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Market Analysis of FCEV Strategies for European OEMs

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Abstract: *This paper assesses the potential feasibility of a stand-alone fuel cell electric vehicle market for Europe to be evaluated as a possible alternative to battery electric vehicles (BEVs) in the global automotive industry. Here, the availability of hydrogen as well as the potential of the infrastructure associated with a fuel cell strategy must be considered. Taking into account the internal and external situations in the area of geopolitics, raw material production and import dependencies as well as the social acceptance of fuel cell vehicles (FCEVs), an actual situation is to be derived that shows what opportunities FCEVs have in a European and international market. The aim is to make clear which entry barriers exist in the industry, but at the same time which potentials a European OEM entry has. As a result, it can be shown that an FCEV strategy in the current situation would theoretically be well achievable.*

1. INTRODUCTION

Europe is to become the first climate-neutral continent. This is how the EU has formulated its objectives for climate policy and the resulting measures. This goal is to be achieved by 2050, and by 2030 a partial target has been set to reduce emissions by 55% compared to the reference year 1990. The EU policy sees an important share in the mobility sector, and here in the automotive industry. To this end, the Commission has decided that from 2035 onwards no more cars may be manufactured that are powered by fossil fuels (EU Commission, 2021).

The dominant alternative to fossil fuels so far is seen by OEMs in purely battery-powered vehicles (BEV), which are considered zero-emission vehicles in the emissions balance for engine technology. The breakthrough to a large-scale rethinking by customers has not been brought about, even though the number of BEVs is increasing. Other alternatives, such as fuels from agricultural products or hydrogen, are not yet implemented in Europe for a nationwide strategy, even though progress has already been made in the area of research and use in the truck sector.

However, the German Association of the Automotive Industry called for 2020 (VDA, 2020), "Especially in view of the major goal of climate-neutral transport, however, we will need all drive options - for example, also e-fuels and hydrogen. The great challenge of combating climate change will only succeed if we are open to all technologies. In our view, a tightening of the climate targets means that hydrogen and renewable fuels will have to be used much more in the future than they have been so far" (p. 3).

The reasons are seen in the not yet fully developed technology, which must first be built up through further research and development. In addition, no major progress has been made in

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the infrastructure of refueling facilities across Europe that would enable a nationwide strategy. Compared to the rest of the EU, Germany still has the largest refueling infrastructure, which, however, cannot be used by customers without problems (Hagendorn et al., 2019, p. 43).

In addition to the technical challenges, building a functioning hydrogen infrastructure is also economically demanding. The construction of hydrogen filling stations is expensive. Moreover, once the technical issues for hydrogen vehicles have been solved, a "chicken-and-egg" problem could loom: as long as there is no nationwide network of hydrogen filling stations, sales of hydrogen-powered vehicles will be slow. Conversely, no one feels motivated to invest in hydrogen filling stations as long as there is no significant population of hydrogen vehicles. (Hilgers, 2016, p. 61).

In the meantime, however, it has been increasingly recognized in electric car development that a pure BEV strategy poses problems for the European market due to various parameters. First of all, there is a high dependence on raw materials for battery production, the battery production itself, and the resilience of the supply chains. In addition, it is increasingly recognized that the recycling system for car batteries does not yet appear to be sufficiently developed (NPM, 2021, p. 10).

On this basis, the possibilities of the European OEMs are to be assessed as to whether a hydrogen strategy for vehicles can create an opportunity for improvement in the problem factors. For this purpose, the market must be recorded in its current situation and the possibilities of all relevant industrial factors for FCEVs must be estimated.

2. RESEARCH METHODOLOGY

The most popular market-oriented approach is associated with the research and findings of Michael Porter, whose well-known five forces model determines the factors for a market entry of new companies or the strategic reorientation of existing companies. In his model, Porter has thereby transferred the observation level of economic theories into an industry analysis model and considered the most important determinants acting on the industry as influencing factors on the existing companies. Porter´s five forces model is used within the desk research conducted for writing this article.

The model dates back to the 1980s and is still considered a stable cornerstone for market and sector analysis today. Thus, for the analysis of the FCEV market, despite existing criticisms of Porter's model, by pointing out usable possibilities for taking up the criticisms and omissions, Porter still has a substantial function.

