cars are more affordable, the public is familiar with them and can meet them personally. Moreover, they do not have to be afraid of their safety. In contrast, hydrogen cars have longer driving distance. In terms of the battery usage or the hydrogen fuel cells, it represents only another source of electric energy. Hydrogen will evolve together with the evolution of electric mobility, both necessarily at the same time. Currently, electricity consumption is increasing however simultaneously there is pressure to shut down nuclear plants whose third generation could be provided as a source of cheap and clean hydrogen. In many companies, hydrogen represents waste product, its availability is thus great but its usability is low since the size of the market is limited and the purity of such waste products is quite low. It is possible to clean hydrogen using the PSA technology. The overall costs for hydrogen are then influenced by the costs for the cleaning process. Moreover, it is necessary to install compressor and filling stations for the trailer filling.

Hydrogen has also potential to be produced from alternative sources of energy, for example from the wind or with the help of electrolysers. Linde company has many ways of producing hydrogen, specifically in the Czech Republic it uses the method of steam reforming from natural gas as well as Unipetrol does.

According to Zbyněk Brada, the biggest player without any doubt is Germany which has the largest infrastructure, then there is the region of London, Scotland (which is mainly active in the bus transport), then there is Milan, Athens and Norway with some but lower impact. The Czech Republic will not be probably at the centre of the development, however, it can at least participate on the highways of foreign countries and connect to their infrastructure. It will be probably possible to travel across whole Europe with hydrogen cars as they have quite long driving distance and the driving can be quite fast when compared to electric vehicles which are less effective in this respect – it is necessary to stop and charge the car more often. South of Germany is the main point of interest for the Czech Republic since it has the largest infrastructure.

Zbyněk Brada points out that among the market risks belong mainly the financial side, unwillingness to invest into new technologies and at the same time the reluctance of companies to move on the production of something, they do not know that well or have not tried yet even if the current production functions well. He sees safety as another potential risk which is mainly perceived negatively by the public even if the safety risks are estimated to be the same as with petrol or even lower since hydrogen has better physical properties. In a case of car crash, petrol gets out of a tank while hydrogen has safety valves thus it disappears more quickly than the explosion can even happen.

He thinks that in the future, the problem which could arise is the fact that there is no qualified workforce in the services who would be able to work with hydrogen technologies. The question at the same time is whether hydrogen cars can be parked in the underground garages. Other questions relate to the tax and legislation field.

Hydrogen can be delivered by several means as it can be inside the volumes of pressure bottles or it can be distributed with the help of trailer. The price of hydrogen in the volumes is high as the capacity is limited and the containers are heavy which contributes to higher filling and transport costs. The price of hydrogen in trailers is on the other hand significantly lower. If the hydrogen is thus delivered in trailers, it is subsequently filled into the trays or stations of several connected volumes which are part of the hydrogen filling station.

In general, hydrogen filling stations work with the input pressure of 5 bar at minimum which is further compressed with the help of compressors up to 1,000 bar and it is subsequently stored in the high-pressure hydrogen containers. The standard filling pressure of the personal hydrogen cars is 700 bar and 350 bar in the case of buses. The tank of buses can be usually filled with approximately 25 kg of hydrogen while the tanks of personal cars can be filled with approximately 5 kg of hydrogen.

In the future, there is a plan to build hydrogen filling stations for example in the city of Litvínov or in Prague (Barrandov).

Namely, subsidy for the construction of filling stations, purchase of personal vehicles/buses mainly by the EU, donations for cities or emission free zones can be seen as appropriate forms of support. In addition, the personal hydrogen cars could be exempt from value added tax or there could be various tax reliefs. The support could be also directed towards the providers of filling stations mainly the EU or state support and it would hold similarly for the companies who would want to build filling stations for themselves, either for public or for private use. The state commitment towards cleaner mobility could be seen as a good incentive. Linde company as a producer of hydrogen would not be interested in the state support towards cheaper hydrogen distribution since in order to have cheap distribution, the amount has to be large and it is necessary to use hydrogen beyond the automobile industry. They see the way in hydrogen production through the wind energy, where the production is ecologically friendly. Moreover, clean hydrogen would be produced.

5.3.1.2 Tomáš Herink

Table 31: Record of the interview: Tomáš Herink

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Tomáš Herink	Research director	Unipetrol a.s.

Record of the in-depth interview

Accoding to Tomáš Herink, Unipetrol company supports innovations, has centre for research and education. They also observe the newest trends in the development of hydrogen across the whole Europe. The first impulse in the hydrogen development was registered in 2007 in Germany (Munich Airport). In 2015, Unipetrol company joined with the people from HYTEP association in order to work together on a vision and idea of the company and thus to get involved in the hydrogen field. The vision and idea of the company is to start deliver hydrogen to the public filling stations in the Czech Republic. The company owns extensive network of Benzina filling stations. Furthermore, it already searched for suitable location where it would be possible to deliver hydrogen. This however was not easy since it is difficult to evaluate such situation economically as the question is where to begin if it is the personal hydrogen cars that should be started with or the filling stations. It is necessary that someone gets this process started so the progress can happen. Unipetrol company contemplated about the construction of filling stations, for example in Prague (Barrandov) or Litvínov (Benzina just next to the area). In this respect, Unipetrol also conducted a study of the estimated investment costs and feasibility. The company worked together with the Ministry of the Environment, Ministry of Trade and Industry and Czech Association of Petroleum Industry and Trade on its vision. Hydrogen as a biofuel is not yet implemented in the legislation and therefore they try to discuss hydrogen more with HYTEP, they also conduct commercial activities in order to show that they are interested in the hydrogen technology, they support it and they want to work with it further. Unipetrol company also considered the realization of hydrogen filling station in a selected location, they mapped the potential customers, they contemplated a consortium of Most and Litvínov cities, interlinkage of the transport providers, hydrogen buses and the distribution of hydrogen itself. The progress was however too slow, the communication with the cities was bad, they did not find an agreement and the plan was thus not realized. Currently, the company is more oriented towards Prague. Unipetrol company is really interested in the hydrogen incorporation in the Czech Republic, they want to deliver it and they also want to build the filling stations. They thus try to discuss the topic in various aspects. For this purpose, they joined the hydrogen platform, they also promote hydrogen not only to various interest groups but also in the political area or online, they always tell the negative aspects of hydrogen usability together with the positive ones. Unipetrol company also participates on the meetings with various ministries and their deputies. Generally, they try to lead „hydrogen enlightenment".

Unipetrol company produces hydrogen from the fossil fuels by steam reforming and partial oxidation of fractions. Currently, Unipetrol does not produce hydrogen in such quality that is required by the FCV technology, however in case it is needed, Unipetrol is able to clean the hydrogen up to the required level in order to bring it to the market. At first, Unipetrol wants to equip the filling stations with filling stands and in the subsequent stage it wants to deliver its own hydrogen. They consider hydrogen as a mean towards clean mobility for all participating parties. Current trend is represented by battery electric cars where hydrogen is a good alternative for electricity cars. From the customer´s point of view, electric cars powered by hydrogen provide greater comfort in terms of the speed of the energy filling process. It is necessary for the market to get saturated by the consumers of hydrogen either from the car, buses side or other means of transport. The next stage according to Unipetrol should then involve the distribution of its own product to the filling stations. The third stage should then include the production of hydrogen from alternative sources (like wind, sun, water etc.). The future visions are to produce clean hydrogen from alternative sources and not only from the crude oil or from the mix of alternative and fossil fuels. Nowadays, the common alternative is the production of fossil fuels and „grey hydrogen", biomass gasification (wood chips) and the municipal waste usability.

They estimate the horizon for the construction of filling stations to take approximately 2 years from the decision till the realization of construction in the Czech Republic. If the decision for the construction of hydrogen filling stations is made and there is full support for the construction in the Czech Republic, the company is going to start the activities that involve clean-ups of the hydrogen and preparations of inner infrastructure for the hydrogen distribution and potential activities involving the equipment of filling stations with filling stands. During the second phase, the distribution of its own product, they estimate the horizon to be 3-4 years which means that it should take place around the years 2020-2021, subsequently they estimate the alternative production of hydrogen to take place around 2027.

It is necessary that the hydrogen is supported, it has to be already implemented in the legislation, and it has to be interesting (trendy) for the consumers and also for the company itself. They propose that the hydrogen could be supported through various channels such as through the EU emission levels, in terms of legislation – value added tax and road tax. Furthermore, it is the support of consumers/companies/ministries who want to purchase these vehicles, infrastructure support, and tax reliefs for the hydrogen purchase. There is a need to have both, the state and also the regional support as it is the case with other projects undertaken in the EU, the transport sector has to be supported as a whole, the whole branch has to be supported. The production costs and the operating costs for the hydrogen cars are two distinct costs. The operating costs have to be guaranteed by the state. At present, Unipetrol company does not see any potential competition for hydrogen in terms of some different technology or alternative which could appear and nobody would have known about it until now. They point out that they represent standard fuels, there are no obstacles, they rather see it as a competitive fight, which means what they are able to win.

Currently, there are many distributors of conventional fuels and the question is how the distributors are going to face this challenge. At the same time, it cannot be said how many crowns it will cost to produce hydrogen, it is difficult to specify it as some secondary industrial companies produce hydrogen as a secondary source which they do not use at all (they either burn it for obtaining heat or burn it without further use). The bus consumption is estimated to be approximately 8 kg per 100 km of hydrogen as compared to diesel where the consumption is approximately 30 l per 100 km.

5.3.1.3 Jiří Pohl

Table 32: Record of the interview: Jiří Pohl

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Jiří Pohl	Senior Engineering	Siemens

Record of the in-depth interview

According to Jiří Pohl, the current form of transportation, which is dependent on fossil fuel (97% of the energy for transportation in CR is provided by oil products and its surrogates), is in the near future impossible to maintain due to high energy demandingness and high production of carbon dioxide. Current goal is to provide sustainable mobility, a mobility with zero dependence on fossil fuels and with zero production of carbon dioxide. This zero-emission mobility will have multiple models. In the case of strong and regular transportation streams, public transportation with line electric power supply will be constructed and used because it is energetically way less demanding then individual transportation. In the case of weak and irregular transportation streams individual transportation (pedestrian, bicycle, car) will be kept as it would be inefficient to construct line constructions – cars with energy accumulators will be used.

Considering the strong development of the electrification of railways and public transportation, the supporting trend in public transportation is the development of electric traction (vehicle collects energy in the duration of the drive from line traction system) and vehicles with energy accumulators will only be used as supplements in areas with lower traffic. These vehicles have the advantage of utilizing fixed traction systems of electric routes for the purpose of charging the accumulators. It is realistic to reach a completely zero-emission public transportation (railways and urban public transportation) in CR by 2030.

The situation in individual transportation is different. Here the line electric power supply doesn't exist and energy accumulators are the basic solution.

Hydrogen or a different fuel cell is not cannot be overloaded and is not capable of receiving a recuperated energy while braking. That is why, in a vehicle, it has to cooperate with the energy storage unit, typically an electrochemical accumulator. Fundamentally it is a hybrid propulsion with the difference that instead of a gas tank for a combustion engine a hydrogen tank is used with a fuel cell.

In terms of technical solution, a hydrogen car is not a counterpart of an electric car, but a certain modification. In comparison with a basic electric car, hydrogen car has most of its parts same or very similar (traction engine, pulse inverter, electrochemical accumulator) plus has only a hydrogen aggregate (hydrogen tank with fuel cell) and a range extender. The advantage of a hydrogen aggregate compared to a lithium accumulator is a lower specific weight and the option of fast refilling (tanking). The disadvantage of the fuel cell is a lower specific output and the inability of recuperation (that is why it needs the addition of electrochemical accumulator) and also a low efficiency of the energy conversion. The chain of the conversion of electric energy into hydrogen (approx. 65% effective electrolysis) and back to electricity (fuel cell with approx. 60% effectiveness) had a resulting effectiveness of 40%. In comparison with a direct electrical power supply or more precisely with an ordinary electric car, a hydrogen electric car has approximately 2.5 times higher energy consumption.

The future of utilizing the hydrogen technology in transport mobility is, to certain extent, dependent on the advancements in the area of petrochemical accumulators of electrical energy.

Traditional lithium accumulators in previous years (Li FePO4) dispose of explicit specific energy around 100 kWh/t and specific utilization energy around 70 kWh/t. Therefore, with electric energy consumption of approximately 20 kWh/100 km the accumulator needs to weigh about 300 kg for the range of 100 km. An accumulator of around 400 kg in weight allows the range of about 140 km. That is sufficient for regular trips to work however it is very insufficient for longer routes, for which a hydrogen aggregate within the range extender function is more suitable.

However, new contemporaneous lithium accumulators (Li NiMnCoC) dispose of explicit specific energy around 200 kWh/t and specific utilization energy around 140 kWh/t. Therefore, with electric energy consumption of approximately 20 kWh/100 km the accumulator needs to weigh about 300 kg for the range of 200 km. An accumulator of around 400 kg in weight allows the range of about 280 km. That is already sufficient for longer (weekend) trips and therefore the hydrogen aggregate within the range extender function would be necessary only for unordinary trips. The feasibility is understandably not the only criterion, a price comparison (investment and operating costs) will also be important.

Other types of lithium accumulators are in development. Accumulators Li S dispose of explicit specific energy around 300 kWh/t and specific utilization energy around 210 kWh/t. Therefore, with electric energy consumption of approximately 20 kWh/100 km the accumulator needs to weigh about 300 kg for the range of 300 km. An accumulator of around 400 kg in weight allows the range of about 420 km. That would further limit the area of meaningful application of hydrogen aggregates within the range extender function.

In light of local influences on the living environment (noise and local exhalation), conventional electric cars, that intake electricity from public or private charging station that are supplied by a regular distribution network, are comparable with hydrogen electric cars, that fuel themselves with hydrogen at a filling station and then self-sufficiently produce electricity using fuel cells while driving. Deleterious emissions (NO_x, SO_2, CO, THC) are not produced by either conventional electric cars with electrochemical accumulators or hydrogen electric cars.

In light of global influences on the climate change (CO2 production), both conventional and hydrogen electric cars are dependent on the structure of the production of electrical energy that is used to charge the accumulator or more precisely that is used for the electrolysis when producing hydrogen. In the case of the same energetic mix the carbon footprint (gCO2/km) of a hydrogen electric car is 2.5 times higher than a footprint of a conventional electric car. The same ratio exists with the consumption of primary energy.

Hydrogen vehicle developmentally follows up on conventional electric car, fully utilizes the components that were developed for conventional propulsion (traction engines, traction switchers). Its strength is a larger energy storage and therefore bigger range (with comparable energy storage weight). In fact, it actually even needs bigger range because the hydrogen filling station network will be very possibly more infrequent than the network of electric charging stations.

The question of purposeful application of hydrogen vehicles will be dependent on the development of electrochemical resources with direct impact on range of conventional electric cars. The advancements in accumulator development can potentially have a negative impact on the hydrogen competitiveness. It is possible (many development teams across the world attempt to do so), that the development of electrochemical resources will advance and conventional electric cars will in the future fully accommodate the range requirements even without hydrogen. However, today we cannot say with confidence that accumulators with adequate parameters, acceptable price and long life span (deciding parameter is Kč/kWh/cycle) will be commercially accessible. Therefore, the question, how big is the application area for hydrogen technology alongside conventional electric cars will remain, is opened.

Another question in comparison of conventional and hydrogen electric cars is the form and time demandingness of the energy filling. Now, at the time of the beginning of the implementation of conventional electric cars, an emphasis is put on fast charging during productive utilization (the tradition of driving to gas stations is adapted). However, the reality that an average car in CR parks for 23.5 hours daily sets out a goal to utilize this time for charging. This is the application of Smart Grids, that in the spirit of the principles of Industry 4.0 counts on the utilization of IOT (Internet of Things), when the car is able to "self-purchase" cheap energy at times of surplus and will recharge itself.

The relationship to the hydrogen application is also influenced by geographical conditions. There is a surplus of electric energy during night time in countries with strong renewable resources (mainly wind energy) and therefore an idea exists to utilize that energy. Alongside of the transport using long-distance power transmission lines to demand area or more so its accumulation, another utilization counts on electrolysis – hydrogen production for direct use or for its conversion to methane (and its transport through common gas conduits). However, the hydrogen cycle has low effectiveness. Moreover, from a quantitative point of view (wind farms have an output of million kW), hydrogen would have to be mass utilized in cars in order for the hydrogen consumption to balance the difference between night energy consumption level and full performance of wind power plants.

There is a completely different situation in CR. This country is an energy importer and will be energetically poor in the future. No surplus of energy produced from renewable resources can be expected – CR doesn't have any wind coasts, no large mountain rivers and no sunlit, flat regions. Hydrogen production from fossil fuels is not perspective (see Paris accords and other CR's contractual obligations). Hydrogen production as a side product from chemical waste is problematic for its low pureness (the quality doesn't comply with the requirements for reliable function of the fuel cells) and furthermore it is only a small volume. Therefore, only the hydrogen production using electrolysis is left, which on the other hand conflicts with the low effectiveness of the entire chain (40 %).

Reasonable hydrogen utilization seems to be a standard and shared range extender for conventional electric cars, where the accumulators will be built for a traditional range of 100 – 200 km and it will be possible to borrow a hydrogen aggregate for occasional longer trips. This thought is supported by the statistics of the Ministry of Transport (MD ČR), that illustrate a very low utilization of passenger cars. That stays true from both an average travelled distance for one drive (32 km/drive) as well as the average travelled distance of one car in one day (29 km/car/day). The deciding factor will of course be the CBA of such entrepreneurial activity.

5.3.1.4 Zdeněk Vomočil

Table 33: Record of the interview: Zdeněk Vomočil

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Zdeněk Vomočil	Technical director	Vítkovice

Record of the in-depth interview

When considering the current state of hydrogen usability, Zdeněk Vomočil thinks that Czech industry has great potential in the hydrogen usability which has not been fulfilled yet. The reason for this can be the nonexistence of any national strategy regarding the hydrogen technology which is then the reason why Czech companies wait with the investment into this sector. The risk is then the fact that the Czech Republic will stay behind other countries and will be forced to buy these technologies in the future. Germany can serve as a good example as it has very good experience with hydrogen and they are more advanced already. Theoretically speaking, the Czech Republic is prepared as from the technological point of view the situation is managed, however, what is missing, is the energy and courage on the political level to move onto the next phase which would move us closer to the implementation.

Zdeněk Vomočil points out that similar situation was few year ago with CNG and nowadays Vitkovice have a complex solution already prepared at hand. He describes main areas of the CNG usage which cover technologies for filling stations, corporate car fleet, public transport services, municipal services, providers of rail transport and technologies of production facilities. Furthermore, he points out that hydrogen represents an excellent source of energy, it can be said that it is kind of an accumulator. Vítkovice use their own high-pressure bottles and special containers for the storage and transport of hydrogen. At present, Vítkovice cooperates with hydrogen platform HYTEP on the construction of hydrogen filling stations.

Zdeněk Vomočil sees the main limitations or weak points mainly in the current state of legislation since it does not support the market creation. Furthermore, there is missing network of filling stations in the Czech Republic and the price for the car line is very high. In addition, he points out that as a result, the risk is in inadequate financial support of the hydrogen mobility development. On the contrary, Zdeněk Vomočil names the following as the main benefits of the hydrogen technology: zero operating emissions, inexhaustibility of resources for its production and at the same time he sees the advantage in the operating cost savings in the public transport or for other vehicles that operate in the same location, the fulfilment of emission obligations as set out by the EU and the connection to the German-Austrian infrastructure (the connection through the TEN-T networks).

5.3.2 Science and Research

5.3.2.1 Daniel Minařík

Table 34: Record of the interview: Daniel Minařík

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Daniel Minařík	Head of the Laboratory of Hydrogen Technologies	VŠB-TU Ostrava, Centre for Energy Units for Utilization of non Traditional Energy Sources

Record of the in-depth interview

According to Daniel Minařík, the current state of hydrogen mobility is in the stage of defining the intention. "We are at the beginning when we create and formulate the conditions and especially all-round awareness of its utilization. We are prepared technologically and I even believe that thanks to the strong industrial foundation of the country we will be able to utilize our know-how in related technological fields. The biggest impact on the future development of H2 technology will primarily have economic factors over the environmental influences. Since Czech Republic does not have ideal conditions for renewable energy resources, the country has to join those energy platforms where hydrogen can play an essential role of a strategic resource which we will be able to generate and transform on our soil and possibly distribute beyond the Czech market".

In the future, there is going to be a gradual integration of the hydrogen technology into everyday lives. An estimated horizon of approximately 20 years exists, which basically stands as one generation of people systematically educated in the given field and simultaneously, that will develop the foundation of the new direction of commercial demand for H2 technology – (new generation of technicians, researchers, endorsers and users). The most important step is to make a state-level strategic decision, set a clear goal and vision – establish a clear declaration of interest and support for the H2 technology in a specific way so that a gradual change of thinking of the future generation occurs.

In contrast with the battery-powered mobility, the situation in the developing areas of mobility, just like the hydrogen one, appears to be well-arranged. The market is not yet filled with large number of hydrogen car manufacturers or distributors of the refilling infrastructure and therefore at first, hydrogen pilot projects of the public transport providers will be realized where the benefits are highlighted with respect to price – with regard to the complete utilization of the new infrastructure. Gradually, the increasing hydrogen consumption will surely lead to the realization of other projects with the added value for the energy distribution networks.

Batteries and hydrogen will coexist, and to some extent they can also create a synergy effect, with the possibility that hydrogen can become a trend, which will subsequently replace some currently accumulator-driven applications. The accumulator technology has its limitations based on the more complicated chemical reactions and more energy demanding manufacturing and consumption chain, when looking at the "electro-carbon mark", than the hydrogen cycle. Cars lose their "status value" and will gradually decrease in numbers. Therefore, we can predict that even current fairly high prices of new hydrogen cars should not present a significant obstacle in their development in the near future. Foreign inspiration can be mainly found in Germany, but also in England, Netherlands, USA or Canada as they are technologically very advanced. Germany declared a new, clear direction of its energy industry and is willing to head in the direction of experiments. There also exists great selection of professionals across different fields who are able to solve problems in a complex manner and whose intensive education and preparation in a given field already started in the previous century.

Thanks to the strong industrial and car production orientated conditions in Czech Republic, a government support could be applied to current firms, which have their own manufacturing capacities and experience with car construction or the production of technological facilities within the supporting infrastructure. Those firms were also able and willing to initiate manufacturing activities in the field of hydrogen technology not in the form of R&D grants but instead using "guaranteed product or technology offtake", which would have to be applied and have to show its preparation and viability. In other words, state support through acquisition of the end product rather than support of the process.

5.3.3 Car companies

5.3.3.1 Lukáš Folbrecht

Table 35: Record of the interview: Lukáš Folbrecht

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Lukáš Folbrecht	SR – Coordinator of external relations	Škoda Auto, a. s.

Record of the in-depth interview

From the Škoda Auto´s point of view which currently specializes more in conventional car production and prospectively on the battery vehicles of the type PHEV and BEV, hydrogen represents an interesting technology with great potential. It is however necessary to overcome several challenges, such as high car implementation costs of this technology and inadequate filling infrastructure, before massive implementation can happen.

The development of hydrogen technologies within the VOLKSWAGEN group and also for other brands is taken care of by AUDI. Wider selection in terms of different models (serial production of the selected group´s brands) is expected to be offered by the group approximately around the year 2025.

5.3.3.2 Martin Peleška

Table 36: Record of the interview: Martin Peleška

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Martin Peleška	Czech Country Director	Toyota CETRAL EUROPE – Czech s. r. o.

Record of the in-depth interview

According to Martin Peleška, there is currently low awareness of hydrogen mobility itself. People do not know that hydrogen cars exist too much, that they are used and that they are serially manufactured and already function in our region. The goal of the representatives of Toyota company is to increase the awareness of the public and to connect its brand with the hydrogen mobility, for example via public relations or with the help of conferences, where it is even possible to present the concept of these vehicles, important information can be communicated and potential customers could also try the vehicles personally. The setback in the development of hydrogen mobility is seen in inadequate infrastructure which should be ensured, its availability should be thus more widespread and proper functioning should be secured. In case the infrastructure functions well, it will be more attractive for the producers of hydrogen cars as they will feel more certainty.