3. MARKET ANALYSIS OF THE AUTOMOTIVE INDUSTRY FOR FCEVS

Asian automakers have established themselves as leaders in the global FCEV market due to their remarkable contributions to the field of technological advancement. The companies have made significant investments in R&D and production, giving them a competitive edge. Due to their extensive investment in R&D, Japan, South Korea and China now dominate the global FCEV market and are the main producers of FCEVs (Lou et al., 2020). The statistical data show that almost 2/3 of all FCEVs registered worldwide are in Asian countries, with South Korea representing the main national sales market with approx. 3/4. Japan follows with the remaining statistically recorded FCEV of approx. 1/4. China will offer its own FCEV models in the future (Wang, 2021), and therefore does not appear in the statistics, as Korean and Japanese models have dominated the range so far.

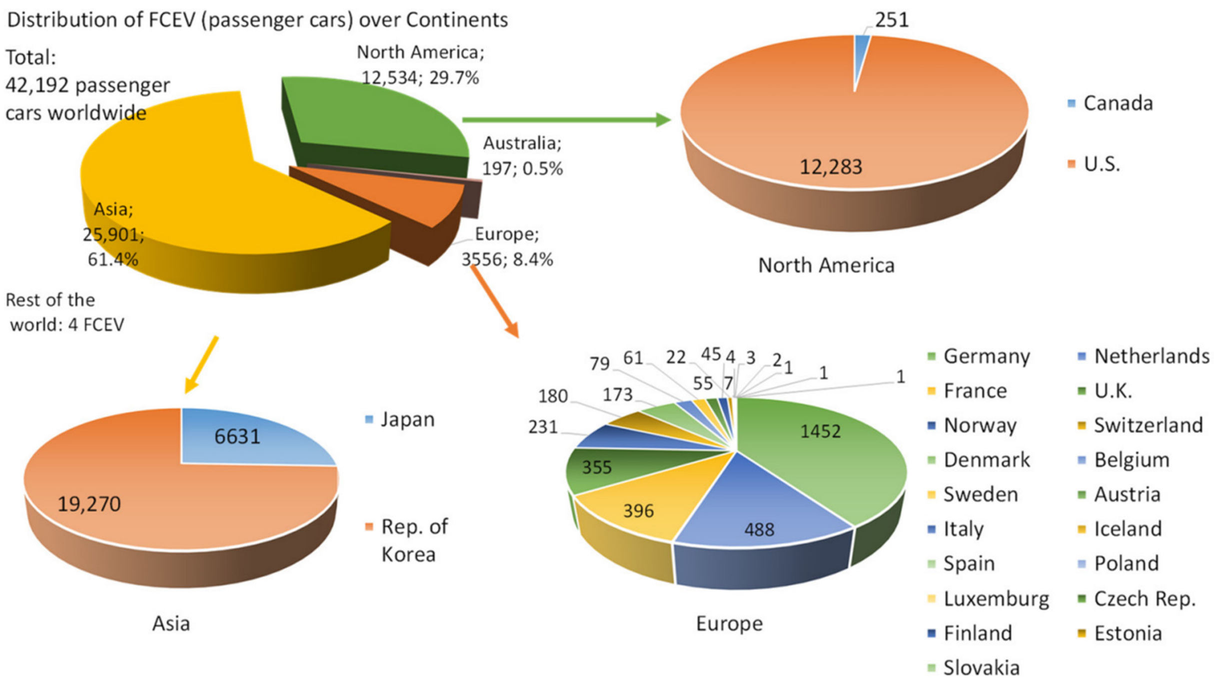

Figure 1. FCEVs in absolute numbers worldwide

Source: Samsun et al., 2022, p. 6

Assuming that there are more than 48 million registered passenger cars in Germany alone and that 2.7 million of them have an alternative drive to fossil combustion (DENA, 2022, p. 1), it is impossible to speak of a real market segment. A comparison with 2020 shows an increase in European registrations of FCEVs, but the share is still very low at 3,556 vehicles and remains below 1% of all vehicles.