According to Martin Peleška the public opinion will be directed towards hydrogen technologies as a certain trend in the following year or two. In 2020, the rule could be that the CNG technology could be significantly worse in comparison with other alternative propulsions, for example hydrogen. He sees the use of hydrogen not only in the personal cars but also in the public transport like tram or bus transportation where the power cables would be replaced by the fuel cells. At the moment, the question is whether it is better to wait or to be the initiator of the change. In this case, Hamburg serves as a good example where the hydrogen mobility functions very well and the public transport is powered by hydrogen already. The car companies see the need in investing into the innovations and progress however it is risky since the innovations do not have to be implemented well. There is not much where to invest in terms of propulsion, the deciding period will be at this moment and it will depend on the type of fuel which will power them or eventually from where the energy is taken. It is also important not to question the hydrogen use in terms of yes or no, but rather it is necessary to ask when it can be implemented. In the context of overall development, it is necessary to ensure the connection on Trans-European networks. At the same time, it would be great if the European Union could ensure at least minimal infrastructure in each country.

Martin Peleška sees the potential in the development of industry in terms of hydrogen processing. Owing to the chemical plants which currently produce hydrogen as their secondary product, the Czech Republic could have great power in the hydrogen production and could become distributor across whole Europe, even without the stock of crude oil. It should be under consideration for the state to submit a request through the CEF (Connecting Europe Facility) network, which enables to draw the resources from the EU into transport infrastructure in the Czech Republic. From the state´s point of view, it is important to motivate the society to greater ecology and thus also towards the hydrogen propulsion for example via the increase in excise duty on the conventional fuels. The goal is to reduce the amount of emissions for example even by support of the restrictive measures. The state support is, however, not a primary motivation for Toyota as a manufacturer of cars. The hydrogen cars are at this moment manufactured manually as the amount of such vehicles is quite small.

In case of the access of other states to alternative fuels, Martin Peleška thinks that Norway is already quite far in this sense as 90 % of population is interested in the electric cars and simultaneously he also thinks that 50 % of hybrid vehicles will exist in Western Europe in 2030 and diesel cars will approach their end by 2020. Diesel cars will become more expensive and the middle or lower class will no longer be interested in these types of cars. By the end of 2020, diesel cars are going to become „unsaleable", the residual value will experience decrease to 10 %. Generally speaking, such fast evolution as in the case of personal vehicles or buses, will not be experienced by the trucks and diesel will represent more efficient mean than hydrogen.

Toyota company is prepared to demonstrate how the hydrogen cars function and they also aim for the connection of Toyota brand with hydrogen. Toyota is engaged in so called Hydrogen council which promotes hydrogen as a clean ecological solution and as the fuel of the future in the transport. It is necessary for the solution to function as a complete unit, not as separate parts thus the infrastructure should be connected and there should not be separate networks. Hydrogen technologies could thus serve as a benefit for the whole society in the future.

5.3.3.3 Jan Vodstrčil

Table 37: Record of the interview: Jan Vodstrčil

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Jan Vodstrčil	Homologation and Product Safety Manager	Iveco Czech Republic, a.s.

Record of the in-depth interview

According to Jan Vodstrčil clean hydrogen can be nowadays used for experimental vehicles either as a fuel into classical combustion engine or in fuel cell. Both are from technical point of view relatively inconvenient due to physical properties of hydrogen as a gas (it is very tiny molecule, problems with its storage). Furthermore, there appear to be problems with the purity of fuels in current experiments with hydrogen cells. At present, Jan Vodstrčil thinks that the ideal hydrogen usage is its utilization as a raw material in the production of synthetic methane (fusion with the waste CO_2 from cement plants). It can be also pointed out that the combustion engine is similarly efficient as the most up-to-date existing fuel cells. Hydrogen is also ideal to be used directly for the electricity production when the environmental impacts are considered – this means some form of fuel cell however with significantly greater efficiency than current technique allows. It will be necessary to resolve the infrastructure and hydrogen storage for the future. The hydrogen can thereafter serve as a fuel for electric cars. At this moment, the world focuses on electric cars with accumulators and super capacitors. The known problems of this technology could be resolved in the horizon of 10–15 years and hydrogen in applicable form (for the mass production of vehicles) could arrive about 5–10 years later.

Jan Vodstrčil sees the key milestones in the transition from the current state of hydrogen mobility to the future state in a significant increase in the efficiency of the fuel cells, the solution to the materials from which the pressure bottles should be made (thus it can be used for the mass production), filling stations, the possibility of service and the presence of

STK in at least every city with the number of inhabitants above 50,000, normalization and safety standards for hydrogen propulsion. He points out that in terms of the transport development, the fuel mix is going to be stabilized. In the near future, battery electromobility starts to displace classical ICE in the city road transport whereas the long-distance road and ship transport will stay with liquid fuels and gaseous fuels – owing to the need of energy density. In this area, the population will move from classical fossil fuels towards biofuels and synthetic fuels. Hydrogen will exist on the border of city and intermodal transport but it cannot be yet reliably predicted where it finds its place. According to Jan Vodstrčil, hydrogen is not a competitor for electromobility in terms of battery vehicles. Both drive systems can and will coexist – BEV for the short distance, whereas hydrogen for the longer distance.

The main decision-making aspect when it is worth to invest for a longer period into hydrogen cars produced in a classical way is the moment when TCO of hydrogen car approaches other types of propulsion in a way that the combination of a (guaranteed for a long time) state support and the attractiveness in the society exceeds other disadvantages for the users. Put in other words, it is the moment when analytic states that from today (5?) years ahead under some probably fulfilling conditions, hydrogen will be attractive for the users to such extent that it outweighs the possible problems, it can cause them.

It is difficult to specify which types of supports and in which forms would be needed, and eventually who should provide them. Considering the public and cargo transport, a lot of factors play role in which neither the price of the vehicle nor the price of the fuel ranks first but the most important thing is TCO. Furthermore, the car usability (how long it does not work but what time does it take to tank the vehicle or the service), political influence (mainly in the city transport) and the approximate certainty of earnings during the service life of the vehicles thus it means at least 5 years or better 10 years.

5.3.4 Transport companies

5.3.4.1 Martin Chovanec

Table 38: Record of the interview: Martin Chovanec

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Martin Chovanec	Technical and Investment Deputy	Ostrava Public Transport Company

Record of the in-depth interview

According to Martin Chovanec, currently hydrogen technology and its usability concerns Ostrava public transport company only at the level of an intended plan, but at the same time in the medium-term horizon, it can represent an interesting opportunity for the electromobility development. Electromobility in the transport sector or under the low-emission concept is realized via the DPO strategy.

At present DPO is operated by 284 buses which makes almost one half of the total number of vehicles in the register. As of today, the bus fleet is already in a possession of 105 buses with the CNG propulsion and the rest represented by the diesel buses is going to be gradually replaced by the CNG buses, electric buses and trolley buses with alternative propulsion on battery. Martin Chovanec adds that economically more efficient is today

CNG but DPO also counts with the electric buses (accumulator drive with the direct charging) which are currently more expensive in terms of the purchasing costs.

The city together with DPO announced that since the year 2020, there are not going to be any diesel buses employed in the regular traffic. They will remain only as reserve buses in case of some strategic reasons (blackout, etc.). In the target year 2020, DPO is going to operate only low-emission and electric cars. There is preparation of the CNG filling station construction in the area near Hranečník transport terminal.

The development of electric buses is limited with regard to the driving distance capacity. At this moment, their most efficient traffic can be achieved by the filling station construction with continuous charging throughout the whole shift. Should hydrogen technology be more efficient in the future than a charging station, it could play a key role in the development of electromobility (when used in a fuel cell).

According to Martin Chovanec, hydrogen technology does not have sufficient support in the Czech Republic yet, such as in neighbouring Germany, which is today the leader in the development of hydrogen mobility. There have to exist conditions which would make „hydrogen“ competitive with other means so that hydrogen technology can be used in the transport in the future.

Technology must be available, that means it will not be a problem to build a station, get a source, and buy vehicles, ideally from multiple manufacturers. The necessary condition, for the manufacturers to get involved in larger scale, is the existence of energy concept that supports hydrogen propulsion and long-term sustainable development. In addition, Martin Chovanec adds that someone has to pay for the development of new technology. Either the price will thus be transferred to the first user (but this will decrease interest in the hydrogen technology) or the state will have to offer some kind of support.

According to Martin Chovanec, zero-emissions, inexhaustibility of the resource for its production, possible operating cost savings in the future in public transport and also other vehicles operating in the same location, belong among the main advantages of the hydrogen technology in transport. Furthermore, it may also represent the way how the Czech Republic can meet its emission obligations towards the EU. Martin Chovanec sees the risks in tax policy as part of the energy policy, or that legislation does not support the emergence of a market, which would include both the production of vehicles and the production of filling stations.

5.3.4.2 Tomáš Jílek

Table 39: Tomáš Jílek

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Tomáš Jílek	Member of the Supervisory Board, ICT Operator	Prague city

Record of the in-depth interview

According to Tomáš Jílek, Prague is open to alternative mobility. The strong line is currently represented by Smart City, which emphasizes the strengthening of the complexity, efficiency and sustainability of all aspects of urban development in particular through economic, social and technological innovations.

Electromobility is only a transitional stage, it represents intermediate stage to hydrogen mobility. At present, hydrogen is where electromobility was ten years ago, but in five years it is likely to be in a state in which electromobility is now. Hydrogen cars are autonomous, they have very low noise and carbon footprint, and at same time when compared to electric cars, the driving distance is extended. Hydrogen represents quite cheap fuel to be produced. The thing that is missing currently is the distribution network, thus it is necessary to build hydrogen filling stations, for example near chemical plant (Litvínov) or to import it collaterally (for example, Linde), however it no longer makes sense to import classical vehicles since there is still some emission footprint.

I think that in ten years there will be a ban on the usage of fossil fuels in cars and as a result they will be replaced by electric cars. At the same time, Škoda will produce 25 % of electric vehicles/hybrids. The necessary steps for the hydrogen mobility to develop are as follows: sufficient amount of hydrogen cars (broad spectrum); sufficient infrastructure coverage; use of hydrogen as a standard variant at the current gas stations, introduction of a tax restriction on fossil fuels, possible restriction of the production of conventional fossil fuel engines, and introducing tax incentives for alternative fuels. Eventually, there could be benefits in the legislation area for the hydrogen car users in the form of a free parking or the use of reserved lanes for buses. Furthermore, there could be direct subsidies for the distribution networks and infrastructure. It should be also known that hydrogen does not represent competition to electromobility as it itself also uses the fuel cells that produce electricity, however, in contrast to electromobility, it does not have to have heavy and expensive storage. Power per kilo is always clearly positive for hydrogen.

Tomáš Jílek states that there is not any significant progress and approach abroad in terms of hydrogen mobility as everything is quite at its beginning. He considers the biggest risks for hydrogen mobility to be safety but in terms how the public and authorities perceive safety since nobody knows hydrogen as such. Certainly, better platform for testing hydrogen in cities represents public transport, taxi or car sharing.

5.3.5 Cities

5.3.5.1 Věra Palkovská

Table 40: Record of the interview: Věra Palkovská

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Věra Palkovská	Mayor of the city	Třinec city

Record of in-depth interview

According to Věra Palkovská hydrogen mobility will not be separated from electromobility. Both are going to coexist simultaneously within the hydrogen mobility trend. Currently, electric bicycles, scooters and cars will be used, mainly in cooperation with ČEZ (there is ongoing negotiation with Tomáš Chmelík, the head of clean technologies). In addition, they are going to be complemented with, for example hydrogen cars from Toyota (there is also ongoing negotiation with the Toyota representatives).

Compared to electromobility, hydrogen is a step further. At present, people are getting used to electric cars (it took almost two years for these cars to be taken seriously). Hydrogen is something new now, you need to give it a time and you cannot expect that it will be quickly accepted by the public.

There are also specific risks related to the introduction of hydrogen. It is necessary to look at the concept in a long-term horizon. Short-term solutions are not the way to cope with the situation. For the time being, people are rather afraid of hydrogen and are careful since they are not equipped with enough information. The town of Třinec offers the opportunity to be a "showcase" for hydrogen technology testing, it represents a suitable place for pilot operation. It is however not possible to use financing from the city budget and some forms of donations are required. Třinec offers its time and capacity as it would like to cooperate on the development of clean mobility and all of its alternatives, thus also on the hydrogen mobility development.

According to Věra Palkovská, a rational legislative support, which would support both electromobility and other clean sources, is a prerequisite for the development of hydrogen. This support, however, has to be sustainable for a long time, there has to be clearly defined framework for new propulsions and alternative technologies in transport. Třinec is willing to join the hydrogen development strategy, however it sees the need of conceptual support from the state, and it cannot solely rely on the political will that changes with every election. Eventual support must focus not only on the cars but also on the overall infrastructure. It is essential to overcome the initial turning point when the perception of hydrogen mobility changes and flips into a viable model.

As for the predictability of hydrogen utilization in ten years, Věra Palkovská proposes the existence of a clean mobility test centre in a particular region, e.g. in the Moravian-Silesian region, which is burdened with high emissions. The aim is to own a fleet of hydrogen cars and buses in order to be able to provide it to the cities.

5.3.6 Investors

5.3.6.1 Aleš Barabas

Table 41: Record of the interview: Aleš Barabas

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Aleš Barabas	Member of the Board	UniCredit Bank

Record of the in-depth interview

According to Aleš Barabas, UniCredit Bank is a major automotive industry in UCB, mainly in the CEE region, Italy and Russia. Germany is in this respect significantly ahead. UniCredit Bank is neutral towards hydrogen itself, as to any other alternative fuel, even if there can be seen clearly intensive development of electromobility. Strong PR is required so that hydrogen can continue its development. Such strong PR would be directed towards majority of the population and mainly to the richer ones who will consider it as a trendy thing. In general, hydrogen needs to be solved globally. Local approach is a good bonus, but if there is no global support (car market is a global market), the emergence of hydrogen cars is going to take longer.

In the case of state support, we cannot expect change in the UCB´s approach, it will still remain as one of the types of automotive. What is far more important in this industry, is the production of components. In the event of a change of the drive (hydrogen, electro, etc.), the supply of components for the car as such will not change significantly. This will thus not mean any major change for UCB.

Aleš Barabáš perceives positively the possibility of car sharing which is already developing abroad (more significantly than in the Czech Republic). This would reduce the total number of cars in cities, which would have a positive impact on transport emissions.

But it would mean material impacts on lending and risk perception of the sector from the point of view of banks.

5.3.6.2 Karel Mourek

Table 42: Record of the interview: Karel Mourek

Respondent´s characteristics		
Respondent	**Position**	**Organization**
Karel Mourek	Member of the Board	Česká spořitelna

Record of the in-depth interview

According to Karel Mourek, the question of the applicability of hydrogen in transport is not crucial, as a member of the Board of Directors of Česká spořitelna, it is rather a question of mobility as such, it is not only about hydrogen as an alternative drive type. The biggest leader in hydrogen mobility is undoubtedly Germany and will represent the major leading force of the entire region. He feels that hydrogen in transport is significantly less safe when compared to other alternative fuels.

Česká spořitelna has financed the petrochemical industry, car manufacturers and final customers on a large scale and it is unlikely that this scheme will change. Česká spořitelna does not have a specific policy on hydrogen, but it deals with a "responsible policy", i.e. an environment that includes, among others, hydrogen. At the same time, however, like any other investment, it must meet the risk analysis. He sees in the outlook that it is possible that, for example, one station will have to be at least for hydrogen cars and one for an electric car. If the state is going to support clean mobility, it is going to set up clearly specified rules and the return on investment will be certain, the potential risks will be analysed, Česká spořitelna is going to have positive approach and it will not stay in the way of this sector´s development.

6 Modelling

The European Union sets European-wide targets in its sustainable development strategy. This study is based on the assumption that these objectives will be fulfilled by the joint force of all member states. These strategic goals also include objectives contained in the White Paper, entitled "Roadmap to a Single European Transport Area" - creating a competitive, resource efficient transport system. In this White Paper, the European Commission has adopted a plan of 40 concrete steps to create a competitive transport system that aims to increase mobility, remove barriers in key areas, tackle the issue of increased energy (fuel) demands of today's society and increase employment. The current White Paper focuses on decreasing Europe´s dependence on the supply of crude oil and also on the significant decrease in greenhouse gas emissions, mainly the emissions of carbon dioxide (CO_2). The White Paper primarily sets goals for the year 2050, however, it also includes short-term partial goals so that it is more probable that the long-term ones will be reached. Among the main goals belong the decrease of CO_2 emissions by 20% by the year 2030 when compared to the year 2008 and there should be also subsequent decrease of the emissions by 70 % by the year 2050 at the European level. Lower emissions should be achieved primarily through the use of alternative fuels (CNG, electricity and hydrogen) as compared to conventional fuels today. Another key objective is to reduce the use of conventional cars in urban transport by half by the year 2030 and to completely remove them from operation by 2050 and replace them with alternative propulsions.

The conducted model aims to predict the likely development of the number of hydrogen cars on the Czech market, the development of the hydrogen filling station infrastructure, the differential cost of supporting the hydrogen industry for the required development in individual scenarios, and the savings from using hydrogen cars instead of conventional ones. Everything is modeled in the context of applying forms of support with varying degrees of impact and in the case of financial measures depending on the size of the subsidy. Four scenarios are forecasted according to the extent of defined measures.

Model is based on the principle that member states of the European Union contribute evenly to the decrease of CO_2 emissions and thus even the Czech Republic sets out the abovementioned quantitative goals as its own and from these mainly the short-term ones that should be reached till 2030. As these targets are addressed for transport as a whole, it is necessary to predict the likely development of all transport categories, including even those in which hydrogen propulsion is not yet planned. For modeling purposes, the distribution is as follows:

- Individual car transport
- Public road passenger transport including buses for public transport
- Road freight transport
- Rail transport

- Ship transport
- Air transport

The model takes into account primary goals for the year 2030 which are represented by the decrease in CO_2 emissions by 20 % when compared to the year 2008 and partial replacement of conventional cars in public transport. The goal to reach the reduction in CO_2 emissions by 70 % by the year 2050 in comparison with the year 2008 seems to be optimistic right now, also due to the lack of partial, yet unspecified, strategies to reduce CO_2 emissions. The model does not intend to achieve this goal, but a trend similar to 2030 is contemplated. On the other hand, complete transition on alternative fuels in public transport by the year 2050, is counted with. More detailed specifications are in chapter 6.2 Model assumptions.

The model is designed in such a way that emissions from all modes of transport are calculated first, where the use of hydrogen is not taken into account yet. Subsequently, emissions from public transport are calculated which are different in each scenario owing to number of conventional buses. The last step involves calculation which is derived from the total number of passenger cars. There is a forecast of the total number of cars, and there is a number of these cars which are conventional and which differ in each scenario. The specification of these scenarios and the number of conventional cars is then important for the specification of the number of cars with alternative propulsion (CNG, electricity, hydrogen). As a data base for the development of alternative fuel vehicles - CNG and electricity - the forecasts of the National Action Plan for Clean Mobility were used. Hydrogen is then added in order to meet the scenario specifics.

The model´s assumptions are based on assumption/the goals presented in the White Paper, National Action Plan of Clean Mobility, on the grounds of in-depth interviews and one expert group (professionals in a given field) and on the basis of expertise of Grant Thornton Advisory s.r.o. and the Ministry of Transport. Statistical data on emissions and number of cars come from publicly available data on the website of the Ministry of Transport.

6.1 Executive summary of modelling

Models are based on the assumption that the Czech Republic will engage itself in the reduction of CO_2 emissions as set out by the European Union in the White Paper´s strategic goals. The two main objectives are to reduce CO_2 emissions in transport by 20 % by the year 2030 as compared to 2008 and to use at least 50 % of cars powered by alternative fuels in urban transport by the year 2030. The goal is that all the cars in public transport should use alternative fuels by the year 2050. For the purpose of the financial model, these European Union objectives were interpreted as follows:

- Emission reduction by 20 % by 2030 when compared to 2008 situation on the Czech transport market.
- Buses in public transport use alternative fuels by 2030.
- Whole bus fleet is powered by alternative fuels by 2050.

Four scenarios are considered in the model, which indicate the extent to which the objectives of the White Paper are met. At the same time, only the ambitious one considers the fulfilment of 100 % of the goals. Other scenarios only approach its fulfilment. It should be noted that these scenarios only consider the impacts of CO_2 reductions in the case of the introduced strategy for hydrogen. In case of other forms of transport, currently known state strategies are counted with (e.g. NAP CM).

The assumption is that the usability and commercialization of hydrogen mobility will burst at the beginning of the twenties and the period of the greatest boom of hydrogen mobility will be between 2025 and 2035. The network of filling stations will be gradually extended, different forms of state support will be available (for more see chapter 8 Relevant forms of support) and the purchasing costs for buses and cars will be decreased.

The table below summarizes the information on the expected number of hydrogen cars in individual scenarios and years, including cumulative costs over a given period. Costs are built up by difference, i.e. as the difference between the acquisition of a hydrogen and a conventional car. These cumulative differential costs show the costs that should be spent in order to be comparable with current conventional cars for the potential buyers.

Scenario 1 represents the optimistic variation when the number of hydrogen cars is significantly higher than for other alternative fuels. At the same time, scenario 4 shows a situation where hydrogen will not be supported by any substantial form of support and will be evolving only under market conditions. Cumulative costs take into account inflation but are not discounted. At the same time, they include the cost of supporting passenger cars, buses and filling stations.

Table 43: The development in the number of hydrogen cars and cumulative support costs regarding different scenarios

Pcs/mil. CZK	2030		2050	
	Number of cars	Support costs	Number of cars	Support costs
Scenario 1	464,692	168,216	1,312,031	508,030
Scenario 2	232,827	85,624	659,520	271,872
Scenario 3	116,977	42,336	333,958	142,687
Scenario 4	3,359	1,980	8,544	4,629

6.2 Model´s assumptions

Four scenarios of possible hydrogen mobility development in the Czech Republic are observed in the model, they are based on potential development which is determined by different level of state support. Different support is reflected in different numbers of hydrogen cars and infrastructure penetration. In line with this, it also depends on the different extent to which the strategic plans regarding CO_2 emission reduction are fulfilled and are further mentioned in the assumptions.

Primary goals of the model are following strategic objectives:

- Reduction in CO_2 emissions in transport sector by 20 % by the year 2030 which means to get under the emission level in 2008 (the White Paper). The scenarios in the model differ in the extent to which they reach this goal.
- Meeting the 2050 target by reducing CO_2 emissions in the transport sector by 70 % as compared to 2008 (White Paper) by using existing programs, and by the use of hydrogen mobility is unlikely to be the case, therefore, continuation of the same trend of development after year 2030 is contemplated (the same trend as between years 2020-2030).

- Reduce the use of conventional cars in urban transport by half in 2030 and substitute them by alternative fuel cars by 2050 (White Paper). The goal is set in the model for public transport including public buses. CNG, electricity and hydrogen are thought of as alternative fuels for public transport. In all scenarios, the goal is estimated to be met, but with a different mix of alternative fuel cars.

It is also necessary to predict other transport sectors where hydrogen usability is not planned yet (road freight transport, rail freight transport, ship and air transport) for the purpose of forecasting the development of CO_2 emissions. Following assumptions are taken into account in order to predict the CO_2 emission development:

- CO_2 emissions in maritime freight transport should be reduced by 40 % by the year 2050 as compared to the year 2005 (the White Paper). We also suppose that emission from ship transport will be reduced by 40 %, however it will not have big impact on the total amount of emissions from transport since ship transport is not that used in the Czech Republic.
- Air transport usability could be doubled by the year 2050, however air transport should become a pioneer in the use of low-carbon fuels. Due to the fact that we see the decreasing trend of CO_2 emissions in the last ten years in air transport, we are thinking of unchanged CO_2 emissions in the future in comparison with 2005.
- The CO_2 emissions produced in rail transport are negligible (electric traction) thus unchanged amount is planned in the future.
- Based on the White Paper, 50 % of freight transport above 300 km should be transferred to rail or ship transport (in the Czech Republic, only rail transport is considered). It is assumed that 25 % of freight transport is above 300 km. Moreover, the use of alternative fuels in freight transport is not considered (in particular hydrogen, as it is at its early phase of testing its use in freight transport and there is uncertainty of its actual prediction) which could have significant effect on CO_2 emission savings. In the model, it is estimated that the total mileage and the number of trucks will slightly increase over time.