For the sector of larger automobiles in the area of buses and trucks, the use of fuel cell technology seems to be most efficient at the current state of the art, as the construction sizes of fuel cells and tank sizes are easier to implement. This vehicle segment is also expected to have the greatest market potential for fully dedicated market segments in the near future (Belmer et al., 2019, p. 13). Outside China, there were still almost no commercial vehicles equipped with fuel cell drive systems in 2020. In addition, the continuous increase in the performance of batteries in terms of range and charging time further limits the market opportunities for fuel cell commercial vehicles (Clausen, 2022, p. 39).

In 2022, the statistical data confirms the clear dominance of registered vehicles in the Asian region. With its expanding strategy of hydrogen use, China has developed a wide lead here that exceeds the use of other Asian markets many times over. The commitment to research and development and its strategic, long-term approach have helped China to achieve a significant share of global supply (Zhang et al., 2017). This is also related to the possibilities of hydrogen production, which in China is based on fossil fuels (coal and natural gas). Of the global share of 63 million tonnes of hydrogen, China accounted for 22 million tonnes (WKÖ, 2022, p. 31). This means that there is a high potential, but the energy balance is sobering due to the production of 'black' (coal-based) and 'grey' (natural gas-based) hydrogen (Clausen, 2022).

The figures for FCEV truck registration show the following statistical distribution by selected countries.