Emissions are calculated at the level of emissions produced during the operation of the car, i.e. no emissions are taken into account which are generated in the car production and in the fuel production. Emissions are measured based on average annual emissions per one car. For the future, it is mostly counted with a slight decrease in average emissions, on the other hand, the increase in traffic (total mileage and number of cars) in individual segments is expected. Other assumptions regarding emissions include:

- CNG cars produce 75 % of CO_2 emissions in contrast to conventional passenger cars (NAP CM).
- Hydrogen cars and electric cars are considered as non-emission ones.
- CNG buses are less effective than passenger CNG cars and they produce comparable amount of CO_2 as conventional buses. However, thanks to new technological advances and CNG production capabilities, buses could also get to lower emission levels than conventional buses. It is counted with the reduction in emissions by 25 % as compared to conventional buses.
- Following development is estimated in the model in given transport sectors:
  - Public transport – total mileage and public transport cars will increase by 25 % by 2050 when compared to the state in 2010.

    - Passenger transport – total mileage and the number of passenger cars will increase by 15 % by 2050 when compared to state in 2010.
- The plan for the development of electric cars and CNG cars was taken from the NAP CM. The plan for the development of the number of CNG cars is a moderately optimistic option.

Other assumptions had to be set in order to meet the objectives of the model:

- It is considered that hydrogen cars will start to travel publicly and appropriate network of hydrogen filling stations will be built for them from 2020.
- The average price of a conventional car that the consumer would choose to purchase a hydrogen car is set at CZK 600,000. The average consumption of a conventional car is set at 5.5 liters and the conventional fuel price is currently at CZK 30.
- The model calculates the current price of a hydrogen car at the level of CZK 1,200,000. (The current price of Toyota Mirai), and it is estimated that the price of hydrogen car will be reduced to 800,000 by 2030. And by 2050 to CZK 600,000. This means that a hydrogen car could be similar to a similar conventional car in 2050.
- The hydrogen car's consumption is set at 0.7 kg/100 km (consumption of Mirai Toyota). The price of hydrogen is around CZK 216/kg. In fact, price of hydrogen could reduce to CZK 189/kg by 2030 and by 2050 to CZK 179/kg (NAP CM).
- Currently, conventional bus costs CZK 12 million. It is expected to rise with inflation in the future. Average bus consumption is 30 l/100 km.
- The price of a hydrogen bus is currently estimated at CZK 17.5 million and by 2030 it could actually fall to CZK 13.5 million and by 2050 by CZK 20 million. The consumption of hydrogen bus is estimated at 8 kg/100 km.
- The life of a hydrogen car and bus is assumed to be 8 years due to the moral obsolescence of a hydrogen car. The amount needed for people to consider purchasing hydrogen car instead of a conventional car is equal to the sum of the differences in acquisition costs and operating costs. The difference in operating costs is the difference in fuel costs over the service life of the hydrogen car.
- The number of hydrogen filling stations in the first years of introducing hydrogen cars is determined individually for each scenario. Otherwise, the number of filling stations is evolving with the number of hydrogen cars. Moreover, it is set that for 1,000 hydrogen cars, there is one hydrogen filling station. After reaching the number of 500 filling stations, growth will drop and further 5,000 cars are expected per one filling station.
- The price for hydrogen filling station construction is estimated to be CZK 27 million and is constant in time.
- The inflation rate is estimated according to CNB´s forecast till the year 2018. It is expected to rise at a level of target inflation 2 % for other years.

6.3 Description of 4 potential scenarios

There are 4 different scenarios of hydrogen mobility development included in the model which are based on the frequency of used defined measures, more specifically on the usage of defined forms of support. Detailed specification of the forms of support for each scenario can be found in chapter 7 Relevant form of support. Scenarios differ in the number of cars powered by alternative fuels in public transport. It is expected that half of the car fleet will use alternative fuels in 2030. The difference is thus in the composition of the cars. The most optimistic scenario called „Ambitious scenario" prefers hydrogen cars to CNG and electric buses while the least optimistic scenario called „Business As Usual" does not count with significant use of hydrogen cars in the public transport. The goal for 2050 is followed in a similar fashion, when the entire fleet is expected to use alternative fuels in public transport.

Shares of alternative fuel cars are determined by the best judgment of Grant Thornton Advisory s.r.o. together with the Ministry of Transport. The share of CNG buses stays constant in the model. In 2030, this share should be 40 % between alternative fuel buses in all variants, which means that this share will be really significant among the means run on alternative fuels. The reason is that CNG buses have the biggest share among buses on alternative fuels and this trend is expected to continue, even though their role is going to be gradually complemented by electricity or hydrogen. CNG buses do not currently represent a significant reduction in CO_2 emissions as compared to conventional buses and for this reason the share of CNG buses as compared to all alternative fuel cars will fall and in 2050 it is expected that in all variants the CNG busses share will be at 10 % level of all alternative buses. Scenarios further differ in the extent to which the goals of total emission reduction by 2030 are met. Trends of development up to 2030 are then used with certain extent of saturation towards the year 2050. There is therefore no observation of any fulfilled goal by 2050.

- **Scenario 1 – „Ambitious scenario"** represents the most optimistic scenario in which all important supports will be provided. These forms of support should fully compensate for the higher price of hydrogen cars as compared to conventional cars. Following CNG, hydrogen and electric bus shares are taken into account in scenario 1: 40 %, 40 % and 20 % in 2030 and 10 %, 60 %, 30 % in 2050. Scenario 1 foresees that the 2030 emission reduction target of 20% by 2030 will be fully achieved in 2030 as compared to 2008.
- **Scenario 2 – „Progressive scenario"** is a scenario in which hydrogen mobility is taken as a comparable variant with electromobility, and thus, very intensive development is expected. As opposed to the scenario „Ambitious scenario", it has lower level of the amount spent on support but it still counts with considerable help from state. The division of CNG, hydrogen and electric buses in terms of buses on alternative fuels in this scenario is as follows: 40 %, 25 %, 35 % in 2030 and in 2050 approximately the same number of hydrogen and electric buses is expected on the Czech market, respectively they would represent 45 %. The overall emissions target in 2030 under otherwise unchanged circumstances is 90 %. This means that the total CO_2 emissions for Scenario 2 are reduced by 19 % as compared to 2008.
- **Scenario 3 – „Basic scenario"** presents hydrogen as an alternative to clean mobility. Forms of support are primarily intended to raise awareness and provide a positive insight into the use of hydrogen mobility in transport, and the threshold for the amount of support spent is again lower than in previous scenarios. It is expected that the hydrogen buses will be promoted more slowly and to a lesser extent than in the previous two scenarios and that in year 2030 they would create

10 % of buses on alternative fuels. Nevertheless, hydrogen in public transport should prove to be usable source of energy in this scenario and the share of buses on alternative fuels could rise to 30 % by the year 2050. In comparison to 2008, the development of passenger hydrogen cars is expected to lead to the reduction in CO_2 emissions by 17 %.

- **Scenario 4 – „Business as usual"** represents a variant based mainly on non-financial state support and almost zero public state financial support. The market counts with the employment of hydrogen buses in the public transport in terms of potential use and it could have 3 % share among the buses run on alternative fuels by 2030. However, electric buses will prove to be more efficient and thus hydrogen buses will be gradually removed from operation by 2030. The development in the number of passenger hydrogen cars will depend on the fans of these new technologies and on the supporters of hydrogen technologies. Hydrogen mobility is not expected to contribute significantly to reduction in CO_2 emissions in this scenario, and emissions will be reduced by only 16 % when compared to 2008 in connection with the NAP CM targets.

6.4 Description of outputs

All the model´s outputs are displayed in next chapter 7.5 Graphs and tables in graphical and table representation. These outputs include the development in the number of hydrogen cars, buses and filling stations in a given period, their cumulative support costs and CO_2, CO, NOx, solid particles and SO_2 emission savings owing to the use of hydrogen mobility rather than the use of conventional cars. Possible construction of filling stations is mapped in chapter 6.7 Prediction of the localisation of filling stations in time. Cumulative costs take into account inflation but they are not discounted thus they represent cumulated cash flows on support. The difference among purchasing costs in the first years of introduction is quite significant and especially at an early stage, the total cost of the support is driven by this difference in costs. In the course of time, however, this difference is decreasing and support costs are determined more or less by the volume of sales of hydrogen cars. For illustration, in 2020 it is assumed that this difference in the cost per passenger car and bus will be CZK 535 thousand, resp. CZK 5 million. However, with the development of technology and commercialization, these costs could be reduced quite rapidly as they could reach CZK 230 thousand for passenger cars, respectively CZK 2 million for buses in 2030. It is estimated that purchasing prices of hydrogen and conventional cars could even out more or less in 2050.

If the scenario „Business As Usual" will not be taken into account, which does not count with any significant state support, the development of other scenarios in the following years will be thus rather cautious and insufficient network of hydrogen filling stations will thus stay in the way to the greater expansion of hydrogen mobility. Hydrogen mobility should be concentrated in agglomerations or regions where the use of hydrogen in public transport is expected. Considerable growth of hydrogen cars is expected after 2025 mainly due to gradual implementation of state supports which are described more in chapter 8 Relevant forms of support for each scenario, greater network of filling stations and lower purchasing costs for hydrogen cars. It is expected that state will actively support hydrogen mobility till the year 2035 so that the awareness is increased, also positive outlook on hydrogen mobility is supported and contributes to greater expansion of the network of filling stations. This should accelerate commercialization and market preparation for further, more independent development. From 2035 on, it is assumed that the hydrogen mobility market will be sufficiently developed and thus it will further develop without the active involvement of the state, and only with the help of a mild form of support.

This trend is thus moderately slowed down but at the same time a continuous increase is expected due to declining cost differences.

6.5 Figures and tables

Figure 32: Development in the number of hydrogen cars

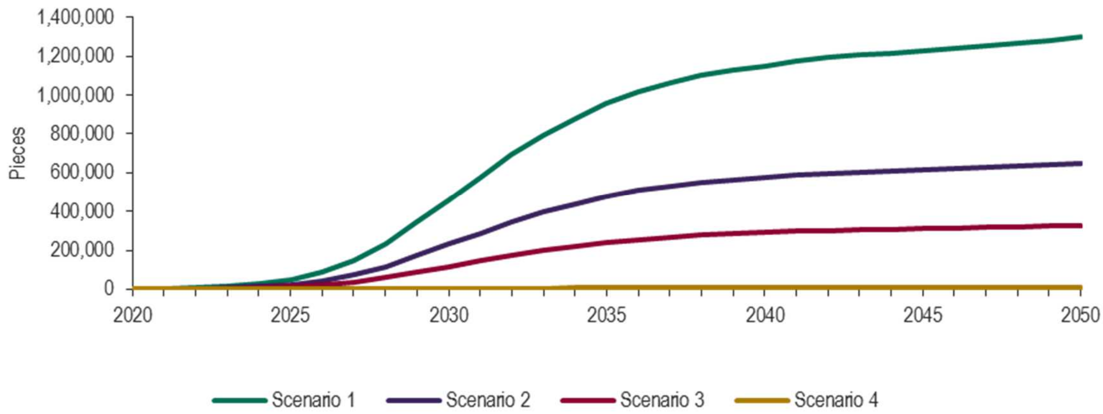


Table 44: Development in the number of hydrogen cars

Pcs	2020	2025	2030	2035	2040	2045	2050
Scenario 1	1,046	50,218	460,329	957,485	1,151,242	1,229,498	1,297,292
Scenario 2	523	25,102	230,101	478,609	575,461	614,578	648,465
Scenario 3	263	12,642	115,886	241,043	289,820	309,521	326,588
Scenario 4	7	331	3,032	6,306	7,583	8,098	8,544

Figure 33: Development in the number of hydrogen buses

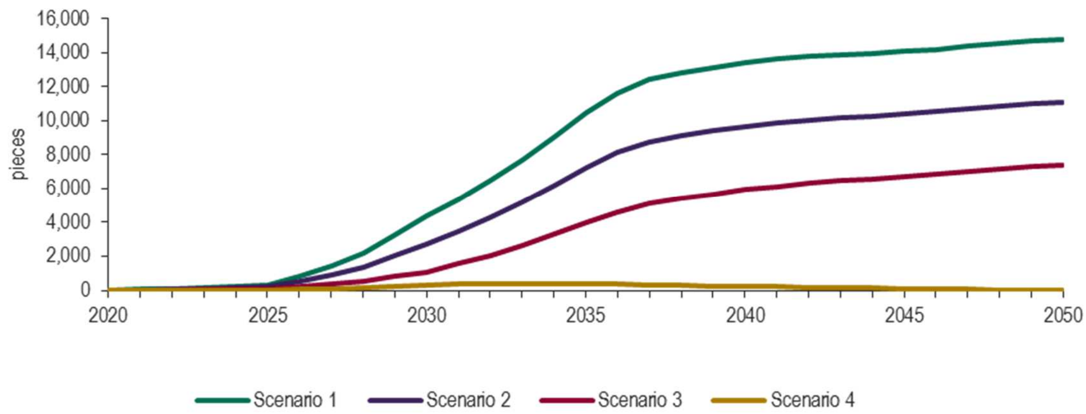


Table 45: Development in the number of hydrogen buses

Pcs	2020	2025	2030	2035	2040	2045	2050
Scenario 1	10	309	4,362	10,435	13,371	13,967	14,740
Scenario 2	6	193	2,726	7,213	9,647	10,319	11,055
Scenario 3	2	77	1,091	3,991	5,922	6,670	7,370
Scenario 4	1	23	327	368	229	94	-

Figure 34: Development in the number of hydrogen filling stations

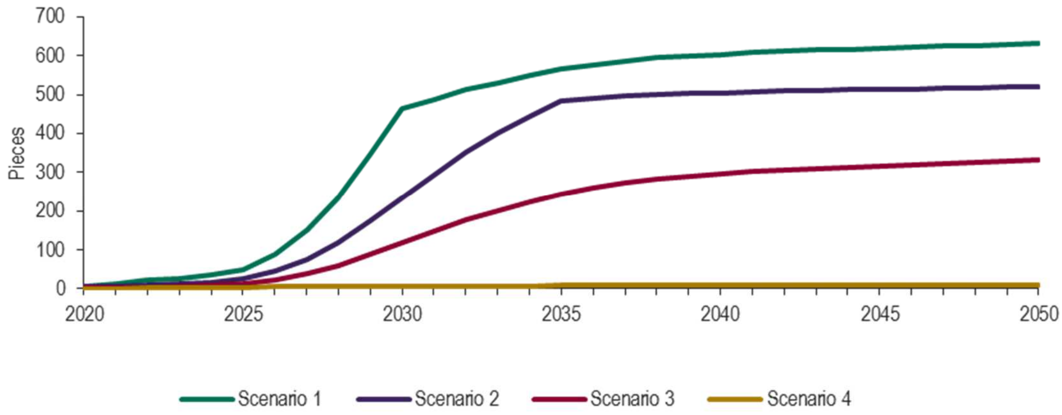


Table 46: Development in the number of hydrogen filling stations

Pcs	2020	2025	2030	2035	2040	2045	2050
Scenario 1	5	50	464	565	604	619	632
Scenario 2	5	26	233	485	505	514	521
Scenario 3	3	12	117	245	296	316	333
Scenario 4	1	4	5	8	8	8	8

Figure 35: Cumulative support costs - passenger car transport

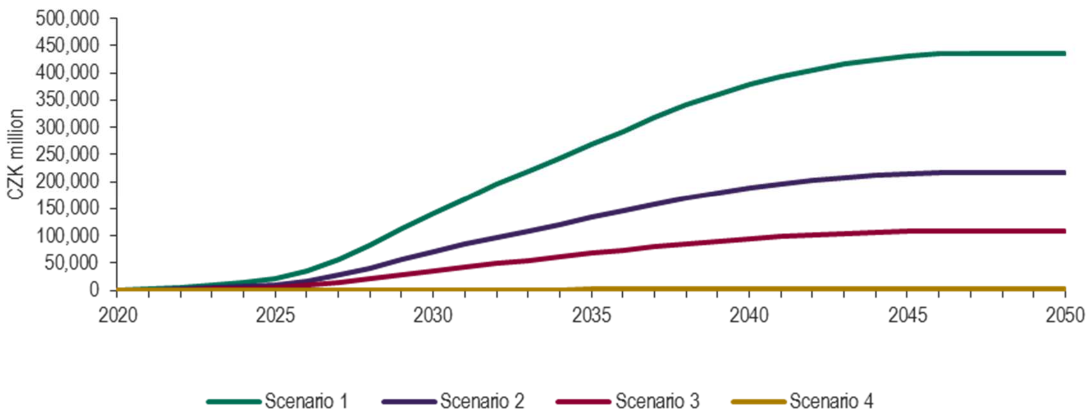


Table 47: Cumulative support costs - passenger car transport

mil. CZK	2020	2025	2030	2035	2040	2045	2050
Scenario 1	560	21,924	140,601	268,311	378,361	431,092	435,227
Scenario 2	280	10,959	70,281	134,118	189,128	215,486	217,553
Scenario 3	141	5,519	35,396	67,546	95,251	108,526	109,567
Scenario 4	4	144	926	1,767	2,492	2,839	2,867

Figure 36: Cumulative support costs – buses

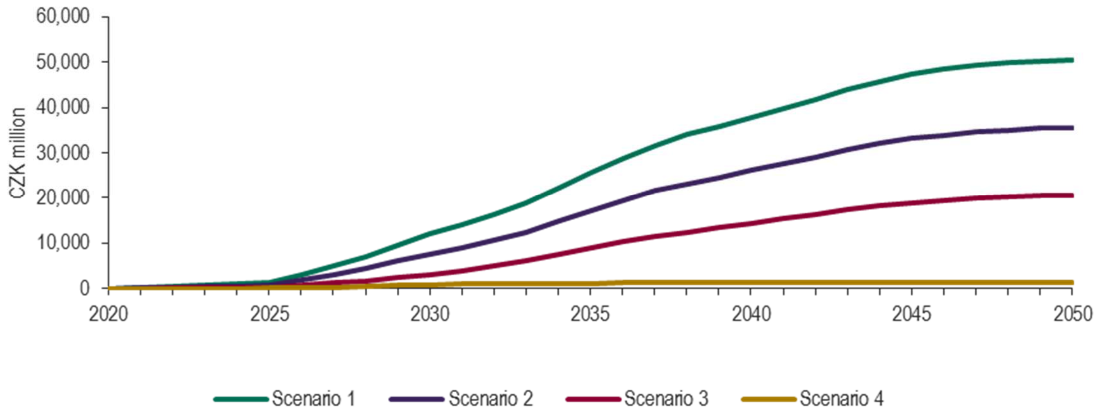


Table 48: Cumulative support costs – buses

mil. CZK	2020	2025	2030	2035	2040	2045	2050
Scenario 1	50	1,289	12,025	25,577	37,804	47,232	50,568
Scenario 2	31	806	7,515	17,254	26,091	33,062	35,598
Scenario 3	12	322	3,006	8,931	14,378	18,892	20,628
Scenario 4	4	97	902	1,157	1,396	1,476	1,496

Figure 37: Cumulative support costs – hydrogen filling stations

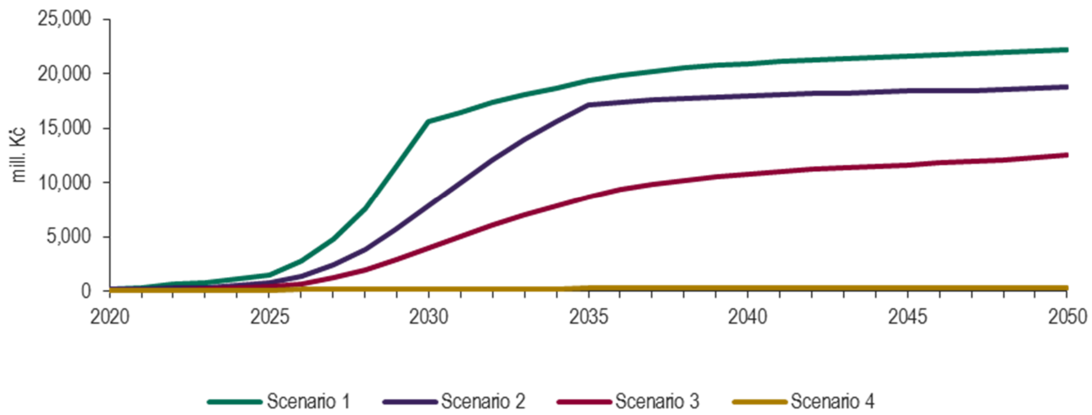


Table 49: Cumulative support costs – hydrogen filling stations

mil. CZK	2020	2025	2030	2035	2040	2045	2050
Scenario 1	144	1,521	15,590	19,326	20,910	21,585	22,236
Scenario 2	144	794	7,828	17,151	17,963	18,368	18,721
Scenario 3	86	367	3,935	8,672	10,743	11,641	12,492
Scenario 4	29	120	152	266	266	266	266

Figure 38: CO_2 emission saving using hydrogen cars instead of conventional cars

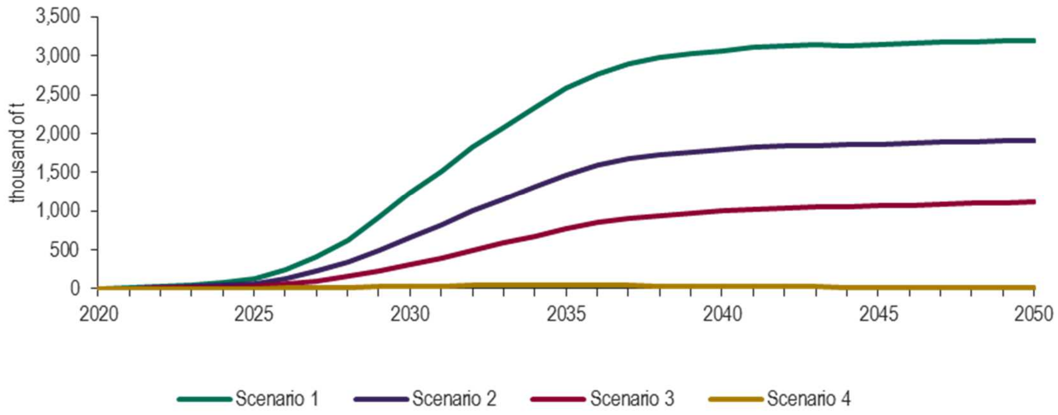


Table 50: CO_2 emission saving using hydrogen cars instead of conventional cars

ths. t.	2020	2025	2030	2035	2040	2045	2050
Scenario 1	3	123	1,227	2,583	3,070	3,139	3,199
Scenario 2	2	65	663	1,470	1,795	1,858	1,912
Scenario 3	1	31	308	772	998	1,063	1,116
Scenario 4	0	3	35	44	33	21	13

Figure 39: NOx emission saving using hydrogen cars instead of conventional cars

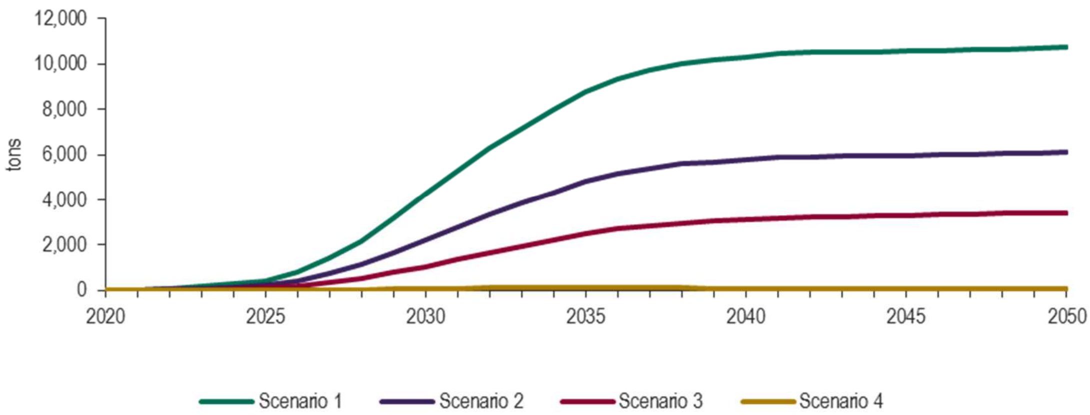


Table 51: NOx emission saving using hydrogen cars instead of conventional cars

t.	2020	2025	2030	2035	2040	2045	2050
Scenario 1	10	443	4,234	8,764	10,320	10,556	10,732
Scenario 2	5	230	2,234	4,805	5,775	5,957	6,102
Scenario 3	3	111	1,064	2,496	3,130	3,301	3,434
Scenario 4	0	8	92	121	97	70	51

Figure 40: Solid particles emission saving using hydrogen cars instead of conventional cars

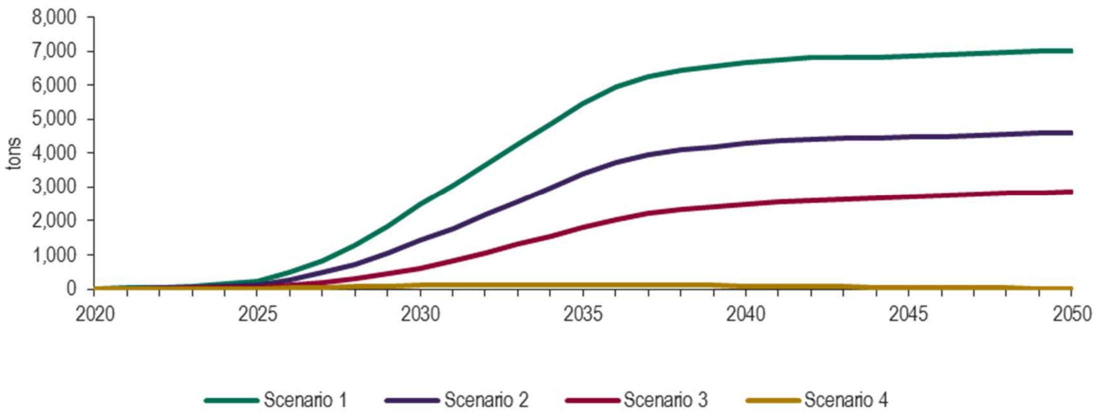


Table 52: Solid particles emission saving using hydrogen cars instead of conventional cars

t.	2020	2025	2030	2035	2040	2045	2050
Scenario 1	6	220	2,481	5,472	6,667	6,832	7,017
Scenario 2	3	123	1,426	3,393	4,279	4,448	4,613
Scenario 3	1	55	622	1,827	2,495	2,696	2,864
Scenario 4	0	9	118	135	89	46	17

Figure 41: SO_2 emission saving using hydrogen cars instead of conventional cars

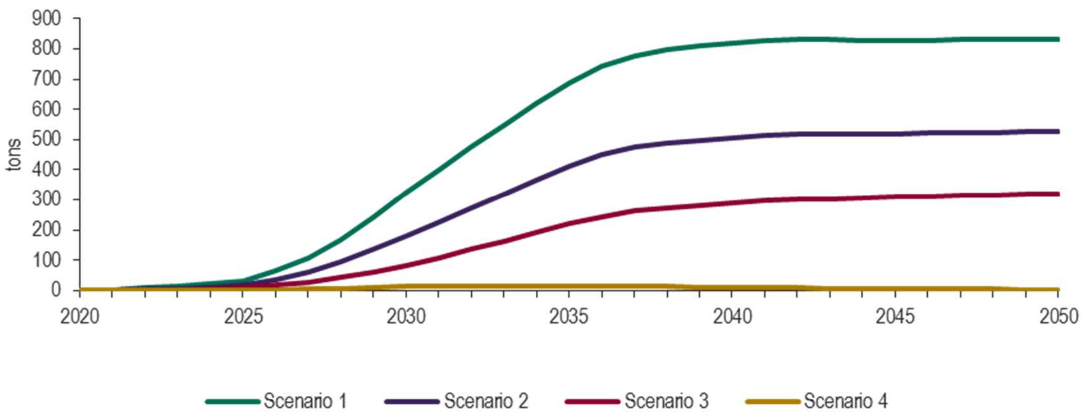


Table 53: SO_2 emission saving using hydrogen cars instead of conventional cars

t.	2020	2025	2030	2035	2040	2045	2050
Scenario 1	1	31	323	688	818	825	831
Scenario 2	0	17	181	413	506	517	526
Scenario 3	0	8	81	220	290	307	319
Scenario 4	0	1	13	15	10	5	3

6.6 Saved CO_2 emissions using hydrogen buses in public transportation instead of conventional buses

Investment into hydrogen buses seems to be a better option than investment into hydrogen passenger cars taking into consideration the ratio of saved emissions and realized expenses for the support of hydrogen vehicles. Based on the Basic scenario, approximately CZK 3 bn. would have to be expended by 2030 in order to support hydrogen buses which presents 8 % of total hydrogen vehicle expenses. Hydrogen buses should subsequently save 99,000 tons of CO_2 emissions in 2030, which would otherwise be produced by conventional buses. That presents 32 % of total saved CO_2 emissions using hydrogen vehicles. This ratio is further accented by the situation when public transportation compared to passenger car transportation doesn't need extensive network. Therefore, a smaller impact on the expenses of filling stations exists. Another impulsive factor is the fact that investment into hydrogen buses in public transport would occur mainly in the urban areas which would lead to effect of lower CO_2 emissions (and other polluting emissions and harmful substances) in key areas. Usage of hydrogen mobility therefore doesn't seem to be only a tool to encourage investment activity into hydrogen mobility but also is an effective way how to lower CO_2 emissions in urban areas. In other scenarios, similar ratios in expenses and avoided emissions occur.

Figure 42: Saved CO_2 emissions using hydrogen buses in public transportation instead of conventional buses

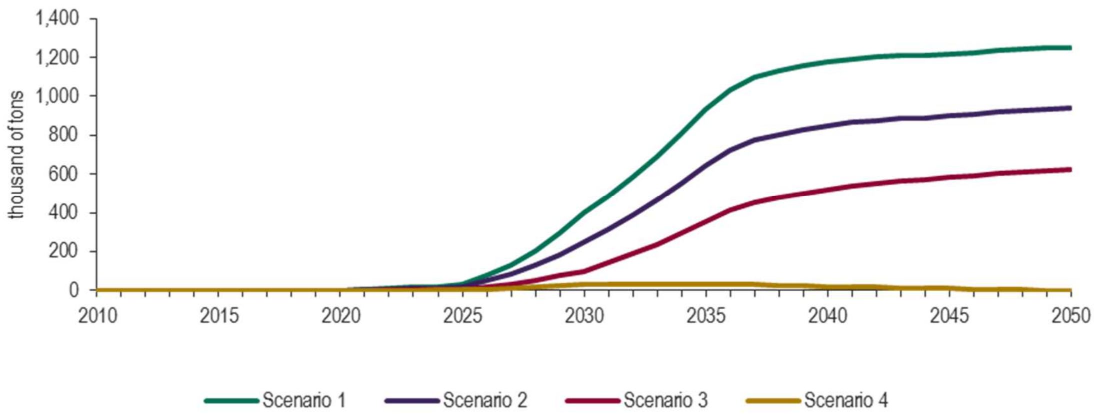


Table 54: Saved CO_2 emissions using hydrogen buses in public transportation instead of conventional buses

ths. t.	2020	2025	2030	2035	2040	2045	2050
Scenario 1	1	29	397	933	1,176	1,208	1,253
Scenario 2	1	18	248	645	848	892	940
Scenario 3	0	7	99	357	521	577	626
Scenario 4	0	2	30	33	20	8	-

6.7 Prediction of the localisation of filling stations in time

The development in the number of hydrogen filling stations differs in each scenario but the sequence of places where the planned construction takes place is the same in each scenario. Since the construction of the filling stations is fairly expensive and the utilization at the beginning of the 20th century is relatively low, filling stations are likely to be built in certain selected agglomerations, mainly in cities with public transport, where they can theoretically serve as a filling stations for both bus and passenger car transport (although no such sharing is accounted for in the conclusions). The cities suitable for this pilot phase could certainly include, for example Prague, Brno, Plzeň and Ostrava, potentially clusters of cities and municipalities that are suffering from high CO_2 emissions (North-west Bohemia, Moravian-Silesian region). After potentially successful pilot phase implementation and the subsequent increase in hydrogen mobility in the form of an increase in the number of hydrogen vehicles, we can expect its expansion on the main highway routes in the Czech Republic. These stations would connect the highway routes in the Czech Republic and simultaneously Germany and Austria, where the filling stations are currently already in operation and at the same time their further development is expected. These highways include motorways D1, D3, D5 and D8. Further expansion of the filling stations can be expected in other larger cities with public transport such as Liberec, Olomouc, Ústí nad Labem, Hradec Králové, České Budějovice, Pardubice, Zlín, Teplice, Most, Opava, Jihlava and Chomutov and to other highways. In the last phase, construction of filling stations is expected in other cities and other roads so that all routes in the Czech Republic and gradually the whole Czech Republic is covered.

6.7.1 Prediction of the filling stations construction in different scenarios relative to time

The following set of maps shows the potential construction of filling station in observed years, in particular for years 2025, 2030 and 2050 across all scenarios and in potential locations. Therefore, the given maps show the differences between the construction of stations in each scenario.

Chyba! Nenalezen zdroj odkazů. shows the filling station networks in 2025 for different scenarios with cumulative expenses used for their construction in the given year.

Figure 43: Prediction of the number of filling stations including accumulated expenses in 2025

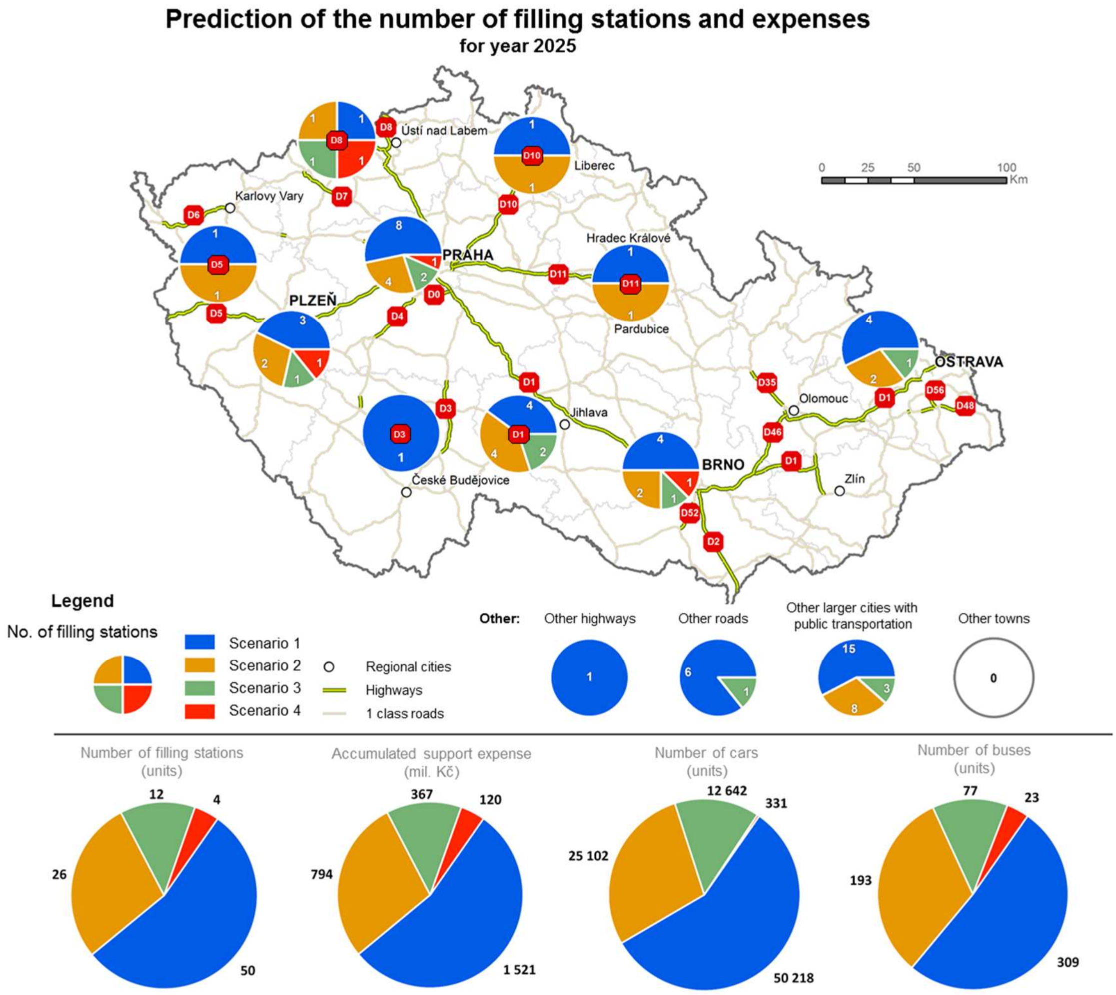


Figure 44 shows the filling station networks in 2030 for different scenarios with cumulative expenses used for their construction in the given year.

Figure 44: Prediction of the number of filling stations including accumulated expenses in 2030

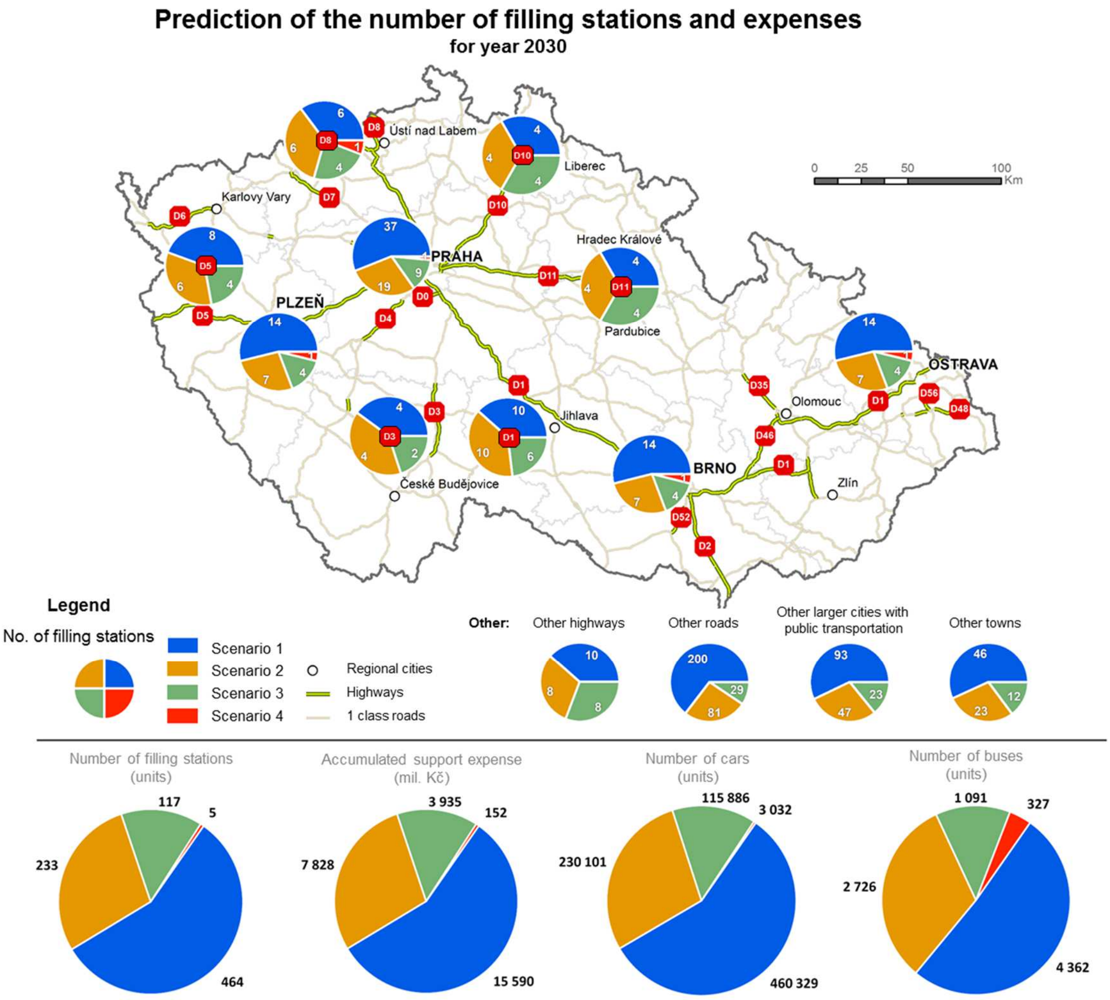
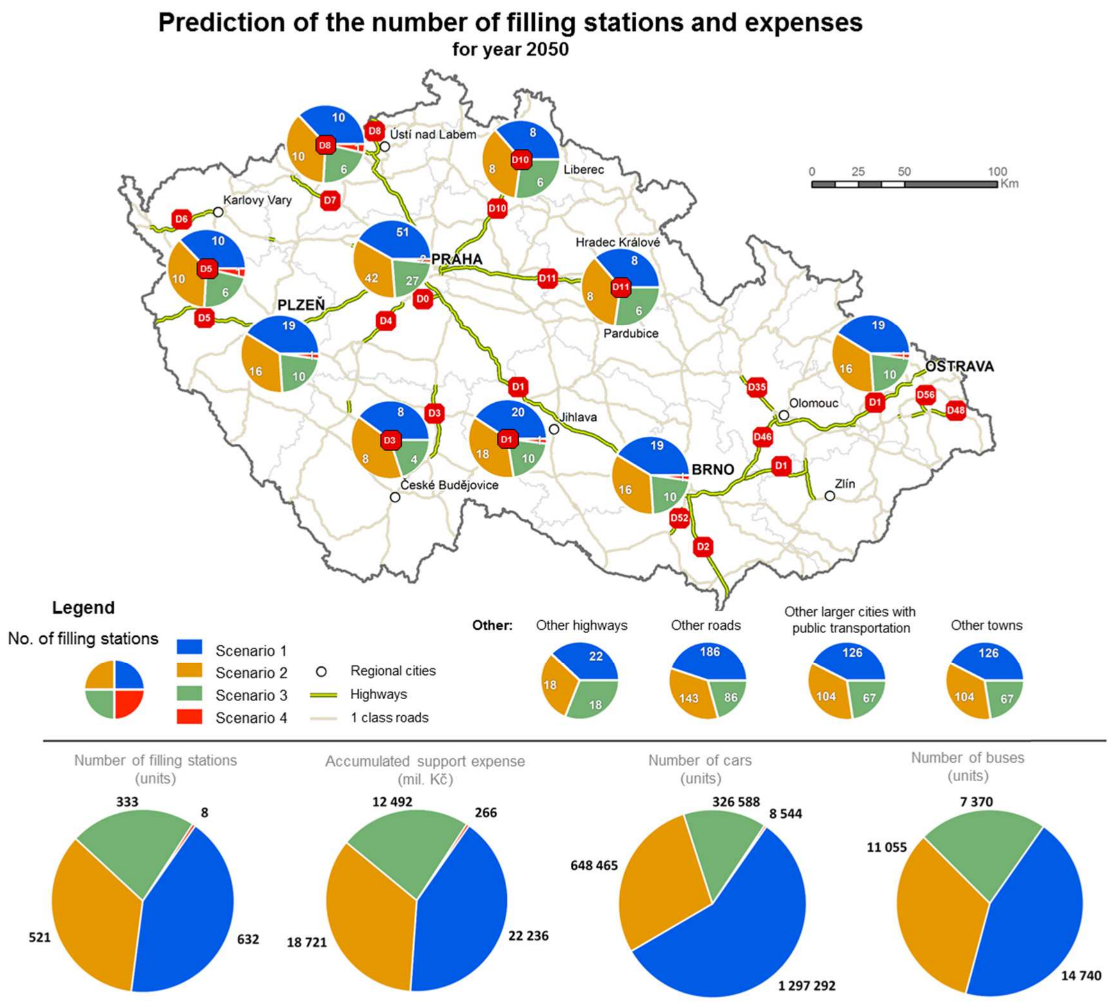


Figure 45 shows the filling station networks in 2050 for different scenarios with cumulative expenses used for their construction in the given year.

Figure 45: Prediction of the number of filling stations including accumulated expenses in 2050



6.7.2 Prediction of the filling stations construction in each scenario

The following set of maps shows the time perspective of the potential filling stations construction in each scenario. The values in the map show potential final state in 2050 and therefore it shows the cumulative values in given scenarios.

Figure 46 shows scenario 1 – „Ambitious scenario" and its development in years 2025, 2030 and 2050. Values in the map describe the final state of the number of filling stations in 2050.

Figure 46: Prediction of the number of filling stations within scenario 1

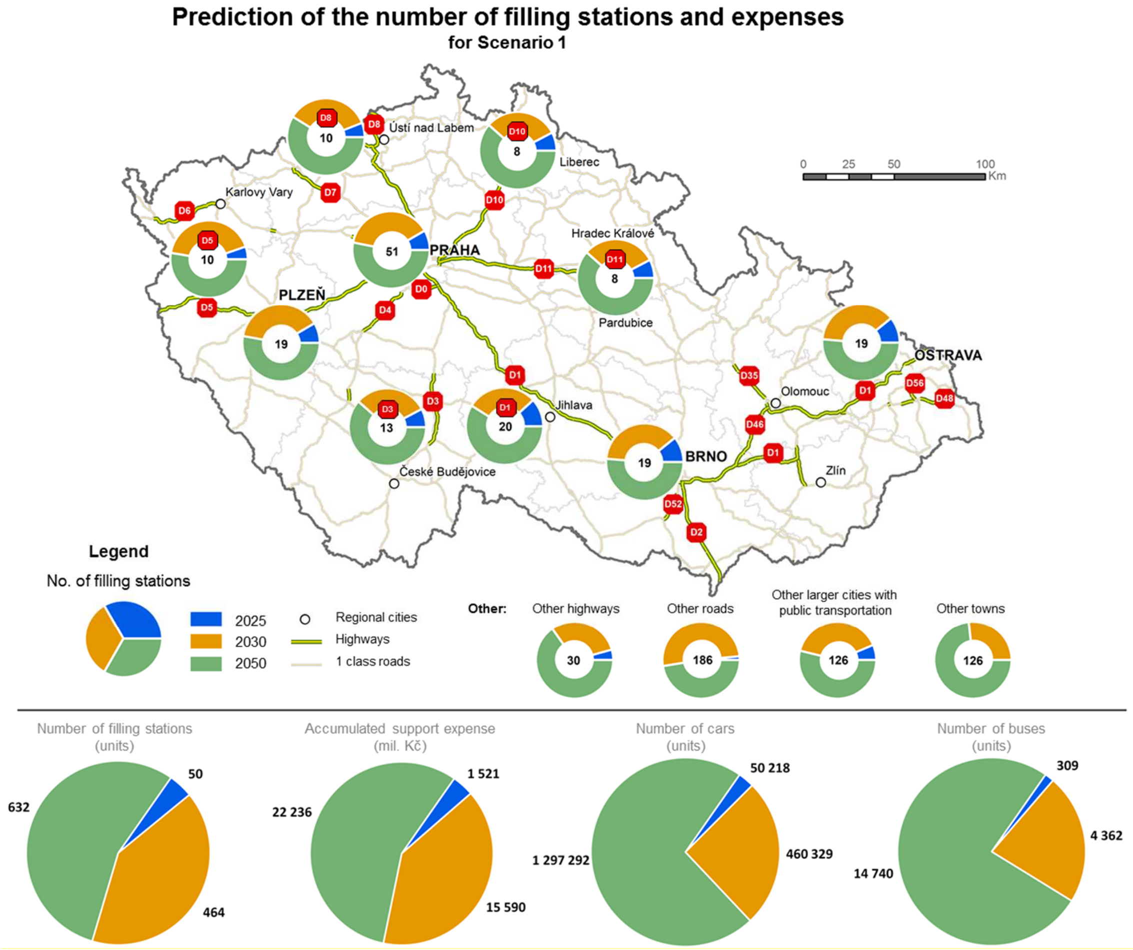


Figure 47 shows scenario 2 – „Progressive" and its development in years 2025, 2030 and 2050. Values in the map describe the final state of the number of filling stations in 2050.