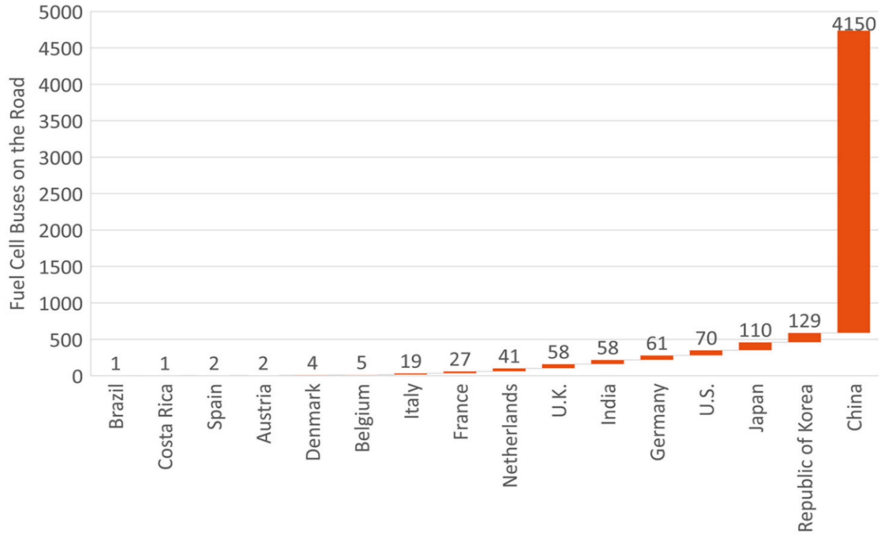

Figure 2. Registered buses on the road as FCEVs

Source: Samsun et al., 2022, p. 8

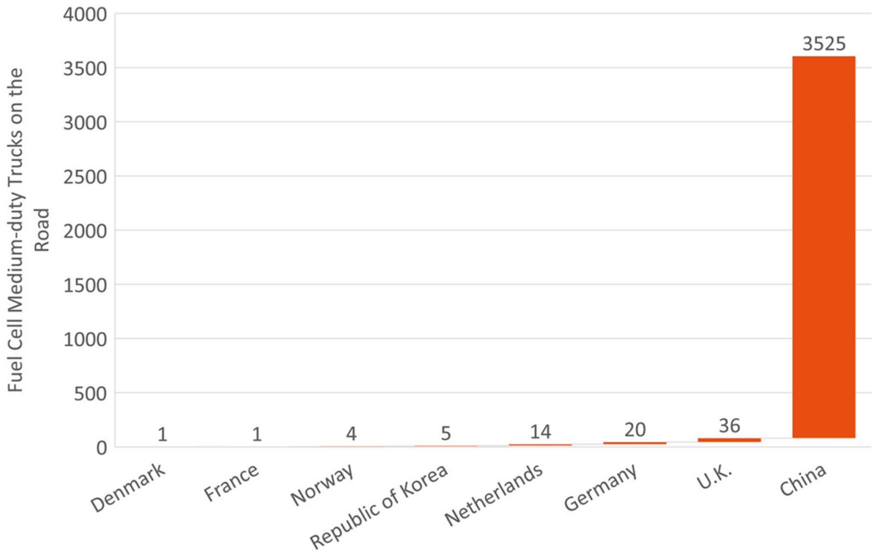

Figure 3. Registered commercial vehicles on the road as FCEVs

Source: Samsun et al., 2022, p. 8

In the past, Asian FCEV manufacturers have focused on meeting domestic demand. Instead of looking outside for economic opportunities, several Asian countries have chosen to focus first on expanding their own economies and supplying their domestic markets (Yang et al., 2020). They have been able to get a head start in manufacturing and expanding FCEV infrastructure, thus creating a solid foundation.

China started the internal expansion of an FCEV infrastructure in 2019 and has provided various government support programmes for this purpose in 2020 (WKÖ, 2022, p. 38). In doing so, China is also relying on market leadership in battery production, which is necessary for FCEVs. The previous autonomy in this area could be maintained through far-reaching state subsidies. In 2020, the subsidies were suspended and the Chinese domestic market was also opened to international battery manufacturers. Korean and Japanese companies have since established themselves in the market.

The widespread adoption of FCEVs requires the development of a comprehensive hydrogen infrastructure that includes an extensive network of hydrogen refueling stations and increased capacity for hydrogen production. The effectiveness of export efforts depends on the availability of the necessary infrastructure for the widespread acceptance of FCEVs by foreign buyers (Xuesong et al., 2005).

There is potential for collaboration between non-Asian stakeholders and Asian manufacturers to jointly increase the attractiveness and stimulate demand for FCEVs in markets outside Asia. Cooperation could bring benefits in several areas, such as FCEVs, hydrogen refueling networks, technological standards and sharing of best practices (Saadi et al., 2020). Building bilateral alliances and joint efforts can also help advance the goals of Asian FCEV manufacturers in exporting their products. Improving international cooperation increases the potential for mutual benefits through the exchange of information, expertise and resources between participating nations. The establishment of these groups can accelerate the development of infrastructure for FCEVs in markets outside of their own country, thus promoting the globalization of the FCEV industry (Raminosoa et al., 2010).

Asian manufacturers are currently investing in the research and development of FCEVs as a viable replacement for battery electric vehicles (BEVs). These manufacturers are particularly focused on the markets in Japan, South Korea and China. These countries are keen to reduce their dependence on fossil fuels and see the development of FCEVs as an important means of achieving this goal. Japan is making significant investments in research and development of fuel cell electric vehicles (İnci et al., 2021) to address energy security and environmental sustainability issues. The Japanese government hopes to have 80,000 FCEVs on the road by 2030. To achieve this goal, all major Japanese manufacturers, led by Toyota, have invested heavily in the development of FCEVs (Akinyele et al., 2020).

Thanks mainly to South Korea's financial investments, (FCEV) technology has made considerable progress (Panday & Bansal, 2014). South Korean car manufacturers Hyundai and Kia were among the first to produce FCEVs (fuel cell electric vehicles). To this end, the South Korean government has invested heavily in hydrogen refueling stations so that citizens can use FCEVs. The result of all these efforts is an increase in sales of FCEVs, making them more competitive with BEVs (Mokrani et al., 2014).

China, which leads the world in automobile consumption, recognizes the inherent opportunities of FCEVs to reduce the country's dependence on non-renewable energy sources. The Chinese government has set a strategic goal of achieving parity between the production of FCEVs and battery electric vehicles (BEVs) within the next decade. Chinese manufacturers, such as BYD and Geely, are actively engaged in the research and development (R&D) of FCEVs to meet growing demand in the domestic market and build a future competitive advantage in international markets (Pei & Li, 2019). For the time being, the Chinese government is planning to increase the number of FCEVs in the commercial vehicle sector. To this end, 100,000 FCEVs are to be produced by 2025 (WKÖ, 2022, p. 42).