Figure 47: Prediction of the number of filling stations within scenario 2

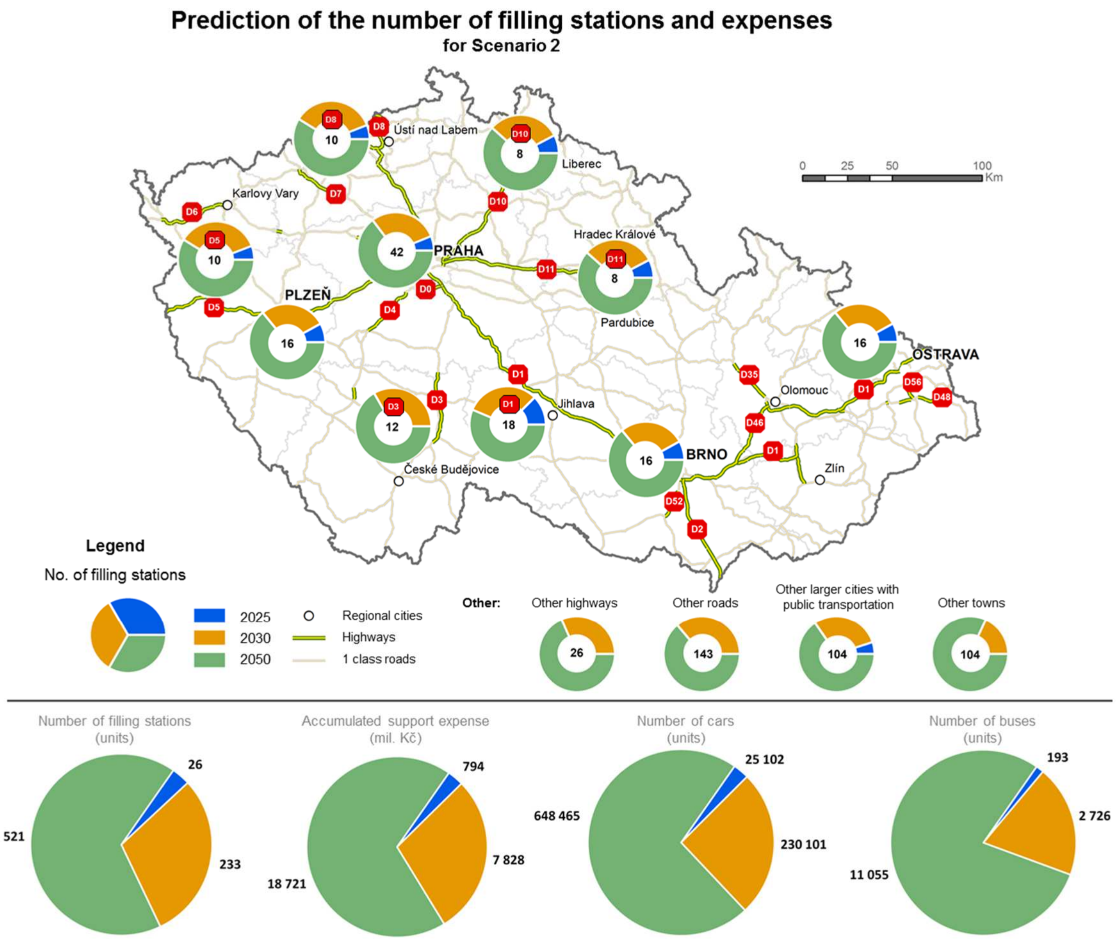


Figure 48 shows scenario 3 – „Basic scenario" and its development in years 2025, 2030 and 2050. Values in the map describe the final state of the number of filling stations in 2050.

Figure 48: Prediction of the number of filling stations within scenario 3

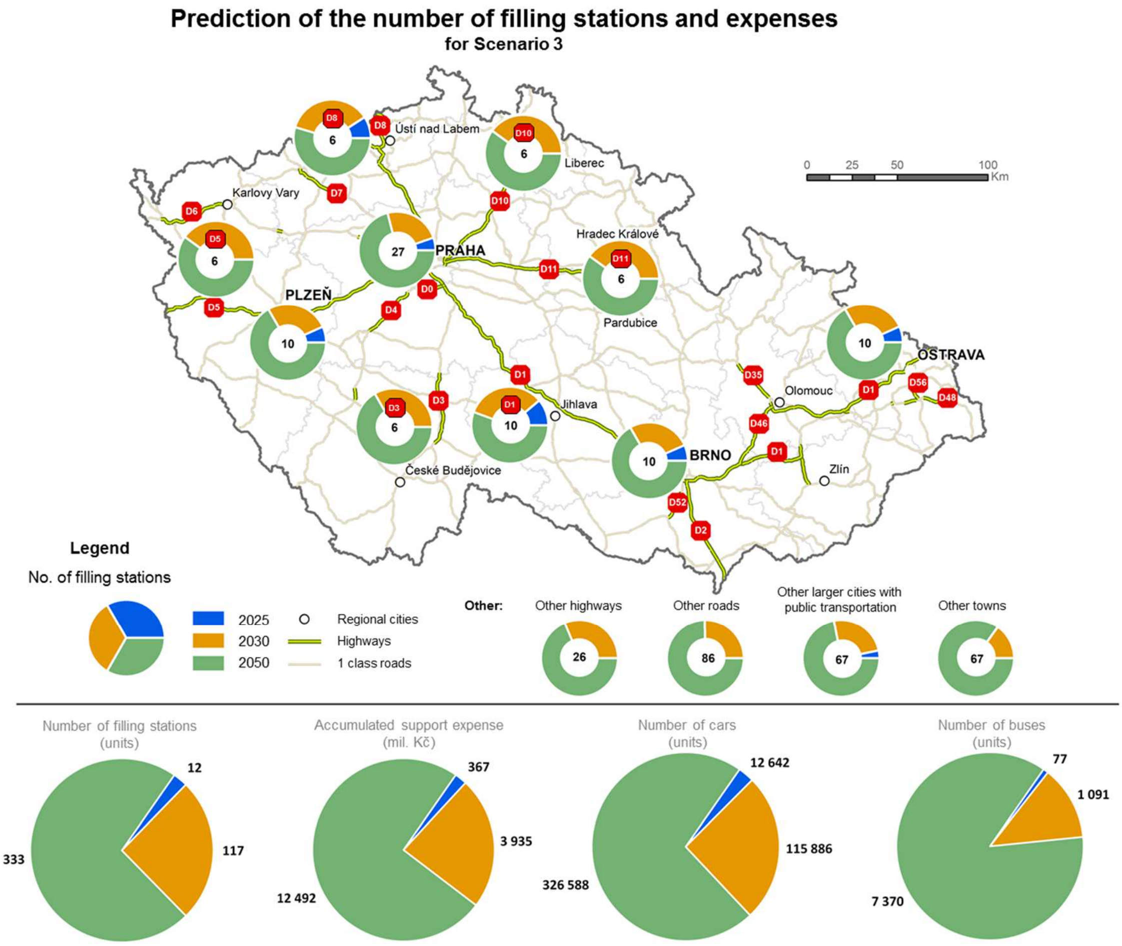
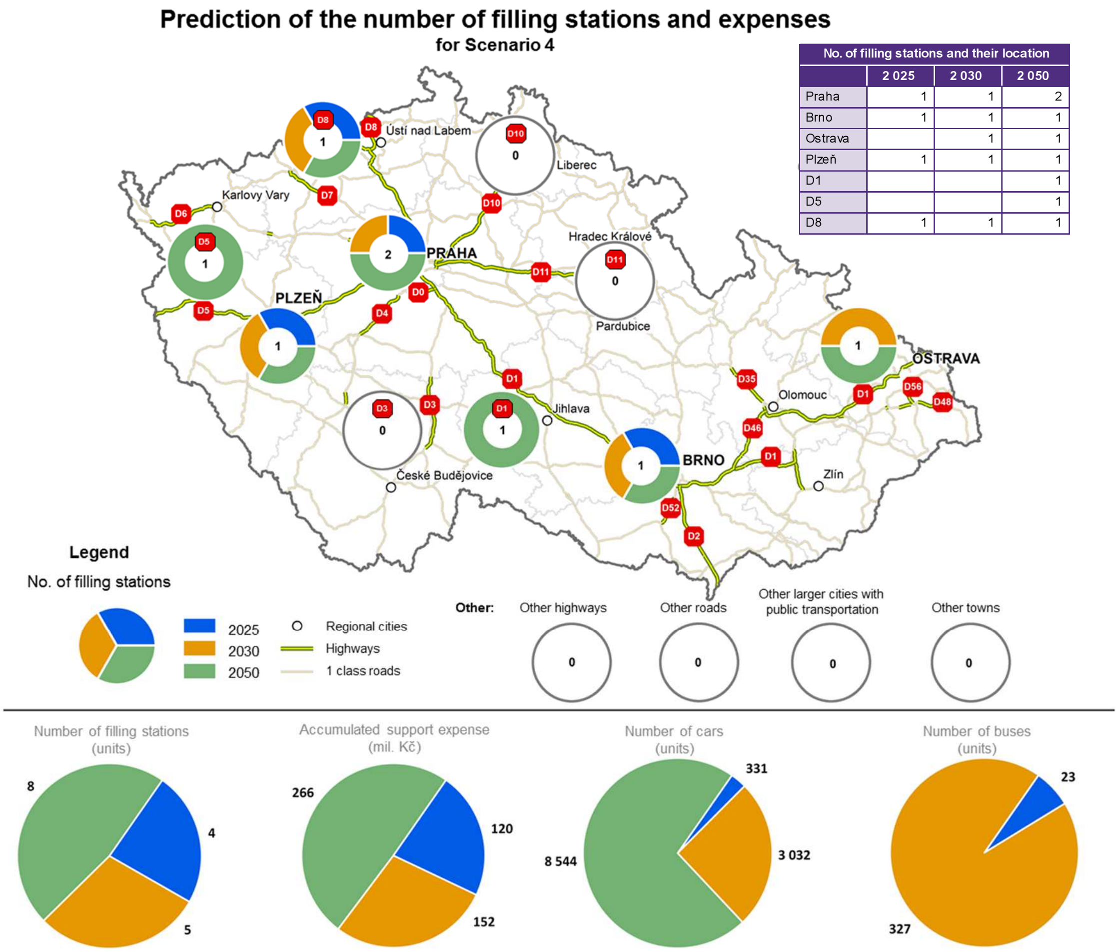


Figure 49 shows scenario 4 – „Business as usual" and its development in years 2025, 2030 and 2050. Values in the map describe the final state of the number of filling stations in 2050. Zero values mean that there won't be any filling stations constructed in given locations.

Figure 49: Prediction of the number of filling stations within scenario 4



No. of filling stations and their location	2 025	2 030	2 050
Praha	1	1	2
Brno	1	1	1
Ostrava		1	1
Plzeň	1	1	1
D1			1
D5			1
D8	1	1	1

7 Relevant forms of support

By joining the EU energy concept, the Czech Republic has announced its public support in reducing greenhouse gases in transport and using alternative fuels in this sector. As a standard, such support can be provided in the form of financial instruments (subsidies, incentives, contributions, interest-free financial tools, guarantees, etc.) and non-financial measures (legal regulations, technical restrictions, tax and fee discounts, etc.). It should be noted that this is not only a financial subsidy provided by the state but other forms of support are available, too.

The analysis of relevant forms of support seeks to define the scope of potential forms of public support, describe them and then makes a pilot assessment of the suitability and effectiveness of this support for the development of hydrogen technologies in the CR transport sector.

The pilot evaluation was made:

1. in terms of timing – estimated time priorities of addressing these issues in relation to steps taken in implementing hydrogen technology in transport
    a. as a priority - support which is the prerequisite for triggering the development of hydrogen technology
    b. in the medium term- supporting activities following up on the already implemented hydrogen technology platform and strengthening the public and private sector motivation to use hydrogen in transport. These activities are measures the efficiency of which will be experienced within five years, and no later than in 10 years. The medium-term measures will continue on their own after being "phased out" and will be generating the desirable activity without the need for further stimulus.
    c. in the long term - support taking effect after 10 or more years, focusing on areas of interest that are not static and require permanent improvement or which are significant and of investment nature. A typical example of this type of support is research and development of public support.
2. in terms of hydrogen technology benefits- we evaluate and describe the benefits encouraging the development of hydrogen technology, we compare the expected effects with potential defects and the level of technical readiness for using public support. Forms of support with the highest added value have been identified.

The following forms of public support can be allocated as applicable for the deployment and operation of hydrogen technology in transport:

1. Elimination of legal barriers
2. Formal support

3. R&D&I support (research, development and innovation) of hydrogen technologies
4. Support for building hydrogen powered vehicle infrastructure
5. Support for the purchase of hydrogen-powered vehicles
6. Financial and tax incentives

The next part of the document gives an overview of all forms of support, and provides a concise form of evaluated information. In addition, forms of support with the greatest added value for the development of hydrogen mobility are highlighted based on information collected so far from in-depth interviews and from international experience.

In addition, based on the definition of development scenarios, forms of support that can help implement the given scenario are outlined.

Hydrogen mobility must be viewed as part of clean mobility which includes electric mobility. All measures proposed in the study can be related to clean mobility, i.e. electricity as well as hydrogen. Some of the measures are already under preparation or even applied for electricity and therefore it is logical that they should also be related to hydrogen given their similar role in clean mobility.

7.1 Executive summary of the forms of support

The provision of public support is determined by political intentions, by methodologies governing EU structural funds and it is also influenced by the budget funds that can be allocated by the Czech central government and self-governments. Therefore, not all relevant public support measures can be used in parallel and it is necessary to define, at least in general, a public support "road map".

We propose prioritizing the following measures with respect to public support:

1. Eliminate legal barriers in order to legalize the "playing field" for the use of alternative hydrogen energy
2. Maximize the involvement of professional community in order to engage the entire private sector that will come up with effective and user-oriented solutions and potentially adopt solutions that will be considered justifiable and which will be financially supported (private sector involvement)
3. Generate financial support to build infrastructure, i.e. to support investment projects that have an impact on both the public transport as well as business-related and private transport
4. Provide continuous formal and non-financial incentives to operate hydrogen technologies in order to encourage the use of hydrogen technology in business or passenger transport.

We expect the application of other forms of public support after the preparatory phase - “hydrogen technology market entry“ - the individual forms of support must then be confirmed by the impact analysis and prioritized according to the status of implementation.

7.2 Elimination of legal barriers

Support in the form of eliminating formal barriers is a task related to legalizing the operation of hydrogen technology and related infrastructure. This activity must result in uniform (non-discriminatory) conditions for the use of vehicles and infrastructure (production, sales, filling stations) and, generally, for doing business in the field of hydrogen technologies such as combustion engine technologies, conventional and presently used alternative fuels.

Amendments or modifications of legal standards can thus be reflected in the fuel regulation, operation of filling stations, costs of acquisition and operating technologies (e.g. VAT) or other related legal restrictions (the Building Act, requirements for technical competence, etc.). During the preparation of the study, the fundamental legislation was amended. According to the main investors in this technology, the hydrogen "playing field" seems to be prepared adequately and further investments can be developed accordingly. Currently, there are certain uncertainties which are not of primary nature and which concern the Land-Use Planning Act No. 183/2006 Coll. (Building Act) as the arrangement results in slow approval-making of construction projects (changes to urban master plans, risk of contested building approvals at various stages, etc.)

Benefits:

1. Development of hydrogen filling stations.
2. Without direct financial impacts on the support, with minimum budget impacts.

Evaluation: this form of support consisting in the elimination of legal barriers is easily achievable over time (with the engagement of government bodies, and other stakeholders involved in drafting the law) with minimal resources allocated from the state budget. As indicated, most difficult points have been dealt with or have even been resolved. This activity is a prerequisite for the deployment of hydrogen mobility in the Czech economy. Subsequent utilisation of the benefits introduced by this measure must encourage the private or public sector to invest its own funds.

7.3 Formal support – non-financial

Formal support consists in the modification of related legislation so as to motivate and provide benefits to the users of hydrogen technology and those purchasing hydrogen-powered vehicle. Operation of such vehicles and "hydrogen" transport business should entail lower demands compared to the use of standard combustion engines , which is based on a risk assessment of hydrogen technologies. In particular, the following modifications should be motivating:

7.3.1 Hydrogen technology vehicle garage parking

Under MV Decree No. 268/2011 Coll., on the technical conditions of fire protection of buildings, it is necessary to review the fire risk associated with hydrogen-powered vehicle garage parking and to minimize the equipment needed for the relevant spaces so as not to restrict the vehicles entry to closed storage spaces, garages and similar spaces.

Benefits:

1. More accessible garage parking for hydrogen-powered vehicles.
2. Development of hydrogen mobility for parking in cities.

Negatives:

1. The review of fire risks and safety conditions for these facilities may result in increased efforts to review these criteria even in relation to natural gas fuelled or hybrid vehicles, which may slow down the entire implementation process.

Evaluation: Complications can occur when implementing the amendment to the Decree within the given time, which may be linked to reluctance of rescue services to ease off the stringent standards. Authorities need to be convinced that the vehicles are equipped with special fire safety technology and that there is no risk of gas explosion. On the other hand, financial expenditure should not pose a significant burden for the government budget.

7.3.2 Hydrogen-powered vehicle servicing

Bring the requirements and conditions for the repairs, maintenance, inspection, promotion and sale of hydrogen powered vehicles and requirements for the fire safety of buildings in spaces where these activities are carried out closer to the requirements and conditions applicable to vehicles with a standard internal combustion engine.

Benefits:

1. Specification of conditions for hydrogen-powered cars where simplification of operational requirements may result in greater attractiveness when making a vehicle type choice.
2. Facilitated car servicing and car dealer business related to increased service availability.

Negatives:

1. Unification of all necessary conditions for the deployment of hydrogen vehicles in normal operation does not necessarily generate funds for the implemented investments. It is necessary to ensure that, for example, the filling stations, the actual construction of which is very expensive, or a sufficiently dense network of service points, will really be established.

Evaluation: It is necessary to compile all necessary conditions related to maintenance, inspection and sale of these vehicles. This is realistic in the medium term, inspiration can be found for example, in the US model where a functional network for the operation and servicing of hydrogen vehicles is in place. Government budget expenditure related to this concept is negligible.

7.3.3 Use of roads, i.e. local roads

Modify the legislation that amends road traffic rules and road traffic control so that the lane reserved for buses and taxis can also be used by hydrogen-powered vehicles.

In relation to the competence of local governments is also possible to allow hydrogen-powered vehicles access to areas with restricted access for vehicles with internal combustion engines or provide other benefits, for example, reduced tolls (future bans on internal combustion engines in city centres, noise reduction requirements, etc.).

Benefits:

1. Greater attractiveness of hydrogen vehicles when driving in built-up areas with a risk of tailbacks during peak hours.
2. Preferential position given to hydrogen powered vehicles in road traffic positively stimulates the demand for these vehicles and at the same time increases public awareness of this technology.

3. It gives a signal to the public, which vehicles will have access to problematic (from the point of view of the environment) agglomerations or towns and municipalities in the future.

Negatives:

1. Modification of road traffic rules and traffic control related specifically and exclusively to hydrogen powered vehicles may give rise to criticism and requests for the same exemption from other entities using other alternative drives, which will potentially threaten the speed of amending the decree.
2. This draft may be subject to disagreement on the part of the road safety authorities whereby owners of hydrogen-powered vehicles may, due to their preferential status, be more inclined to risky and hazardous behaviour on the roads.

Evaluation: Amendment to the Decree or local regulations (if the government wishes to support the development of this type of vehicles) should be implemented without any significant complications because of the need to comply with the safety conditions for operating hydrogen vehicles on the roads. Nothing prevents from this type of stimulus thanks to the technical readiness in the transport sector. On the other hand, high level of lobbying for other alternative fuels can be expected. No significant government budget expenditure is expected.

7.3.4 Enabling parking in otherwise reserved parking places

Possibility of parking for owners of these vehicles in restricted access zones (e.g. blue zones in Prague). This is inspired by the current status and benefits provided to electric cars.

Benefits:

1. Guaranteed preferential position of hydrogen-powered vehicles implies increased public interest in these vehicles.

Negatives:

1. The approval of this proposal may again be delayed by negative reactions from the owners of other alternative fuel vehicles who might ask for the same advantage (now, for example, electric vehicles can park in Prague).
2. Reduced revenues of the zone operators (cities, municipalities) are expected.

Evaluation: The preferential parking option in restricted access zones may face resistance by other alternative drive vehicle owners (this would probably have to be introduced for other types of clean alternatives (electricity)) too, and there can also be reluctance of the cities to allocate parking spaces, specially designed for hydrogen-powered vehicles, from the already insufficient pool of parking places. However, the implementation itself should be feasible without any major expenditure. As regards the private sector, this may also become a non-financial bonus – more convenience.

7.4 Support for R&D&I for hydrogen technologies

The support of research, development and innovation is one of the major development activities that do not have a direct impact on the development of the market as such but they can serve to implement various pilot solutions related to this technology. Emphasis is placed here primarily on the development of pilot projects followed by research work conducted at universities.

7.4.1 Support for research, development and innovation for hydrogen technologies

Public support contributes to deepening co-operation between universities, research institutes and business entities in the field of hydrogen technology, facilitates research and development of hydrogen technology or related technologies and infrastructures and generates and partly covers the costs of pilot hydrogen technology operation projects.

Benefits:

1. Sharing and bringing together theoretical and practical know-how.
2. Support for competitive advantages of the Czech Republic in the field of hydrogen technology.
3. Increasing cooperation across the research sector will also increase interest in doing business in this field along with increased investments in technological development.

Negatives:

1. Activity demanding in terms of time, technically and financially demanding activity.

Evaluation: this support creates new technologies and contributes to the competitive advantages of hydrogen technology; however, in the long run. It calls for subsidies or support totalling higher orders of magnitudes in terms of value. There is a risk that even adequate financial support may not finally contribute to a significant improvement, new technology development or its widespread use in practice. It places high demands on R&D projects within the context of practical use and calls for knowledgeable management by experts.

7.4.2 Public support in establishing expert communities and interoperability

Support in establishing expert communities of a predominantly private nature with the aim of establishing cooperation, initiating innovation or attracting new investments. This is an expert grouping starting from public administrations (establishing and developing communities), interest groups of operators, contractors, infrastructure users and customers, R&D, hydrogen producers, its distributors and hydrogen vehicle manufacturers. The largest part of pilot project funding is expected in this area.

Benefits:

1. Synergy of experience and effective preparation of infrastructure development (user-friendly solutions).
2. Integration of public service customers, private and business sectors and shared use of infrastructure (mutual recognition).
3. Establishing the competitiveness of hydrogen technology and hydrogen-powered vehicles (linking theoretical knowledge, studies and practice).
4. Better perception of hydrogen technology.

Negatives:

1. Uncertainty when launching real-life operation.

2. Focus on pilot projects "only".

Evaluation: Public support in this area can generate greater benefits than subsidized research and development, usually willower financial requirements as the private sector is able to offer private financial grants in duly justified cases. It is advisable to support creation of clusters and implement interoperability solutions in the maximum possible extent. Linking these areas can have a very positive impact. However, uncertainties related to the real functioning of the relevant technology can always slow down its active use.

7.5 Support for establishing infrastructure for hydrogen powered vehicles

Backbone infrastructure is a prerequisite for creating a market and opportunities for developing hydrogen mobility. The allocated part of costs associated with the construction of hydrogen filling stations is proposed to be funded by grant schemes provided by the Ministry of Industry and Trade and the Ministry of Transport of the CR. Effective support can be seen in developing public infrastructure for passenger cars fitted with hydrogen technology, developing public and non-public hydrogen infrastructure for public mass transport and public transport and developing corporate infrastructure.

7.5.1 Support for developing public infrastructure for hydrogen powered vehicles

This support partly covers the costs of building hydrogen filling stations for private, corporate and government vehicles fitted with hydrogen technology. The disbursement and amount of the subsidy take into account the current status of the hydrogen filling station infrastructure in the relevant region and its usability in vehicle operation. It is a suitable condition for the development of hydrogen mobility. It is necessary to bridge the initial state "0" and start up the market up to the breaking point where it can do without investments or operating subsidies.

Benefits:

1. Establishing a space for hydrogen technology operation in practice, start-up of hydrogen technology development in transport.
2. Support for the construction of hydrogen stations.
3. Subsequent deeper impact of the construction - use of hydrogen filling stations in the private sector.

Negatives:

1. Larger agglomerations will receive support.

Evaluation: This is a financially demanding part of the support (based on model calculations) in terms of priority. The key fact is that only larger agglomerations are likely to benefit, as smaller territorial units will prefer other forms of investments. In addition, it is important to inform the public about the benefits and to prove the benefits of the construction so that this infrastructure can be used in the long term. In order to maintain the stations in operation it is necessary to link this support with the vehicle fleet support so that the operators of the planned/constructed stations can estimate the operation model and the station profitability.

7.5.2 Support for establishing non-public hydrogen infrastructure for public, municipal and suburban public transport and municipal services

The support covers partly the costs of constructing hydrogen stations for hydrogen-powered vehicles providing public and public transport services or municipal services. The disbursement and amount of the subsidy correlates with the number of service vehicles (urban, suburban, communal) or the coverage of the public serviced area.

Benefits:

1. Creating a space for the operation of hydrogen technology in practice, starting up the development of hydrogen technology in public transport.
2. Support of the construction of hydrogen filling stations in depots and motorway service areas.
3. Support for the expansion of the operation of buses and technical vehicles with hydrogen technology (pure alternative fuel in agglomerations).
4. Motivation of the private sector by the public attitude.

Negatives:

1. Expenditures paid from the government and local government budgets pushed to the background.

Evaluation: This is a financially quite demanding part of the support (based on model calculations) in terms of priority. As regards public transport in smaller territorial units with smaller budgets there is a risk of backgrounding the projects due to other expenditures or less costly projects. Although the value of the initial investment is several times higher than in the case of private transport, it must be emphasized that the amount of financial support decreases over time. Furthermore, as regards the filling station network, it may not be as dense in terms of public transport as in the case of private cars. Overall, the construction of stations would mainly be concentrated in public transport depots. Another considerable benefit is the use of alternative clean fuel, which is desirable mainly in regions facing high emission pollution.

7.5.3 Support for corporate infrastructure development

In connection with the acquisition and subsequent operation of hydrogen-powered vehicles by business entities, eligible costs are considered to be the costs of acquiring the related technologies and hydrogen stations. In theory, it can also be a combination of a hydrogen filling station and hydrogen powered vehicles (Operational Programme Enterprise and Innovation for Competitiveness model - OP PIK).

The support covers partly the costs of hydrogen filling station construction intended for vehicles owned by business entities. At the same time, according to OP PIK model, it can support the hydrogen powered vehicle fleets themselves. The disbursement and amount of the grant correlates with the number of vehicles used.

Benefits:

1. Establishing a space for the hydrogen technology use in practice, starting up the development of hydrogen technology in the business sector.
2. Penetration of hydrogen-powered vehicles into corporate fleets.
3. Extension of hydrogen technology infrastructure into business entities.

Negatives:

1. The support will probably be received by larger agglomerations.

Evaluation: This is a financially quite demanding part of the support (based on model calculations) in terms of priority. The benefits are seen in a similar model of support as the one used for electromobility under the OP PIK programme. Even in the business sector it is likely that only larger agglomerations will receive support because of the costly construction of hydrogen filling stations. There is also a risk that the business sector will not cover the missing infrastructure, but will build a duplicate one instead. On the other hand, there is a possibility for additional benefit in the form of using the corporate network for the needs of general public.

7.6 Support for hydrogen technology vehicle acquisition

The public support financially stimulates (subsidises) the purchase of vehicles for personal use, for corporate fleets, the public sector or other public sector entities. It is a support for hydrogen powered vehicles purchases (e.g. according to the current grant schemes- electromobility for business entities, alternative mobility in towns and municipalities). In fact, this reduces the currently very high (compared to conventional fuel) purchase price of the vehicles so as to encourage not only alternative fuel and new technology enthusiasts but also ordinary people who want to keep a cleaner environment but who are not willing (unable) to spend money on more expensive technologies. The main goal is to bridge the initial period before a real "market" is formed.

7.6.1 Support for public transport and municipal services– public transport operators, public transporters, municipal service transport and utility companies

Public bus operators and municipal services providers purchase hydrogen-powered vehicles using public support provided by the central governments and local governments, which reduces the purchase price of these vehicles. It may be linked to specific regions or generally to introducing alternative fuels into this type of transport. Hydrogen technology is perceived as a good alternative for public transport also in other parts of the world (Germany, Italy, Japan). The municipal waste collection and other public services can be very well provided using hydrogen powered vehicles thanks to funding from the central and local governments . Of course, the business case of each project must be developed in order to determine whether this type of technology is suitable for the relevant type of transport and operation savings must be calculated. This type of support would accelerate the transition to alternative fuels in public transport or in municipal services.

Benefits:

1. Reduction in the volume of emissions from the busy public transport network, which can improve the local air condition in cities that often suffer from smog and, in the long run, mitigate health issues caused by this problem.
2. Economic and environmental savings resulting from lower fuel consumption related to municipal services.
3. Support for expanding the operation of buses, public means of transport and technical vehicles equipped with hydrogen technology.

Evaluation: The financial part of this support is one of the most demanding but it is expected that it will become one of the important stimuli for this technology development and will then positively motivate private transporters to use this technology. The overall demand for hydrogen-powered means of transport **should increase significantly as a result**.

7.6.2 Support for central and local government bodies and their subordinate, controlled or established organizations

Replacement of a part of central and local government fleet by hydrogen powered vehicles for the purposes of civil servants' longer distance trips. This measure is based on the NAP CM setting the conditions for developing alternative mobility in public administration. This can be extended to local governments. In general, this can also be seen as the start-up of cars-haring in public administration which is nowadays based on standard fuels.

Benefits:

1. Financial savings related to the operation of alternative fuels in public administration and local governments
2. Motivation of the private sector by the public attitudes and encouraged demand for these vehicles

Evaluation: the replacement of vehicles used by the government bodies and self-governments does not call for as high expenditure as in the case of public transport given the number of vehicles and therefore it should be somewhat easier to implement. In addition, it also positively motivates the private sector to become familiar with hydrogen technology. Car-sharing will not only provide financial savings but it will certainly be very well received by the general public and it encourages more environmental-friendly behaviour.

7.6.3 Support for business entities

Replacement of part of the vehicle fleet and development of commercial use of hydrogen. The business sector may see some potential for further development of its business also from the transport point of view (e.g. distribution) in covering certain distances. At the same time, with lower transport costs we can expect the use of this type of transport in order to reduce business costs.

Benefits:

1. Penetration of hydrogen-powered vehicles into corporate fleets.
2. Accelerated process of adopting hydrogen technology, as the private sector has more capital available to replace the fleet and become familiar with the technology.

Evaluation: Replacement of corporate fleets may be many times faster thanks to the presence of higher capital in the private sector. Along with the support by transport companies, transporters and utility companies is it advisable and justifiable to link the support to the private sector. The support will then become log-term, from pilot projects to hydrogen technology end-user.

7.6.4 Support for private individuals

Hydrogen powered vehicles are purchased by private individuals without the need for an identification number. Similarly, the MoE is now discussing this option for electromobiles.

It makes sense that the support should also be directed at "ordinary" customers who are interested in alternative fuels, in this case hydrogen. The objective is to enable registration of passenger cars together with a grant provided for the purchase or operation by private individuals.

Benefits:

1. Economic savings resulting from lower fuel consumption associated with emission reductions and improved air quality over the longer term.
2. Penetration of hydrogen-powered vehicles into the private sector

Evaluation: It is meaningful to direct support at the private sector, too. This is mainly true if the pilot project support in public services is proved efficient. It is another piece of puzzle to support the development of hydrogen technology. At the same time, it is advisable to link it with the private sector and public administration. This support must be put in place after infrastructure construction pilot projects.

7.7 Financial and tax incentives

Financial and tax incentives have different forms and different importance in launching hydrogen mobility. They can rather be seen as an additional motivation along with the financial support (subsidies). They add financial incentives for the application of hydrogen technology or replacement of the current technology. They are applied from the moment of hydrogen market creation (reduction in the purchase price by exemption from VAT), through operating reliefs (reduction/exemption from road tax payment) to potential financial and banking instruments for reducing loan-related costs. This concerns support measures such as:

7.7.1 Motorway and road use “reliefs“

This relief is defined as a discount or exemption from the payment of motorway vignettes or tolls applicable to the given types of means of transport and is graded in terms of the vehicle parameters.

Benefits:

1. Partial reduction in the costs of ownership through savings related to motorway vignettes and tolls.
2. Additional incentives for potential owners of hydrogen powered vehicles.

Negatives:

1. It is estimated that the revenues of the State Fund of Transport Infrastructure will drop by units of millions of CZK by 2030 with a resulting negligible coverage of the costs of construction/modernization, operation of the electronic toll system, regular maintenance, management and operation and costs associated with the consequences of traffic accidents.
2. With increasing vehicle penetration it will be necessary to establish a long-term market “penetration“ and terminate this type of support.

Evaluation: The exemptions from road vignette and toll payment will act as an additional positive incentive for the public to purchase hydrogen powered cars. The estimated drop in the revenues of the State Fund for Transport Infrastructure is absolutely irrelevant in this time perspective. In general, this form of support can only be considered as additional and it can be expected that this will not be the main reason that could change the public way of thinking.

7.7.2 Local road use reliefs and services provided by the local administration

The extent of the exemptions will be decided by the local governing bodies and this is entirely within their competence. As regards grant schemes, they correlate with the objective of this measure. Account is taken primarily of the types of vehicles and their parameters, the level of serviceability and the role in public interest. In the event of partial fees for use, it will be possible to follow the procedure defined under point 3.2.3 in the context of setting free of charge services of using public areas, or partial exemptions set out under this point.

Benefits:

1. Guaranteed preferential position and operation of hydrogen-powered vehicles and related technology demand stimulation.
2. Partial reduction of the cost of ownership of hydrogen powered vehicles.
3. Partial reduction of costs of constructing hydrogen filling stations.
4. Promotion of public awareness raising related to the existence and benefits of hydrogen technologies.

Negatives:

1. Reduction of local -government budgets and related insignificant but lower coverage of construction/upgrade costs, costs of regular maintenance, management and operation.
2. Support may rather be expected in "richer agglomerations."

Evaluation: The question is to what extent it makes sense to provide hydrogen powered cars with preferential position on local roads in smaller territorial units and suburban areas if infrastructure such as filling stations is not established. However, this preferential position and implementation of this strategy in the so-called "richer agglomerations" should not encounter any major institutional and budgetary obstacles where public awareness raising related to these benefits and advantages of using hydrogen powered vehicles is expected to increase.

7.7.3 Tax reduction or exemption

Adjustment in the tax system or rates including the introduction of other exemptions, in particular for road tax, VAT or third party liability based on EURO vehicle emission classes. These include, for example, tax exemptions, lowest rates, exemptions for a certain period of time or in a given region, an increase or 100% depreciation of the purchase price in the 1st year, repairs of CO_2 emission vehicles as a tax-deductible item.

Benefits:

1. Competitiveness of hydrogen as fuel, competitiveness of hydrogen-powered vehicles
2. Partial reduction in the cost of ownership of hydrogen-powered vehicles and associated technology demand stimulation.
3. Start-up of the hydrogen technology development.
4. Facilitated construction of hydrogen filling stations.

5. Motivation to purchase new vehicles, departure from higher emission vehicles.

Negatives:

1. It is expected that the budget of the State Fund for Transport Infrastructure will be reduced – reduced road tax.
2. Reduction of state budget revenues related to the value-added tax is expected.

Evaluation: Tax reductions or exemptions are motivations for potential buyers of hydrogen powered vehicles, where increased demand will also trigger increased infrastructure construction rate necessary for the vehicle operation. The taxpayer is most motivated by value added tax relief, which is the highest, although one-off, savings in the investment acquisition. Another effect can be expected in relation to the road tax where the savings make a negligible amount; however, such savings are introduced for electric cars following the NAP CM and therefore it is logical to ask for such a relief for hydrogen vehicles as well. However, the tax relief also means a significant reduction in both the state budget (as already been shown in CNG vehicles) and the budget of the State Fund for Transport Infrastructure and therefore the implementation of this measure is significantly hindered and potentially threatened. An important debate can be expected with representatives of the Ministry of Finance on the justification of these measures and, above all, quantification of the exact costs, i.e. reduced state budget revenues, needs to be provided. In particular, these measures must be supported by impact analysis during the follow-up activities.

7.7.4 Attractive loans and guarantee instruments

The financial contribution (reduced interest rates, state guarantees, financial guarantees, etc.) or bonus in the form of changed parameters of standard banking products (repayment period, required principal, guarantee amount, extension of guarantees, etc.) are additional possibilities of motivating investors/customers to buy hydrogen powered vehicles These measures concern new vehicles equipped with hydrogen technology, construction or modernization of transport infrastructure and formation of business entities in the relevant region. This motivation is largely appreciated by the European Commission and is also used in Western Europe. In the Czech Republic, this incentive encounters long-term scepticism, as the Czech Republic, as a cohesion country, has always been more used to the traditional forms of subsidies, i.e. both its citizens and companies. These guarantees or interest rates covered by the state are an advantage for projects that are very close to a viable project. In the beginning, negligible use can be expected but once it starts functioning, when a real market starts emerging or the projects start becoming profitable, these instruments may become increasingly attractive. For this reason, this support should be taken into account and should not be omitted.

Benefits:

1. Partial reduction in the cost of ownership of hydrogen powered vehicles.
2. Partial reduction in the cost of constructing hydrogen filling stations.
3. Stimulation demand in the hydrogen technology sector.

Negatives:

1. Reduced revenues of the financial institutions which may be offset by the development of business and employment in the region and associated additional demand for passive products offered by the financial institution.

2. The financial institution revenues will be covered by the state, i.e. the state pays the "risk" interest rate premium (provides a guarantee) or covers the entire interest rate associated with the investment.

Evaluation: These instruments will deliver the highest effect in the medium term, once at least the necessary infrastructure is in place. From the financial point of view it can be assumed that the cost of public support **will be offset by the expected increase in transport performance** and related higher fuel consumption. Priority support for the business sector could multiply the effect in private sector. It is necessary to bear in mind the necessary involvement of the state that would cover the risky part of the interest rate, or cover the entire interest rate, i.e. there would be certain demands on the state budget if such instruments are not finally implemented. This coverage could also be provided by European funds. After all, the EC proposes the use of these instruments and considers them as a financing instrument on the part of the EC or the member states.

7.8 Overview of forms of support

Table 55: Overview of the forms of support

Form of support	Measure	Main reasons	Evaluation (quantitative)	Effect in terms of time
7.2 Elimination of legal barriers		• Development of hydrogen stations • More accessible services • Accelerated infrastructure development	• „Free of charge“ • Calls for changes to the law	• **Priority** • Precondition for starting up the market • Already implemented in a large extent
7.3 Formal support – non-financial	7.3.1 Hydrogen technology vehicle garage parking	• More accessible garages or parking for hydrogen powered vehicles • Potential delays in approving the standards	• Low financial demands • Calls for change in the status	• **Mid-term horizon** • Precondition for starting up the familiarisation with hydrogen technologies
	7.3.2 Hydrogen-powered vehicle servicing	• Higher attractiveness of hydrogen drives when choosing vehicle type • Follow-up investments are not guaranteed	• Necessary developed of service conditions, sale and inspection of hydrogen powered vehicles • Financially feasible	• **Mid-term horizon** • Precondition for starting up the familiarisation with hydrogen technologies
	7.3.3 Use of roads, i.e. local roads (fast lanes, restrictions, toll, access to city centres)	• Greater attractiveness of hydrogen vehicles thanks to advantageous conditions • Preferential position of hydrogen vehicles in the transport system stimulated	• Only minor financial burden	• **Long-term horizon** • Financially not demanding and important measure

Form of support	Measure	Main reasons	Evaluation (quantitative)	Effect in terms of time
		demand for these vehicles • Use for clean mobility (electricity, hydrogen) • Potential disapproval by authorities in charge of traffic safety		
	7.3.4 Enabling parking in otherwise reserved parking places	• Advantages implying growing interest in hydrogen vehicles • Reduced revenues for zone operators, compensation through environmental improvement	• Financially easy to implement • Potential use on road, i.e. local roads, resistance of cities justified by the lack of parking places	• **Priority** • Precondition for start-up in terms of time preference (works for electricity in some cities)
7.4 Support for R&D&I for hydrogen technologies	7.4.1 Support for research, development and innovation for hydrogen technologies	• Shared know-how • Encourages competitiveness • Technically, time wise and financially demanding	• High financial demands • Introducing the support is technically demanding	• **Long-term horizon**
	7.4.2 Public support in establishing expert communities and interoperability	• Synergy-experience and user oriented solution • Mutual recognition • Hydrogen technology PR • Will be applied in larger agglomerations • Pilot project support	• Lower costs with the private sector discipline involvement	• **Mid-term horizon** • Precondition for efficient preparation and implementation • Most likely effect
7.5 Support for establishing infrastructure for hydrogen powered vehicles	7.5.1 Support for developing public infrastructure for hydrogen powered vehicles	• Support of hydrogen station construction with impacts on private sector in • Application across the CR	• High costs (capex) • Partial use of the existing infrastructure and current position of petrol stations	• **Priority** • Highly likely positive effect

Form of support	Measure	Main reasons	Evaluation (quantitative)	Effect in terms of time
	7.5.2 Support for establishing non-public hydrogen infrastructure for public, municipal and suburban public transport and municipal services	• Triggering hydrogen technology development in public transport • Application primarily in a „selected" region or agglomeration interested in public transport hydrogen mobility	• Financially a major part of the support • Potentially great positive rate of return over time • Expected start-up of hydrogen use	• **Priority** • Positive long-term effect
	7.5.3 Support for corporate infrastructure development	• Penetration of hydrogen technology into corporate fleets • Hydrogen PR through companies	• Financially costly part of the support	• **Priority** • Positive long-term effect
7.6 Support for hydrogen technology vehicle acquisition	7.6.1 Support for establishing non-public hydrogen infrastructure for public, municipal and suburban public transport and municipal services	• Penetration of hydrogen technology into public transport • Reduced emissions • Lower consumption of conventional fuels • Public services motivating private sector	• Long term high costs • Necessary measures to establish private sector incentives	• **Priority** • Precondition for start-up despite high financial burden
	7.6.2 Support for central and local government bodies and their subordinate, controlled or established organizations	• Triggered sharing of alternative (clean) technologies in central government and local government administration bodies	• Easies vehicle fleet replacement thanks to a smaller number of vehicles	• Measure implementable in the **mid- or long-term run**

Form of support	Measure	Main reasons	Evaluation (quantitative)	Effect in terms of time
	7.6.3 Support for business entities	• Penetration of hydrogen technology into corporate fleets • Based on the current OP PIK programme	• Replacement may be much faster thanks to the presence of greater private sector capital	• **Priority** • Precondition for start-up despite high costs
	7.6.4 Support of private individuals	• Savings related to reduced fuel consumption associated with reduced emissions • The costs or purchase for the private sector must be compensated	• Once proved efficient in the public sector and business entities it will make sense to start supporting this technology in private sector	• This measure should be taken as a **priority, however no later than in the mid-term run**
7.7 Financial and tax incentives	7.7.1 Motorway and road use "reliefs"	• Motivation to purchase new vehicles • Reduced revenues for road and motorway operators	• Positive motivation to purchase hydrogen powered vehicles • Considerable reduction in the revenues generated by the State Fund of Transport Infrastructure	• Measure implementable in the **mid-term run**
	7.7.2 Local road use reliefs and services provided by the local administration	• Preferential position and operation of hydrogen vehicles • Stimulated demand for this technology • Support in „richer agglomerations" may be expected	• Relatively easy implication • Positive motivation towards combustion engine vehicles replacement	• Measure implementable in the **mid-term run**
	7.7.3 Tax reduction or exemption	• Triggering hydrogen technology development • Impact on the CR budget can be expected in view of lower VAT revenues	• Increase demand for new vehicles determined by high costs	• **Mid-term measure** but with a major impact and therefore recommended to be considered at the borderline of priority and mid-term period

Form of support	Measure	Main reasons	Evaluation (quantitative)	Effect in terms of time
	7.7.4 Attractive loans and guarantee instruments	• Reduced cost of ownership of hydrogen powered vehicles • Stimulated demand for this technology	• It is expected that the cost of public support will be compensated by increased transport performance • Thus is accompanied by an impact in the state budget which will have to set off the project risk rate for private financial institutions	• **Measure of the mid-term-run nature**

7.9 Forms of support with the highest benefits for hydrogen mobility implementation

Expert group discussions, in-depth interviews and survey have also highlighted some forms of support and have tried to identify those forms of public support that will accelerate the launch of hydrogen technology considering the limited budget options and the defined time framework. The decision-making on incentive prioritization has a significant impact on the relevance of the demand for private sector support, which is also motivated by the rate of support, its availability and continuous effects related to the ownership of hydrogen-powered vehicles, and it also determines the use of public support, the anticipated impact of the implemented measures and time-related feasibility in the Czech Republic. It is necessary to realize that this prioritization was not forced but it is the outcome of several months of discussions with experts and market representatives from the entire country. These representatives, or entities, provided their views on the potential impacts of each form of support, which then resulted in the combination of supports. Following such defined forms of support, experience from past implementations of other alternative fuels has also been taken into account. The work on NAP CM, and the approach to CNG and electromobility in previous years, could also serve as a model. The aim is not to become limited by existing subsidies with various levels of successful implementations, but to develop a set of measures that should motivate not only applicants for subsidies but also the public administration offering these subsidies and preparing support programs, as well as local governments that can help implement partial non-financial forms of support in their localities.

The most convincing forms of support, according to the expert opinion, include two main groups, being: a) support for basic hydrogen technology market stimulation and b) support for simple implementation or additional benefits which, when combined, can result in a decision made by entities hesitating to adopt hydrogen and its use in transport along with other topics related to hydrogen mobility.

The basic hydrogen technology market simulation will be ensured by the following forms of support:

1. **Support for building public and private infrastructure**, i.e. for private vehicles, for public urban and suburban transport, for municipal services and for the business sector. The key importance of the support consists in launching the technological

development, its long-term use and it is an essential element for the hydrogen-powered vehicles penetration. This can be considered the crucial form of support.

2. **Support for hydrogen-powered vehicles purchasing**, especially related to public transport vehicles, municipal services and corporate fleets as well as for private individuals. This support reduces the consumption of conventional fuels and reduces CO_2 emissions, while establishing demand on the part of public utilities and the business as well as demand for vehicles for private individuals, who can get inspired thanks to the positive PR. Given the present and expected costs of purchasing hydrogen vehicles in the coming years, the support for purchasing these vehicles is the only potential significant driver.
3. **Tax reduction or exemption –** the value-added tax reduces the costs of acquiring or operating hydrogen-powered vehicles. It is considered as one of the most important drivers but a major debate is expected with other ministries, namely the Ministry of Finance. In fact, a reduction or deduction of VAT can be expected to become one of the most important incentives for the buyers but implementing this measure seems to be next to impossible. Nevertheless, this point should be listed in this overview.

In general, forms of support that are easy to implement or which provide additional benefits if combined, may finally influence the opinion of entities hesitating to apply hydrogen-based technology and its use in transport as the basic hydrogen technology market stimulation while providing the hydrogen-powered vehicle owner with an added value. In particular, the following measures can be envisaged:

4. **Allowing parking in otherwise reserved places** – this is fairly easy to implemented thanks to experience with electric cars. At the same time, it needs a relatively simple modification of local decrees. And the benefit is once again very well perceived possibility of driving the vehicle in cities facing complicated parking situations. It is necessary and suitable to combine the support for clean mobility in this respect (electricity and hydrogen).
5. **Preferential use of roads, i.e. local roads**, in particular the use of bus and taxi lanes while allowing access to city centres (or reduced tolls) where entry is prohibited to combustion engine vehicles. This provides positive clean mobility PR and stimulates the demand for hydrogen-powered vehicles. Their use will enable faster car trips, especially in cities facing traffic jams at peak hours, and this will be a motivation to purchase this type of vehicle.
6. **Hydrogen-powered vehicle garaging** will allow for more accessible use of hydrogen vehicles in urban areas and result in the considerations to purchase these vehicles when parking spaces are provided. Nevertheless, the law (decree) needs to be adjusted, but on the other hand it can be a significant benefit when considering the purchase of a new vehicle or replacement of an existing one. This concerns amendments to the decree in terms of parking safety (in relation to LPG and CNG that cannot be parked in garages).
7. **Motorway and road use exemptions – tolls, motorway vignettes** – these make it possible to reduce the costs of vehicle operations, offer an additional motivation to purchase a hydrogen-powered vehicle, it is not an important item but a welcome

benefit. With the current proposal of alternative vehicles, marking this is a suitable addition for the vehicle operator.