The promotion of FCEVs is in line with the long-term goals of these three countries to reduce greenhouse gas emissions, improve energy security and combat climate change (Zhang et al., 2018). Asian manufacturers recognize that FCEVs have the potential to compete with battery electric vehicles (BEVs) due to their advantages in terms of longer range, shorter refuelling time and the ability to use renewable hydrogen as a fuel source.

South Korea is likely to set more ambitious targets for the widespread adoption of FCEVs in the near future. The goal is to sell 700,000 fuel cell electric vehicles by 2030. The government is working on a strategy to achieve this goal by offering financial incentives to promote the use of FCEVs and supporting the expansion of hydrogen refuelling stations (Samsun et al., 2022, p. 14).

In recent years, both the production of FCEVs and the widespread use of this technology have not increased in Europe until 2021. While there was significant development of FCEV technology in the region in the late 1990s and early 2000s (Mohrdieck et al., 2017, p. 64). In contrast, however, battery electric vehicles (BEVs) have emerged as market leaders in recent years (Mitzel & Friedrich, 2018, p. 131). As a result of this shift, Europe fell behind other regions in the development of FCEVs. Several European countries investigated the feasibility of fuel cell vehicles. Some European car manufacturers have developed fuel cell prototypes or produced fuel cell cars in small numbers. BMW, Mercedes-Benz, Peugeot, Renault and Volkswagen are just some of these manufacturers. The purpose of these tests was to evaluate the performance of FCEVs under realistic conditions (Weider et al., 2003, p. 14).

The number of FCEV registrations in Europe has remained shockingly low despite pioneering efforts and technical achievements. There are currently less than 4,000 FCEVs on the road in Europe. One problem area is the infrastructure for refuelling FCEVs. Hydrogen refuelling stations have not become widespread for many reasons, including a lack of supporting infrastructure, high costs and complicated logistics.

In the meantime, however, the efforts to achieve the climate goals as well as energy supply problems are being expanded by geopolitical tensions in the European markets. The looming energy crisis caused by Russia's attitude towards massive European support with military goods for Ukraine as well as a threatening conflict with China over the Taiwan issue are currently massive triggers here.

The expansion of hydrogen infrastructure will thus continue, which will also lead to an increase in the number of hydrogen filling stations worldwide. Asia leads the way with 275 hydrogen filling stations, followed by Europe with about 200, of which almost 100 are in Germany. In North America, 75 hydrogen filling stations are in operation, 50 of which are in California alone, where the implementation of climate change in the USA has progressed the furthest (H2-Mobility, 2021, p. 7).

The shift in thinking has become more apparent, especially currently. The ongoing crisis in Ukraine since 2014 has led to a looming reduction in the availability of natural gas, an energy source that has long been crucial for Europe (Chaitanya & Rambabau, 2014). Following recent disruptions in natural gas supplies, demand for reliable alternatives has increased as prices have risen significantly (OECD, 2022, p. 5). These factors have led Europeans to invest in researching and developing alternative energy sources, as well as in upgrading their energy infrastructure. Cooperation between European countries and energy-rich countries such as Qatar and Abu Dhabi to build liquefied natural gas (LNG) facilities is crucial. The use of these terminals is crucial for the production of hydrogen, which acts as a flexible and environmentally friendly energy carrier (Huang et al., 2019).

The introduction of FCEVs in Europe has the potential to increase the region's competitiveness, reduce its dependence on fossil fuels and make a significant contribution to the decarbonisation of transport (Uzunoglu & Alam, 2007). Moreover, the global automotive sector provides a highly competitive environment for the effective introduction and diffusion of FCEVs, as well as for solving energy supply problems (Gautam et al., 2021). In comparison, the European market for

FCEVs records a much lower number of registrations (Ahmadi et al., 2018; Samsun et al., 2022). In contrast to the established standards in the Asian market, one problem that is hampering the progress of truck and bus manufacturers towards widespread series production is the inadequate infrastructure (García et al., 2013; H2-Mobility, 2021).