8. **Tax reduction or exemption – road tax** – the support provides better perception of this vehicle operation in the form of a repeated, although insignificant, financial savings; it is not a significant item but a welcomed benefit. It is also perceived from the point of view of future potential flat road tax rate for all operators based on the type of drive used. At that point, such a benefit provided for clean (hydrogen, electricity) mobility would certainly be much more interesting. In addition, this benefit already exists for electricity in relation to the NAP CM and therefore it is logical to expect and ask for its introduction or hydrogen vehicles, too.

7.10 Scenarios and matching forms of support

A variant approach has been selected to model the potential development of hydrogen mobility in the Czech Republic. Based on various forms of support, their combination, weights and scope of the measures, a total of 4 development scenarios have been established. In reality, however, "only" 3 development scenarios are based on the forms of support. The 4th scenario is a zero option that includes non-financial support based on the currently known initiatives aimed to make the use of hydrogen drive more "pleasant" but these are not the main drivers for shifting users towards hydrogen technologies.

Development scenarios and matching forms of support:

scenario 1 – "Ambitious scenario" is a scenario in which all currently applied significant forms of support will be employed as selected by the project team in cooperation with the expert group and on the basis of information from in-depth interview. At the same time, these forms of support must be applied so that they can bridge the entire difference between the costs of introducing hydrogen mobility compared to conventional fuels, with this amount equalling the cost of investment in infrastructure construction, investment in the support for passenger cars and buses (public transport). This scenario has a major impact on public budgets due to the large difference between the acquisition costs of conventional and clean technologies. This scenario promotes hydrogen alone and pushes other forms of alternative or clean mobility to the background.

scenario 2 – "Progressive scenario" - is a scenario in which hydrogen mobility is comparable to electromobility as an alternative of clean mobility and thus, very intensive development is expected. It should be noted that this scenario contains all additional measures. In addition, it also involves all 3 major forms of support. There is a lower expended limit amount set here compared to scenario 1 but, at the same time, there is still a significant impact on the state budget as the amounts spent are very high. Its aim is to maximize market development. Therefore, it will focus on providing the necessary infrastructure and the exemptions granted for the use of hydrogen technology. This scenario offers hydrogen as a dominant clean alternative where diversion from "dirtier" technologies while maintaining the same approach to electricity as predicted now is envisaged.

scenario 3 – "Basic scenario" – it describes hydrogen as a clear alternative of clean mobility, however with less priority, and thus with lower impact on the public budget. Public support combines here the "soft "measures outlined above in this chapter. This measure is set to improve public awareness and give a positive view of the use of hydrogen in transport. These measures should outweigh the short-term negative impacts (cost, initial shortage of filling stations, etc.). In relation to these benefits, the most important forms of support, such as the construction of filling stations, purchase of vehicles and reduction of value added tax on the purchase of these vehicles, should be applied. The support is set at a level covering the difference between the costs of conventional and hydrogen powered vehicles. In fact this will result in a lower allocation or lower engagement (% of the subsidy) of the public sector in this funding compared to scenarios 1 and 2. It may be expected that the rate of support will depend on the actual interest of the applicants' according to implemented sub-projects so as to enable the market environment start-up.

scenario 4 – "Business as Usual" presents a variant with (almost) zero public support, which does not consider any financial support from the state. The support concerns legislative or local modifications adjustments that will also be gradually implemented for other alternative vehicles, in particular electric vehicles, and it is logical that hydrogen powered cars should benefit from the same advantages. At the same time, the development of hydrogen technology is indicated only on the basis of the current development where the market will be driven primarily by new technology enthusiasts or by motivation on the part of private entities, which logically, will not be willing to finance the development on a large scale.

The following table summarizes engagement of the forms of support:

Table 56: Engagement of the forms of support

Form of support	Ambitious scenario	Progressive scenario	Basic scenario	Business as Usual
1. Support for building public and private infrastructure	Support for building public, non-public and corporate infrastructure. Allocation is significant and with a high level of grant participation according to the type of project. Market development and growth is supported so that hydrogen becomes dominant fuel. The costs are considerable. All filling stations across the whole Czech Republic are supported.	Support for building public, non-public and corporate infrastructure, Allocation is significant and with a medium and high level of grant participation according to the type of project. Market creation is supported, followed by reduced support which is then, however, still in existence for better hydrogen mobility support.	Support for building public, non-public and corporate infrastructure; however, in a restricted amount (lower allocation) compared to previous scenarios and with medium amount of grant co-funding. It is necessary to support the projects mainly at the initial market (cycle) stage. All filling stations across the whole Czech Republic are supported with the focus on	-

Form of support	Ambitious scenario	Progressive scenario	Basic scenario	Business as Usual
		All filling stations across the whole Czech Republic are supported with the focus on agglomerations (public transport) and TEN-T in the early stage.	agglomerations (public transport) and TEN-T in the early stage.	
2. Support for hydrogen-powered vehicles purchasing	Support is provided for public (public transport), government, corporate and private vehicles. The public, government, corporate and private sectors are greatly supported for the continued usability and multiplier effect. Allocation is crucial - it will in finally support development under this scenario indicating a major increase in hydrogen mobility. Use of hydrogen is dominant.	Support is provided for public (public transport), government, corporate and private vehicles. The public, government, corporate are greatly supported for the continued usability and multiplier effect. The private sector is supported at a level making it most advantageous to purchase a hydrogen powered vehicle. Allocation is crucial - it will finally support development under this scenario indicating a major increase in hydrogen mobility.	Support is provided for public (public transport), government, corporate and private vehicles. The public, government and corporate sectors are supported as currently possible. The private sector is supported only insignificantly but this support is still interesting for the applicants. Allocation is crucial - it will finally support development under this scenario.	-
3. Tax reduction or exemption - VAT	VAT exempt	VAT reduced to 10 %	VAT reduced to 15 %	VAT at 21 %
4. Allowing parking in otherwise reserved places	Parking is enabled in reserved parking spaces (e.g. blue lines), it is guaranteed in public car parks (x parking places for clean mobility)	Parking is enabled in reserved parking spaces (e.g. blue lines), it is guaranteed in public car parks (x parking places for clean mobility)	Parking is enabled in reserved parking spaces (e.g. blue lines), it is guaranteed in public car parks (x parking places for clean mobility)	Parking is enabled in reserved parking spaces (e.g. blue lines), it is guaranteed in public car parks (x parking places for clean mobility)

Form of support	Ambitious scenario	Progressive scenario	Basic scenario	Business as Usual
5. Preferential use of roads, i.e. local roads	Traffic lanes reserved for buses and taxis to be used also by hydrogen (clean) cars for smoother traffic flow	Traffic lanes reserved for buses and taxis to be used also by hydrogen (clean) cars for smoother traffic flow	Traffic lanes reserved for buses and taxis to be used also by hydrogen (clean) cars for smoother traffic flow	Traffic lanes reserved for buses and taxis to be used also by hydrogen (clean) cars for smoother traffic flow
6. Hydrogen technology vehicle garaging	Hydrogen powered cars may park in underground garages	Hydrogen powered cars may park in underground garages	Hydrogen powered cars may park in underground garages	Hydrogen powered cars may park in underground garages
7. Motorway and road use exemptions - tolls, motorway vignettes	Hydrogen powered vehicles do not pay road vignettes and tolls	Hydrogen powered vehicles do not pay road vignettes and tolls	Hydrogen powered vehicles do not pay road vignettes and tolls	-
8. Reduced or exempt tax – road tax	Hydrogen powered vehicles are not subject to road tax	Hydrogen powered vehicles are not subject to road tax	Hydrogen powered vehicles are not subject to road tax	-

It should be noted that outputs of the model and the amounts given as cumulative costs do not reflect the absolute rate of support to be allocated under various scenarios from the subsidy programmes but they show the difference between capital and operating costs of hydrogen mobility compared to standard conventional vehicles following the current price development predictions. The benefits described above are of non-financial nature and, along with the financial ones, they are to establish certain foundations for the development of hydrogen mobility in the Czech Republic. However, this is based on the prerequisite that the support will only be provided for a limited period of time to accelerate the commercial (commercial) take-up of hydrogen mobility. Once the market becomes viable (in particular, reduced costs of purchasing the hydrogen vehicles) these supports should be terminated.

8 Final recommendations

The aim of this study is to formulate or prepare strategic recommendations for the fulfilment of selected scenario of the hydrogen mobility development in the Czech Republic on the grounds of findings obtained during the preparation of this study. These recommendations are formed with reference to positive experience from abroad, experience with the first use of hydrogen filling station and hydrogen bus in the Czech Republic. They are also formulated on the basis of information obtained from the in-depth interviews, public survey and expert group in the context of potential prospect for the hydrogen use in the Czech Republic for all users.

These recommendations cannot be perceived as dogma but rather that in general with their right combination, the sector can be accelerated more quickly which will consequently enable the flow of potential investment into the sector with guaranteed, yet starting market environment.

This however represents building block for any new emerging initiative. The same is thus applicable in case of hydrogen mobility. Foreign experience implies that it is convenient to prepare **clear state concept of hydrogen mobility while respecting all other alternatives**.

The key requirement for launching a new initiative, that hydrogen in transport undoubtedly is, is the **definition of clear vision along with the setting of real goals and clearly defined measures**.

Following section summarizes basic **strategic recommendations which should not be omitted in the government strategy** of hydrogen technology usability support and if the Czech Republic decides to follow this way, the recommendations should not be forgotten.

8.1 Strategic recommendations

8.1.1 Support for the construction of hydrogen infrastructure

The long-term implementation of hydrogen mobility depends primarily on **two pillars**. **The first one requires the existence of functioning and safe infrastructure of filling stations**, which would ensure hydrogen tank filling of the cars. **The second pillar is then represented by the cars themselves.**

Majority of the experts along with the broad public (according to the conducted survey) agrees that one of the most complex questions of the hydrogen technology launching in the transport sector is whether to start primarily with the infrastructure design (i.e. construction of filling stations and the use of free hydrogen production capacities) or rather start with manufacturing of the cars themselves. Both factors are necessary for each other and thus activity only in one of these two areas does not make sense.

According to the Directive 2014/94/EU of the European Parliament and of the Council which deals with the infrastructure launching for alternative fuels and which includes measures to support the market for alternative types of propulsion (including hydrogen), the state is obliged to propose specific numbers of public stations for alternative fuels on its territory. **National Action Plan for Mobility is designed to target 3-5 public filling stations for year 2025**.

This study´s findings imply the need to support basic infrastructure for hydrogen mobility development. It cannot be expected that the initiating costs will be paid by the private entities in full. This recommendation is thus introduced first. It is estimated that this will be the basic building block of development in order to achieve potential development of hydrogen industry.

It is convenient to distinguish between two main groups to which the support should be directed in terms of exact measures specification. The two groups are represented by public filling stations for regular users and non-public filling stations for public transport and also for communal services if needed. In both cases, it is **desirable for the state to actively support investments by means of the above-mentioned forms of support**, focusing in particular on the construction of hydrogen filling stations. It is possible to make optimal use of available European subsidies to support the use of alternative fuels and the construction of alternative infrastructure, whether it is directed towards a transport operational programme or towards promotion of business and investment. The construction of both groups of stations will undoubtedly lead to the acceleration of the construction of all the necessary infrastructure, the presence of which will then more easily convince the public to actually buy the cars.

8.1.1.1 Public hydrogen stations

One of the main obstacles to the further development of personal hydrogen cars represents missing infrastructure and network of public filling stations. If the state ensures a functioning and sufficiently dense network of filling stations, the car manufacturers will feel motivated to expand their offer of hydrogen cars as certain guarantee of usability will be ensured for them. This will also lead to greater awareness of the public about hydrogen mobility itself and it will motivate them towards further potential purchase of a hydrogen car.

It is recommended that the state focuses on sufficient coverage of the main communication routes (in the first phase the focus should be on highways, 1st class roads, etc.) so that the serviceability of cars for potential owners of the new cars is as comfortable and affordable as possible. The use of current locations of gas stations serves as a possibility. Recommendation that emerged from the in-depth interviews with experts is to gradually replenish hydrogen as a standard option at the current gas stations, of course, taking into account the necessity to comply with the required safety measures and standards.

An interesting addition, which does not require building a large number of filling stations, is **the use of vehicles in a modern way, in the form of car sharing**, whether in the sphere of companies or individuals. A good inspiration is the Bee Zero project in Munich, Germany. This project is not disadvantaged by an insufficient infrastructure, as it enables it to fulfill its performance with a limited number of filling stations within the urban environment. If there is a region or local government in the Czech Republic for which this alternative would be interesting, it would be another less costly step towards hydrogen mobility in a specific region that can serve as a pilot inspiration.

This should be also of interest for the state to support projects of similar fashion in the Czech Republic, again in order to increase the public´s interest in this technology. The same conclusion was not only reached by the expert group, but also by many professionals who were asked during the in-depth interviews.

8.1.1.2 Non-public hydrogen stations for public transport

With regard to the construction of infrastructure for hydrogen cars in public transport, the actual construction of the filling station infrastructure should not be a significant obstacle in this respect, **as a significantly lower number of stations are needed for the use of hydrogen buses (cars for communal services)**.

From the investment´s point of view, this solution is significantly cheaper, even if the possibility of potential testing of the technology in real life is taken into account. The pilot operation can be provided with one filling station in the location of the carriageway and number of buses that would ensure, for example 1 particular bus line instead of the existing conventional propulsions. Moreover, information obtained from the in-depth interviews also imply that some cities will move to alternative fuels at a certain time. It should be emphasized here that some of them owing to the state support can ensure hydrogen infrastructure and subsequently be the first in clean hydrogen mobility.

In fact, this is being tested abroad, the **CHIC** (Clean Hydrogen in European Cities) project demonstrates the **successful international implementation of hydrogen mobility in public transport**. The aim of the project was to demonstrate that hydrogen buses in public transport represent a functional solution for decarbonisation and noise reduction in large agglomerations. One of the most important results regarding the hydrogen infrastructure project is the reliability of the operation (low filling times of the stations, the buses were in operation for up to 20 hours a day).

Recommendation is thus to start with hydrogen buses testing in the public transport in a region or agglomeration of a certain size in order to find out how it functions in a sharp operation at a certain amount of traffic. In such region, the network (buses + infrastructure) will be used the most which will result in faster return on investment. At the same time, it increases the public awareness about hydrogen mobility and sustainable modes of transport as a whole. **Such region can be selected on the basis of experience with other alternative propulsions, respectively on the grounds of discussions with local authorities who have long been thinking about moving their car or bus fleet to clean fuels.**

8.1.1.3 Distribution of hydrogen stations / Utilization of the transit potential between Germany and Austria in passenger transport

As it has been already pointed out above, the undisputed advantage of building the filling station infrastructure within the **urban public transport segment is their low number needed to operate the vehicles in the depot.** From this point of view, it is logical to use some agglomeration which would be interested in developing this type of mobility and eventually, after the technology´s certification, continue with it in other regions. The aim would thus be to use the dense transport and dense transport network of particular agglomeration or region for pilot project of the hydrogen public transport.

The second direction of investment as described above is the public infrastructure investment. In the context of potential and logical development with the greatest impact and added value, it is proposed to move them on highways or 1st class roads, at least in the first phase. Although, this direction is certainly suitable, there is still another supporting argument for this. There is ongoing investment construction of hydrogen mobility in Austria and Germany and the plans in Germany imply interesting boom which could be enriching for whole middle Europe. **Germany is considered the pioneer of hydrogen mobility within the EU and the number of hydrogen filling stations behind the western border of the Czech Republic is constantly growing**. The primary interest of the Czech Republic should be thus continuous support aimed at linking these international hydrogen infrastructures. Another undisputed advantage of network interlinkage realization among the Czech Republic, Germany and Austria is the **opportunity to benefit from new foreign technologies and know-how.** Both countries find themselves substantially beyond the Czech Republic in the area of hydrogen mobility progress.

In line with the above-mentioned Directive 2014/94/EC of the European Parliament and of the Council, it is also appropriate to place stations on the Trans-European Transport Network (TEN-T) lines, which are referred to as the recommended backbone network for the construction of this infrastructure, as it includes major transport routes.

In the framework of the TEN-T network, the focus is mainly on the busy international routes, namely the corridor from Dresden through Prague to Austria. The following recommendation is thus to direct the support on **hydrogen infrastructure construction along this trajectory (which is also supported by the TEN-T Community programme or CEF).**

The first implementation of public hydrogen station in the Czech Republic thus takes place in connection with TEN-T network. Unipetrol company plans to use free hydrogen capacities for the hydrogen production to supply the filling hydrogen stations built within the Benzina gas stations network. The first hydrogen filling station construction is planned to take place during the year 2018 in Prague.

8.1.2 Support for the purchase of hydrogen cars

As mentioned above, **hydrogen cars themselves are the second pillar for long-term sustainability of hydrogen mobility.** This is particularly desirable in terms of following the trend of European legislation on the necessary emission reductions, as only a large fleet using alternative (clean) fuels generates overall air quality improvements within the Union. Hydrogen, as a fuel that does not release any emissions, is one of the fuels that has the greatest positive impact on emissions in the transport.

From the approach of other EU countries that are significantly behind the Czech Republic's implementation of hydrogen mobility, it is clear that only **permanent and clearly defined anchor support for vehicle purchase motivates both the private and the public sector to buy them**.

At present, there are only 3 types of hydrogen cars available which are produced at a maximum of 3,000 units per year, the Toyota Mirai, the Hyundai ix35 FC and the Honda Clarity FC. The development of hydrogen mobility should thus logically trigger the demand for the cars. As a consequence of this situation, we can expect an increase in the portfolio of hydrogen cars, the price of which, with the increase in the volume of units sold, should be reduced rapidly and thus no significant support for the introduction of cars between users would be required.

8.1.2.1 Passenger cars

From the conducted survey among the citizens of the Czech Republic, it is obvious that the public **supports the introduction of hydrogen technology and perceives it very positively**, among other things due to its environmental friendliness. People especially appreciate zero emissions and noise reduction on transport roads.

Respondents´ responses, however, suggest that **environmental consciousness itself is not enough motivation for them to get a hydrogen car.** Regarding the conventional car owners, it is necessary to set up the advantages in a manner that they will be substantially motivating for the switch to hydrogen.

It is uncertain whether it will be possible to prepare a grant program to support the purchase of vehicles for private individuals in the short term (respectively fast enough). It is not realistic to prepare a subsidy programme for the purchase of cars in the short-term period for private persons. On the other hand, there is a room to prepare such a form of support in connection with the realized (supported) infrastructure. It really makes sense to select pilot projects that can develop hydrogen technologies with the vision of, for example, operating savings. These include, for example, corporate fleets. A support programme for electromobility for companies has indicated the potential for developing alternative mobility. It would be logical to continue with it even for other types of mobility as hydrogen. Firstly, if the support continues for the public filling stations, it **makes sense to invest also into the development of company´s hydrogen fleets.** In companies, however, there is a mass purchase of cars and thus there is a greater potential for testing in larger quantities than in the case of individuals. Subsequently, after testing of the donation use and estimation of its theoretical allocation for common users, it is thus convenient to support this type of mobility to be used by private persons.

At the same time, the goal should be to raise awareness of other options when they decide about an alternative or clean drive. It is not only about electricity or hybrids, but also hydrogen plays a role and under certain conditions, it can be also considered as an option.

In general, firstly the support should be directed towards business customers and subsequently after donation allocation testing, the support could be also offered to common customers.

8.1.2.2 Public transport

Current agglomeration of big cities faces for long time now serious problem of the presence of high amount of CO_2 emissions in the air. In addition, let's add value to the noise levels of communications. Implementation of hydrogen buses into public transport thus represents attractive solution to both problems. According to the results of the Basic scenario the expenses for the support of hydrogen buses should reach 8 % of the overall hydrogen vehicle expenses and at the same time these buses partake in lowering all saved CO_2 emissions using hydrogen vehicles by a total of 32 %. This ratio of avoided emissions and expenses for the support of hydrogen vehicles appears to be more favorable with bus transportation than with passenger car transportation.

Hamburg, city situated in Germany, can serve undoubtedly as a foreign inspiration where the network of public hydrogen transport functions well today. Since April 2012, when it was launched, hydrogen buses traveled more than 500,000 km. City management also promised not to buy other vehicles than the non-emission ones by 2020. In addition, it is possible to draw inspiration from this type of project as it can be used in similar region in the Czech Republic.

It is also worth mentioning the success of the CHIC project again. In the context of adopting the cars themselves, first of all, hydrogen buses have reached a comparable mileage like diesel cars. CO_2 emissions were decreased by 85 %. Furthermore, 4.3 million litres of diesel were saved in total. As a result, hydrogen propulsion was judged to be 26 % more economically efficient than diesel.

If the state decides on potential public transport support, which according to this study´s results represents one of the best variants in the ratio of cost vs. performance, respectively the impact is clearly to set up a subsidy programme with sufficient allocation to cover the investment costs for a sufficiently large or strong agglomeration that will have the potential to use hydrogen buses and it will be possible to test it in the real life. The outputs can be subsequently compared with the example from Germany and other countries where the clean public transport already works. Agglomerations that are affected by emission pollution, for example in the Moravian-Silesian region, seem to be a very good base for such a pilot project due to their positive attitude towards alternative fuels.

8.1.3 Formal and legal aspects analysis

At the beginning of this study, legislation was perceived as being very inadequate. More specifically, legislation did not defined hydrogen as a potential fuel, it was not clear under which conditions it will be possible to build filling stations and general statement that Czech legislation does not know hydrogen, was absolutely accurate.

Legislation represents essential condition in order to define playing field for all subjects who want to join hydrogen sector, respectively its mobile part.

It is very good, that the expert group at the time of this study formation created constant pressure on the creation of the key legislation in this area Of these major impacts, it is worth mentioning in particular the amendment to the Fuel Act which now defines hydrogen as fuel (see § 2b). Simultaneously, the draft of the directive on the Building Act regulates the technical conditions for the construction of hydrogen filling stations and thus allows a better preparation of station projects based on defined standards and norms.

Following these changes, there are still concerns whether the amendments to the deciding act under the auspices of the Ministry of Trade and Industry were sufficient. **According to the opinions of subjects involved in the expert group, who were trying themselves to reach these changes, current wording is adequate and it enables the development of hydrogen market. The European directive is implemented in sufficient manner according to professional opinion.**

Expert representatives identified as a problematic part in the legislation area certain parts of the Building Act. This concerns in particular the factual lengths of the change in the territorial plan which, in the case of the construction of the filling station, must meet certain conditions and the changes to the territorial plans are generally very lengthy to infinite. It also relates to the length of building procedure and its several-stage procedure, but this is a general problem not only for filling stations, but also for the management of territorial and building procedure for any construction. The circle of objections and appeals from various entities can be repeated over and over, and then slow down the entire process of preparation for implementation.

There are other aspects that need to be thought of to enable the development of hydrogen mobility. These are amendments of state and local decrees that are linked to defined forms of support, and are more easily implemented and thus are from the category seen as supportive. Some of them are already used for electric cars therefore their implementation for hydrogen cars is more of a technical matter. These amendments would enable, for example the omission of road tax, parking of hydrogen cars on reserved places and in underground garages.

8.1.4 Increasing public awareness of hydrogen mobility, PR activities

Public surveys have shown that even though there is a positive attitude towards hydrogen technology as such, people do not have information about the functioning, the mechanism, and the undeniable benefits of hydrogen technology. **The fact that a hydrogen car is actually an electric car in terms of engine construction is not widespread among the general public**.

As the potential threat to further development is identified by many experts the non-existence of the public awareness about hydrogen mobility.

Strong positive PR is thus significant factor which will contribute substantially to further development of hydrogen in the transport. An expert view suggests that it is necessary to target most of the population, making hydrogen a trend and an interesting choice for both consumers and society as a whole. Effects are interlinked across areas - for example, the adoption of hydrogen buses and passenger cars in car sharing itself encourages ordinary citizens to notice energy-efficient cars around them more.

PR activities conducted by the Ministry, respectively by the state, are certainly essential, however, the involvement of industry and interest groups is the most crucial aspect in this respect. This can also be supported by an association in a working group (continuation of an expert group) that would regularly provide information on this type of propulsion.

Even the author of this study plans to further develop this topic (after termination of the contractual relationship with the Ministry of Transport of the Czech Republic) as he perceives it as essential for the future use of alternative fuels in transport and feels that positive PR is what can cause inclination towards hydrogen use in the Czech Republic.

The big minus of hydrogen mobility is that there is nobody like „Elon Musk“, who would promote it. It is thus necessary to engage more subjects who would have the same strength and impact on the media. This again leads to hydrogen expert group.

8.1.5 Hydrogen expert group continuation

The expert group was formed for the preparation of this study. It includes more than 20 experts who are interested in hydrogen mobility and see some potential in the direction towards hydrogen clean mobility. This group, throughout the preparation of this study, represented a certain internal opposition towards the findings prepared by the contracting authority. The expert opinions have been reflected in the study, and thanks to this expert view, it is possible to claim that the study on the hydrogen perspective in mobility in the Czech Republic looks much more complex than it might have been at the beginning of the work.

Other in-depth interviews were carried out with subjects outside the expert group in order to complement the opinions of expert group (13 in-depth interviews in total), which were supposed to deepen the complexity of the given topic.

It is not convenient for this group, which operated from January to June 2017, to cease its activity together with the completion of the work and with the handover of the study to the client, the Ministry of Transport of the Czech Republic. Its continuation, respectively **the continuation of its activities is a key point for the successful implementation of all related requirements and the transmission of information between entities.**

In-depth interviews with experts (in connection with the SWOT analysis) defined numerous drawbacks and threats of hydrogen mobility which will have to be faced when the market is created. It is thus exactly the group of experts from which the group consists, who is able to react quickly and design an efficient and effective solution.

At the same time, it is advisable for the group to operate in the future update of the NAP CM in order to ensure a certain continuity of activities and opinions. The group activity should by primarily characterized by constant pressure on Czech legislation bodies so that they ensure adequate implementation of recommended measures and certain benefits for hydrogen car (or generally clean) technology. Another activity should be oriented towards the use of EU subsidies and the dissemination of this opportunity among the public, i.e. to work together with the state in the field of PR.

8.1.6 Actualisation of NAP CM

Considering the information above, it is necessary in NAP CM (basic strategic document of the Czech government for alternative mobility) to significantly expand this part of the document regarding hydrogen and at the same time reflect all main recommendations included in this study. Besides, that is one of the accented findings from the in-depth interviews. It is necessary to simultaneously update the goal for the number of hydrogen stations. Current goal for 2025 is considerably undersized (3-5 stations). Modelled results of this study clearly show that when at least the basic development scenario is fulfilled, it is necessary to increase the ambitions of the hydrogen infrastructure construction. **Based on the hydrogen vehicle projection it is expected that at least 12 hydrogen filling stations will be necessary in Czech Republic in 2025.** The station locations are shown in chapter 6.7 Prediction of the filling stations location over time.

Sources

[1] *STUDIE O VÝVOJI DOPRAVY Z HLEDISKA ŽIVOTNÍHO PROSTŘEDÍ V ČESKÉ REPUBLICE ZA ROK 2013* [online]. B.m.: C e n t r u m d o p r a v n í h o v ý z k u m u, v. v. i. 2014 [vid. 2017-02-10]. Dostupné z: http://www.mzp.cz/C1257458002F0DC7/cz/studie_vyvoj_dopravy/$FILE/OOO-Studie_o_vyvoji_dopravy_2013-20141020.pdf

[2] *L_2007171CS.01000101.xml* [online]. [vid. 2017-01-29]. Dostupné z: http://eur-lex.europa.eu/legal-content/CS/TXT/HTML/?uri=CELEX:32007R0715&qid=1485725611322&from=EN

[3] DECOURT, B., R. LAJOIE, R. DEBARRE a O. SOUPA. Hydrogen-Based Energy Conversion Factbook. *Schlumberger Business Consulting* [online]. únor 2014 [vid. 2014-08-24]. Dostupné z: http://www.sbc.slb.com/SBCInstitute/Publications/Hydrogen.aspx

[4] Ropa, ropné produkty a zemní plyn - prosinec 2013. *Český statistický úřad* [online]. podzim 2014 [vid. 2014-08-23]. Dostupné z: http://www.czso.cz/csu/2013edicniplan.nsf/publ/8105-13-m12_2013

[5] *DOE Hydrogen and Fuel Cells Program: Well-to-Wheels Case Studies for Hydrogen Pathways* [online]. [vid. 2017-02-08]. Dostupné z: https://www.hydrogen.energy.gov/well_wheels_analysis.html

[6] *innogy | Vznik a historie ZP* [online]. [vid. 2017-02-09]. Dostupné z: https://www.innogy.cz/o-innogy/vznik-a-historie-zp/

[7] KALAMARAS, Christos M. a Angelos M. EFSTATHIOU. Hydrogen Production Technologies: Current State and Future Developments. *Conference Papers in Energy* [online]. 2013, **2013**, 9. Dostupné z: http://dx.doi.org/10.1155/2013/690627

[8] DOUCEK, Aleš, Luděk JANÍK, Daniel TENKRÁT a Petr DLOUHÝ. VYUŽITÍ VODÍKU K REGULACI VÝKONU OBNOVITELNÝCH ZDROJŮ ENERGIE. *CHEMAGAZÍN*. nedatováno, **2010**(3).

[9] *A portfolio of power-trains for Europe: a fact-based analysis - The role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles* [online]. B.m.: McKinsey & Company. 2010. Dostupné z: http://www.fch.europa.eu/sites/default/files/Power_trains_for_Europe_0.pdf

[10] Česká vodíková technologická platforma. 2017

[11] *Hyundai ix35 Fuel Cell | Hyundai Motor Company* [online]. [vid. 2017-02-06]. Dostupné z: http://worldwide.hyundai.com/WW/Showroom/Eco/ix35-Fuel-Cell/PIP/index.html

[12] *Heavy Duty Motive*. B.m.: BALLARD POWER SYSTEMS. 2016

[13] *Multi-Annual Work Plan | www.fch.europa.eu* [online]. [vid. 2016-09-22]. Dostupné z: http://www.fch.europa.eu/page/multi-annual-work-plan

[14] TOYOTA MIRAI TIDBITS. *Simanaitis Says* [online]. 27. červen 2015 [vid. 2017-02-08]. Dostupné z: https://simanaitissays.com/2015/06/27/toyota-mirai-tidbits/

[15] 54 new hydrogen refuelling stations worldwide in 2015. *www.tuev-sued.de* [online]. [vid. 2017-02-11]. Dostupné z: http://www.tuev-sued.de/company/press/press-archive/54-new-hydrogen-refuelling-stations-worldwide-in-2015

[16] *Hydrogen Filling Stations Worldwide - H2-Stations | netinform* [online]. [vid. 2017-02-09]. Dostupné z: http://www.netinform.net/H2/H2Stations/

[17] *International Partnership for Hydrogen and Fuel Cells in the Economy* [online]. [vid. 2017-02-10]. Dostupné z: http://www.iphe.net/partners/austria.html

[18] *Letter of Understanding on the Development and Market Introduction of Fuel Cell vehicles* [online]. 2009 [vid. 2017-02-10]. Dostupné z: http://www.hydrogenlink.net/download/LoU-fuelcell-cars.pdf

[19] *Car search on mobile.de – find your vehicle quick and easy* [online]. [vid. 2016-09-22]. Dostupné z: http://suchen.mobile.de/fahrzeuge/search.html?isSearchRequest=true&s=Car&ft=HYDROGENIUM&vc=Car&dam=false&od=UP&sb=p&ssid=13899040&sset=1471871045

[20] *Final Report MOVE/C1/2015-648 Study on the Implementation of Article 7(3) of the "Directive on the Deployment of Alternative Fuels Infrastructure" – Fuel Price Comparison* [online]. B.m.: European Commision. 25. leden 2017. Dostupné z: https://www.google.cz/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiPt7LNxoTSAhUrIcAKHXcsBgUQFggZMAA&url=http%3A%2F%2Fec.europa.eu%2Ftransport%2Fsites%2Ftransport%2Ffiles%2Fthemes%2Furban%2Fstudies%2Fdoc%2F2016-01-alternative-fuels-implementation-good-practices.pdf&usg=AFQjCNG6Rqy9qiiUz1IgmYyvKSn9cVCBtA&sig2=NPkGiHBzfNcqWarK3kRr7w&bvm=bv.146496531,d.ZGg

[21] *Green cars, Low emission cars, News, Reviews | Next Green Car* [online]. [vid. 2017-02-09]. Dostupné z: http://www.nextgreencar.com/fuelcellcars/available-models/

[22] *Toyota Mirai – The Turning Point* [online]. [vid. 2017-02-09]. Dostupné z: http://www.toyota.com/mirai/

[23] 2017 Clarity Fuel Cell – Environmentally-Conscious Vehicles | Honda. *Honda Automobiles* [online]. [vid. 2017-02-09]. Dostupné z: http://automobiles.honda.com/clarity

[24] ANNELI OJAPALO. *Proposal for Implementation Plan Hydrogen as Alternative Fuel in Finland* [online]. 30. prosinec 2015 [vid. 2017-02-07]. Dostupné z: http://hit-2-corridors.eu/wp-content/uploads/2015/01/NIP-Finland.pdf

[25] HUA, Thanh, Rajesh AHLUWALIA, Leslie EUDY, Gregg SINGER, Boris JERMER, Nick ASSELIN-MILLER, Silvia WESSEL, Timothy PATTERSON a Jason MARCINKOSKI. Status of hydrogen fuel cell electric buses worldwide. *Journal of Power Sources* [online]. 2014, **269**, 975–993 [vid. 2016-09-21]. ISSN 0378-7753. Dostupné z: doi:10.1016/j.jpowsour.2014.06.055

[26] *Annual Work Plans | www.fch.europa.eu* [online]. [vid. 2016-09-22]. Dostupné z: http://www.fch.europa.eu/node/843

[27] *Clean Hydrogen in European Cities - Guidelines for delivering fuel cell bus projects (D.4.8c)* [online]. B.m.: FCH JU. březen 2016 [vid. 2017-02-11]. Dostupné z: http://chic-project.eu/wp-content/uploads/2016/04/CHIC_Guidelines-for-delivering-fuel-cell-bus-projects-D4.8c.pdf

[28] *CHIC » Fuel cell electric bus project CHIC launches final project report as tool for cities and bus operators* [online]. [vid. 2017-01-19]. Dostupné z: http://chic-project.eu/newsevents/news/fuel-cell-electric-bus-project-chic-launches-final-project-report-as-tool-for-cities-and-bus-operators

[29] *Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe | www.fch.europa.eu* [online]. [vid. 2016-09-23]. Dostupné z: http://www.fch.europa.eu/publications/fuel-cell-electric-buses-%E2%80%93-potential-sustainable-public-transport-europe

[30] *Members | N.ERGHY* [online]. [vid. 2016-09-22]. Dostupné z: http://www.nerghy.eu/members/

[31] *In- Kind Additional Activities | www.fch.europa.eu* [online]. [vid. 2016-09-22]. Dostupné z: http://www.fch.europa.eu/page/in-kind-additional-activities

[32] *FCH JU Projects | www.fch.europa.eu* [online]. [vid. 2016-09-22]. Dostupné z: http://www.fch.europa.eu/fchju-projects

[33] SIMONSEN, Bjørn. *Nel Hydrogen*. 2. srpen 2017

[34] ELEMENT ENERGY FOR FCH JU. *Strategies for joint procurement of fuel cell buses - Final Report* [online]. červen 2016 [vid. 2016-09-18]. Dostupné z: http://www.fch.europa.eu/sites/default/files/Strategies%20for%20joint%20procurement%20of%20FC%20buses_0.pdf

[35] *NOW: now-gmbh.de | NIP funding programme* [online]. [vid. 2017-02-09]. Dostupné z: https://www.now-gmbh.de/en/national-innovation-programme/foerderprogramm

[36] NIP to Continue Until 2026: "Unique Success Story" › H2-international. *H2-international* [online]. 6. únor 2017 [vid. 2017-02-09]. Dostupné z: https://www.h2-international.com/2017/02/06/nip-to-continue-until-2026-unique-success-story/

[37] H2-Stationen. *H2 Mobility* [online]. [vid. 2017-02-10]. Dostupné z: http://h2-mobility.de/h2-stationen/

[38] TINKHAUSER. Linde Austria

[39] Projects. *HyCentA* [online]. [vid. 2017-02-10]. Dostupné z: http://www.hycenta.at/en/projects/

[40] *Circumstances of the national plan for hydrogenization of road transport in Poland* [online]. listopad 2015 [vid. 2017-02-10]. Dostupné z: http://hit-2-corridors.eu/wp-content/uploads/2015/01/NIP-Poland.pdf

[41] PGE to build Polish hydrogen filling stations. *WBJ* [online]. [vid. 2017-02-10]. Dostupné z: http://wbj.pl/poland-to-install-hydrogen-filling-stations/

[42] KLINGENBERG, Heinrich. The Hamburg Experience in the Context of the Pan-European Procurement of Fuel Cell Buses. In: *Hydrogen Days 2016*. Praha. 8. 4 2016.

[43] *V4 H2 COMPETENCIES* [online]. [vid. 2017-02-10]. Dostupné z: http://www.hytep.cz/V4-H2-competencies/

[44] ADMIN. About SHHP. *Scandinavian Hydrogen Highway Partnership* [online]. [vid. 2017-02-10]. Dostupné z: http://www.scandinavianhydrogen.org/shhp/about-shhp/

[45] Perspectives for a EU Roadmap for Rollout of Hydrogen Energy Infrastructure for Mobility - Current Plan Status. In: . Brusel. březen 2016.

[46] *National Implementation Plan Hydrogen Refuelling Infrastructure Belgium* [online]. prosinec 2015 [vid. 2017-02-10]. Dostupné z: http://hit-2-corridors.eu/wp-content/uploads/2015/01/NIP-Belgium.pdf

[47] NEWTON, Pascal a Xavier MONTAGNE. Research and Innovation on Hydrogen in France. In: . Brusel. 24. listopad 2016.

[48] ARICÓ, Antonino a Angelo MORENO. Italian National Activities. In: . Brusel. 19. květen 2016.

[49] National rollout plan of hydrogen refuelling infrastructure in Italy. *Mobilità Idrogeno Italia* [online]. [vid. 2017-02-10]. Dostupné z: http://www.mobilitah2.it/plan

[50] *IPHE Country Update May 2016: Korea* [online]. B.m.: INTERNATIONAL PARTNERSHIP FOR HYDROGEN AND FUEL CELLS IN THE ECONOMY. 2016 [vid. 2017-02-11]. Dostupné z: http://www.iphe.net/docs/Meetings/SC25/25-SC-Statement-Republic-of-Korea.pdf

[51] JUNBOM KIM. *Hydrogen Industry and Association of KOREA* [online]. B.m.: Hydrogen Industry and Association of KOREA. 2014 [vid. 2017-02-11]. Dostupné z: https://www.iea.org/media/workshops/2014/asiahydrogenworkshop/1.10_HydrogenIndustryKOREAJunbomKim.pdf

[52] *South Korea's Fuel-Cell Strategy Takes Page From China Solar Playbook | FuelCellsWorks* [online]. [vid. 2017-02-11]. Dostupné

z: https://fuelcellsworks.com/archives/2015/05/18/s-korea%e2%80%99s-fuel-cell-strategy-builds-on-solar-panel-model/

[53] *IPHE Country Update November 2016: JAPAN* [online]. B.m.: INTERNATIONAL PARTNERSHIP FOR HYDROGEN AND FUEL CELLS IN THE ECONOMY. 2016 [vid. 2017-02-11]. Dostupné z: http://www.iphe.net/docs/Meetings/SC26/26-SC-Statement-Japan.pdf

[54] Safety concerns hold back hydrogen stations. *FuelCellsWorks* [online]. [vid. 2017-02-11]. Dostupné z: https://fuelcellsworks.com/news/safety-concerns-hold-back-hydrogen-stations

[55] *IEA - Japan* [online]. [vid. 2017-02-09]. Dostupné z: https://www.iea.org/policiesandmeasures/pams/japan/name-24924-en.php

[56] EDELSTEIN, Stephen. Japan Eases Laws, Boosts Incentives For Hydrogen Fuel-Cell Cars. *Green Car Reports* [online]. [vid. 2017-02-09]. Dostupné z: http://www.greencarreports.com/news/1096324_japan-eases-laws-boosts-incentives-for-hydrogen-fuel-cell-cars

[57] Tokyo Aims to Realize „Hydrogen Society" by 2020 / JapanGov - The Government of Japan -. *JapanGov - The Government of Japan -* [online]. [vid. 2017-02-11]. Dostupné z: http://www.japan.go.jp/tomodachi/2016/spring2016/tokyo_realize_hydrogen_by_2020.html

[58] *2013 ZEV Action Plan* [online]. B.m.: California. 2013 [vid. 2017-02-09]. Dostupné z: https://www.opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf

[59] *Zero Emission Vehicle (ZEV) Program* [online]. [vid. 2017-02-11]. Dostupné z: https://www.arb.ca.gov/msprog/zevprog/zevprog.htm

[60] *2015 Development Plans | Northeast Electrochemical Energy Storage Cluster* [online]. [vid. 2017-02-11]. Dostupné z: http://neesc.org/publications/2015_roadmaps/

[61] *Hydrogen Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development* [online]. B.m.: California Environmental Protection Agency. červen 2016 [vid. 2017-02-11]. Dostupné z: https://www.arb.ca.gov/msprog/zevprog/ab8/ab8_report_2016.pdf

[62] NAVAS, Carlos. *Fuel Cells and Hydrogen Joint Undertaking*. 21. prosinec 2016

[63] *European Comission: Clean energy for all* [online]. [vid. 2017-03-03]. Dostupné z: https://ec.europa.eu/energy/sites/ener/files/documents/technical_memo_renewables.pdf

[64] ISO - Technical committees - ISO/TC 197 - Hydrogen technologies. *ISO* [online]. [vid. 2016-09-22]. Dostupné z: http://www.iso.org/iso/iso_technical_committee?commid=54560

[65] *Hydrogen Mobility Europe | www.fch.europa.eu* [online]. [vid. 2016-09-22]. Dostupné z: http://www.fch.europa.eu/project/hydrogen-mobility-europe

[66] *Hydrogen Mobility Europe 2 | www.fch.europa.eu* [online]. [vid. 2016-09-22]. Dostupné z: http://www.fch.europa.eu/project/hydrogen-mobility-europe-2

[67] *Hydrogen Mobility Europe* [online]. [vid. 2016-09-22]. Dostupné z: http://h2me.eu/

[68] *NREL: Hydrogen and Fuel Cells Research - Hydrogen Fueling Infrastructure Analysis* [online]. [vid. 2017-02-10]. Dostupné z: http://www.nrel.gov/hydrogen/proj_infrastructure_analysis.html

[69] *NREL: Hydrogen and Fuel Cells Research - Hydrogen Fuel Cell Bus Evaluations* [online]. [vid. 2017-02-10]. Dostupné z: http://www.nrel.gov/hydrogen/proj_fc_bus_eval.html

[70] *NREL: Hydrogen and Fuel Cells Research - Publications* [online]. [vid. 2016-09-23]. Dostupné z: http://www.nrel.gov/hydrogen/publications.html

[71] *Home | California Fuel Cell Partnership* [online]. [vid. 2017-02-10]. Dostupné z: http://cafcp.org/

[72] *Cars | California Fuel Cell Partnership* [online]. [vid. 2017-02-09]. Dostupné z: http://cafcp.org/cars

[73] Clean Vehicle Rebate Project. *Clean Vehicle Rebate Project* [online]. [vid. 2017-02-09]. Dostupné z: https://cleanvehiclerebate.org/eng

[74] *CHIC » Publications* [online]. [vid. 2017-02-11]. Dostupné z: http://chic-project.eu/info-centre/publications

Annex 1 – Model questionnaire

Hello,

We kindly invite you to participate in the survey "Use of Hydrogen Powered Vehicles in Transport in the Czech Republic". The questionnaire is anonymous and consists of 18 questions which take up to a maximum of 5 minutes to complete. The survey results will serve as one of the supporting documents for the strategic planning of the Ministry of Transport of the Czech Republic. If you are interested, we will be happy to provide you with the survey results.

Thank you very much for your time and answers,

Grant Thornton Advisory

Hydrogen mobility interest survey

1. **Do you know that hydrogen powered passenger cars are already being manufactured and in standard operation?**
   - Yes
   - No

2. **Would you be motivated to purchase a hydrogen-powered car by the fact that it is environmentally friendly (0% emissions)?**
   - Certainly yes
   - Rather yet
   - Rather no
   - Certainly no

3. Would you be willing to purchase a hydrogen-powered car at the acquisition cost of:
- At least 25% lower than the costs of conventional drive cars (petrol/diesel)
- Identical with the current costs of conventional drive cars
- Up to 25% higher than conventional drive cars
- Up to 50% higher than conventional drive cars

4. Would you be willing to purchase a hydrogen-powered car at the operating cost of:

- At least 25% lower than the costs of conventional drive cars (petrol/diesel)
- Identical with the current costs of conventional drive cars
- Up to 25% higher than conventional drive cars
- Up to 50% higher than conventional drive cars

5. Would you be motivated to purchase a hydrogen-powered car if financial support was provided by the government or car maker?

- Certainly yes
- Rather yet
- Rather no
- No

6. What minimum distance to empty would you tolerate in a hydrogen-powered car?

- Min 300 km
- Min 400 km
- Over 500 km (as with conventional cars)

7. What approximate refuelling time are you willing to accept in hydrogen powered car ?

- By ½ faster than in conventional drive cars
- The same as in conventional drive cars
- 2x longer than in conventional drive cars

8. Do you think that a hydrogen-powered car is safe?

- Yes, just like conventional cars
- Rather yes
- Rather no
- No, I find it very dangerous

9. Do you have any concern if buying a hydrogen-powered car?

(multiple answers are possible)

- High costs (purchase, operation, ...)
- Low availability of filling stations
- Low service availability
- Short distance to empty
- Low level of safety
- Smaller storage space
- High hydrogen price
- I do not have any
- Other:

10.Specify the main reasons why you would:

- PURCHASE:
- NOT PURCHASE:

a hydrogen-powered car.

Information about the respondent

11. What is your age?

- Up to 29 years
- 30 – 40 years
- 41 – 50 years
- 51 – 60 years
- 61 years and more

12. What is your gender?

- Female
- Make

13. What car do you use?

- Personal
- Company
- None

14. If you use a car, what fuel do you currently use?

- CNG
- LPG
- Diesel/petrol
- Electric car
- Hybrid
- I do not drive

15. How many kilometres a year do you drive on average?

- Up to 5 thousand km
- 6 to 10 thousand km
- 11,000 km or more

16. Which region do you live in?

- Capital of Prague
- Central Bohemian Region
- South Bohemian Region
- Pilsen Region
- Karlovy Vary Region
- Ústí Region
- Liberec region
- Hradec Králové Region

- Pardubice Region
- Vysočina Region
- South-Moravian Region
- Olomouc Region
- Moravian-Silesian Region
- Zlín Region

17. What is your highest level of education?
- primary
- secondary
- tertiary

Thank you for completing the questionnaire.

If you have any questions, please do not hesitate to contact Ms. Marie Kozmová (marie.kozmova@cz.gt.com).

18. We will be happy to send you the survey results If you are interested, kindly send us your e-mail.

Annex 2 – In-depth interviews

Topics of the questions:

- Introduction of GTA and the project
- Introduction of the respondent: describe your current position or job description related to H2

Usability of H2 in transport

- Description of the current and future status of hydrogen mobility incl. key milestones from the respondent's point of view
- Transport development prediction and position of hydrogen vs. electromobility
- Comparison of the approach to hydrogen mobility in other countries
- Financial/time/capacity investments in the topic of hydrogen
- The most significant risks/market opportunities and potential competitors in this segment

Definition of potential suitable support

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