Passengers cars	BMW	FCEV passenger car (2022) iHydrogen Next as technology project
Light commercial vehicles	Opel	Vivaro-e-Hydrogen (end of 2021) and two similar models Peugeot/ Citroën as small series, produced in Rüsselsheim (Germany)
Heavy commercial vehicles	Daimler/Volvo Joint-Venture (Found March 2021)	Develpoment of FCEV lorry, serial production from 2025
Busses	Different manufacturers	Actual projects in Europe, e.g., Solaris (Poland), Safra (France), Van Hool (Netherlands), CaetanoBus (Portugal)
Automobile suppliers	Different companies	• e.g., Bosch (inclusive a Joint Venture with Chinese Commercial vehicles manufacturer) • e.g., Joint Venture Elring/Klinger/ Plastic Omnium • e.g., Joint Venture Michelin/ Faurecia • e.g., Mahle

Figure 4. Projects for the production of FCEVs in Europe
Source: AT-Thuringia, 2021

4. RESULTS

If one first considers the internal competition of the OEMs in Europe and the existing possibilities for using fuel cell technology, then a concentration on commercial vehicles would be worthwhile for Europe, similar to China. The technology has been researched and can be classified as proven in numerous test series (Blaumeiser & Artz, 2022, p. 4). Since long-distance transport accounts for a large part of the traffic volume, concepts here are also worthwhile in terms of climate balance. Similarly, the expansion of the public transport sector in the area of public passenger transport would be a planning model that, with government support, would mean a push factor for fuel cell technology.

An expansion of the refuelling infrastructure would thus be worthwhile with government support if a large number of trucks and buses have a fuel cell drive. Within an infrastructure plan, primary areas can thus be identified that could be served with infrastructure. The NPM (2021) recommends, "In principle, the filling stations must be set up primarily to meet demand. This means that close cooperation with the relevant vehicle manufacturers should take place on the first pilot routes" (p. 14).

These include motorways, major cities and transport interfaces between road and rail, water transport and airports. Similarly, regions with strong industries can also be planned into the networks in a reach-oriented infrastructure. In addition, urban areas would have to be developed to make public transport by bus profitable. To this end, natural gas pipelines could also be converted into a hydrogen pipeline system in the existing infrastructure, which would accelerate the development of the supply infrastructure (NPM, 2021, p. 12).

Commercial vehicle manufacturers in Europe include numerous manufacturers in a wide range of countries that could participate in an expansion. Mercedes, VW, MAN, Steyr, Volvo, etc. are spread across the continent and the use of the infrastructure can be exploited throughout Europe. In the passenger car segment, an expansion of the infrastructure of refuelling stations would also increase, as demand can increase among customers since fuel cell vehicles have clear advantages in areas that customers perceive as important in their utility behaviour. Here they are similar ranges to fossil drives, fast refuelling and zero emissions in terms of climate-relevant morals (H2-Mobility, 2021).

When considering suppliers, hydrogen is an important area to include in strategies in Europe, in addition to technical goods. Nations in Europe with large OEM market shares such as Great Britain, France and Germany are dependent on imports of hydrogen. Other countries, Norway, Spain and Portugal, rely on the export strategy, although the quantities will not be sufficient for European consumption. This is also dependent on the further development of natural gas supplies from Russia, which are currently failing and cannot be rebuilt in the foreseeable future. Therefore, new supply chains for natural gas and liquefied petroleum gas are being established that focus on the Middle East, Canada and Australia. However, these solutions are also linked to other conditions, as Australia and Canada rely on grey and black hydrogen, respectively, which cannot be considered conducive to climate goals.

In addition, the UK, Germany and France have already passed a supply chain law that places strict requirements on companies in terms of sustainability, so that theoretically certain nations are excluded from the conditions (Grünewald, 2022). This would include Australia and Canada, which do not comply with the concept and principles of the law due to the high energy requirements for hydrogen production. In addition, there are long delivery routes via the sea, which is not resilient and is also reflected in the eco-balance. Green hydrogen is not yet available in sufficient quantities in production to gain an overall advantage in the life cycle assessment.

Moreover, in terms of supplier structures and power influence on OEMs, the battery also remains a factor to be considered. Already in the BEV sector, the battery was seen as one of the weak points in the resilience of European value creation for the entire continental automotive industry. High dependencies on Asian manufacturers, with China in the lead, must also be taken into account in a hydrogen strategy. These are mainly due to the large demand, which is expanding faster than Europe's and thus forcing networks worldwide, which can restrict Europe (Heuser et al., 2020).

The power of customers in the FCEV scenario can be seen as significant in that a corresponding offer would always be popular and FCEVs would generate a demand that would consolidate a market maturity. However, similar to what was the case with BEVs, the factors of private mobility and cost are decisive. For customers, however, the FCEV seems to be an alternative to the BEV. One-third of Germans, as one of the largest demand markets in Europe, would like to see an FCEV on offer (Clausen, 2022, p. 1). However, it has already been shown with pure BEVs that customers are increasingly investing in model segments that provide larger car models, despite a greater awareness of sustainability.

5. DISCUSSION

Europe is in a difficult position when it comes to the question of climate neutrality. This is particularly evident in the area of public mobility, where dependencies on other nations as suppliers of energy and important components and groups can be described as high. The transport sector is important here in that it is seen as having great potential for achieving the climate neutrality targets, but these have not been met. Other sectors are already on a more successful path here, as the data show. In Figure 5, the dotted line above is the EU's intended reduction targets in the transport sector (Corneille & Maier, 2021).

The requirements for fully aligned green infrastructures in the areas of energy, electricity and mobility can currently only be met to a small extent. Hydrogen production is dominated by energy-intensive and emission-intensive processes (IEA, 2019; World Energy Council Europe, 2021). There is a need for generally intensive investment to lay the foundations.

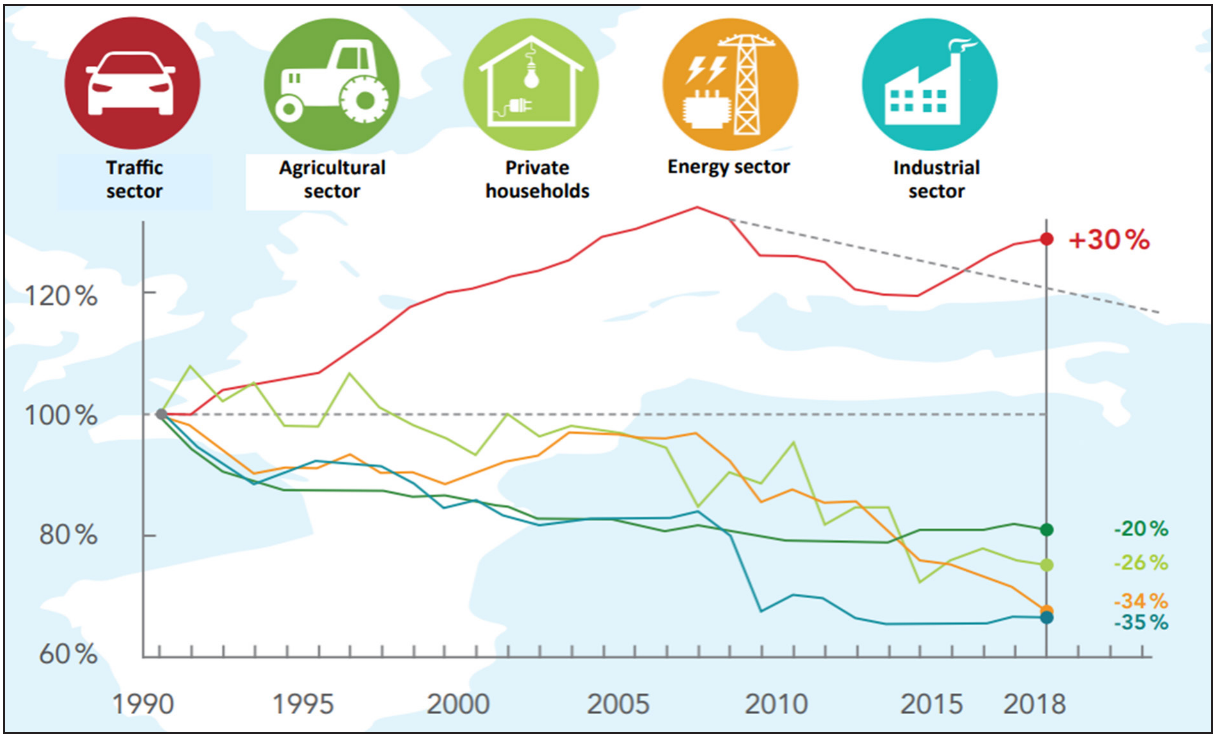

Figure 5. Greenhouse gas emissions in Europe by sector 1990 to 2018

Source: Pro-Rail Alliance; in: Corneille & Maier, 2021, p. 7

Possibilities of intensive production for green hydrogen are already seen, but implementations so far have not been tackled. Heuser et al. (2020) have shown in studies that the possibilities would be possible using photovoltaic and wind energy in certain nations. In Europe alone, Norway, Ireland, Great Britain and Iceland would use wind energy, which could cover a large part of the demand (p. 14). In addition, large quantities of emission-free hydrogen could be produced through photovoltaics in African states in the north and south, as well as in the Middle East. This also includes Libya and Egypt, which as Mediterranean countries would be in direct contact with Europe (Heuser et al., 2020, p. 16).

However, the production routes to date are concentrated in the use of natural gas and coal. Particularly important is the development of economic relations with Russia, which are currently at a minimum. As an energy supplier of natural gas and in some areas of raw material extraction of ores, Russia has so far been the most important trading partner (CEPR, 2022). After the war of aggression on Ukraine, a reorientation has become necessary.

China is also an important trading partner in many areas of supply and production of necessary industrial goods, but here too the future basis for cooperation is very uncertain. The situation surrounding the Chinese attitude towards Taiwan can quickly turn into a military intervention, forcing Europe into a stance like the one it already has towards Russia today. Waiting is a bad option, so intensifying the disengagement from Chinese imports must be considered at a higher level now.

If Europe decides to maintain BEV production to meet mobility needs, the following points must be taken into account.

- Detachment from battery production in the international area through intra-European production.
- Obtaining sufficient quantities of raw materials for the production of batteries as a key technology, lithium, graphite and cobalt are the critical factors here (Bünting et al., 2023, p. 41).
- Supply chain legislation as an alignment criterion of supply chains according to the guidelines of humanity and climate protection (Frieske et al., 2022; Grünewald, 2022).
- Sufficient capacities in the electricity grids to be able to meet the increasing demand (risk of overloading existing grids) (Hagendorn et al., 2019, p. 150; Korzynietz et al., 2023; Zapf, 2020).
- Climate balances by producing more electricity from renewable/alternative sources (Korzynietz et al., 2023).

When expanding the possibilities of an FCEV strategy, necessary points of consideration for European OEMs are:

- Hydrogen imports from geopolitically safe regions.
- Import from nations that meet delivery law requirements.
- State and industrially supported hydrogen production in Europe.
- Requirement for climate neutrality by means of expanding the production of green hydrogen.
- Autonomous battery production in Europe for FCEV technical requirement.
- Commodity security from geopolitically secure regions.
- Expansion of the infrastructure
- Cooperation with petrol station operators and new providers in the fuelling segment.

These points represent the core elements but are further development moments for a fuel cell strategy due to other - also still to be researched - influencing factors.

6. CONCLUSION

An introduction of hydrogen as an alternative to pure BEVs is technically possible. However, it depends on many factors that need to be addressed now in order to achieve greater continental independence. For this, the own continental resources and production potentials must be better utilized, but this directly follows from the requirements for sustainable productions. Grey, black and brown hydrogen are options here that could still be used in a transitional phase for a time in order to build up the possibilities of green production during this period. Wind and photovoltaics are factors to be used here.

In general, due to current uncertainties in the geopolitical situation, Europe needs to think about a so-called Plan B with nations that have supported the current BEV strategy. Russia and China, as economic giants, are at the forefront of this. Russia's economy is already decoupled from Europe in many areas and China could follow with a military intervention in Taiwan. It would therefore be negligent if the consequences were only assessed when the worst comes to the worst. Europe should therefore intensively detach itself from many currently existing dependencies now and build up a continental strategy that is resilient and at the same time can also build up renewed market leadership. The FCEV market still offers great potential in this regard, as it is still being built up worldwide, but can in turn become a disadvantage for European OEMs due to Asian efforts, as is already the case with BEVs.

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