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ADVANCED FUEL CELLS TECHNOLOGY COLLABORATION PROGRAMME

REPORT ON MOBILE FUEL CELL APPLICATION: TRACKING MARKET TRENDS

Mobile Fuel Cell Application: Tracking market trends

R.C. Samsun*, L. Antoni**, M. Rex***

*Forschungszentrum Jülich GmbH, IEK-14: Electrochemical Process Engineering, 52425, Jülich (*Germany*)

**Commissariat à l'énergie atomique et aux énergies alternatives, 38054, Grenoble *(France)*

***Secretariat Technology Collaboration Programme on Advanced Fuel Cells, 40476 Dusseldorf *(Germany)*

Abstract – This report gives an overview of the present market trends in transportation applications. AFC TCP survey on the deployment of fuel cell vehicles as of end 2019 estimates a total of 25,212 vehicles worldwide. The number of passenger cars reached 18,913 showing 69% increase in one year. Most of the passenger cars are on the U.S. roads, whereas China dominates the numbers for buses and light- and medium-duty trucks. The total number of hydrogen refueling stations, including both public and non-public ones, reached 470. Public stations in three countries, namely Japan, Germany and the U.S. represent more than half of the total number of stations worldwide. The report also includes data on technical specifications of passenger cars, available incentives, technical data on refueling stations and finally some perspectives on a timeline.

1. Introduction

The fuel cell technology can provide a substantial contribution to achieve the worldwide set of emission targets in several sectors. This report gives an overview of the present market trends on mobile fuel cell applications. Firstly, the results of the AFC TCP survey on the worldwide deployment of fuel cell vehicles are presented. This is followed by information on selected vehicles, subsidy schemes and purchase prices in selected countries. Secondly, the status quo on the hydrogen refueling station infrastructure is captured with additional information on stations. In the third part, an update on the announced targets, visions and projections is given.

2. Fuel cell vehicles

This section firstly presents an overview of the results of the AFC TCP survey on the number of fuel cell vehicles registered worldwide as of end of 2019. Furthermore, the development of the numbers from 2017-2019 are discussed. Afterwards, technical information on available passenger car models is given. The final section gives an overview of the incentives in selected countries, together with some figures on the purchase prices.

2.1. Results of the AFC TCP survey on the number of fuel cell vehicles

At the beginning of 2020, AFC TCP started a survey to monitor the number of fuel cell vehicles on the road as of end of 2019. This is the third AFC TCP survey on this topic, followed by the ones, which reported the status at the end of 2017 and 2018. On the one side, data from AFC TCP member countries was provided by the Executive Committee Delegates for their own

country. On the other side, publicly available information was collected to fill the gaps and cover the complete world. In addition, European data was provided by the FCH 2 JU Program Office. The information sources for the data collection on fuel cell vehicles are given in references [1] to [15]. Data is as of 31.12.2019 unless otherwise stated in the reference. The numbers represent the number of vehicles on the road (registered) with the exception for [9], where the data is provided by OEMs and is related to cars sold (cumulative 2013-2019).
The survey results showed that 25,212 fuel cell vehicles were on the road as of end of 2019 worldwide. Figure 1 shows the distribution of these vehicles to different countries. Most of the vehicles are in the U.S., followed by China, South Korea and Japan. Figure 2 shows that 59% of the vehicles are in Asia, followed by 32% in North America and 9% in Europe. The total number includes passenger cars, buses, light- and medium-duty trucks and heavy-duty trucks. As presented in Figure 3, most of the vehicles are passenger cars (75%), followed by buses (17.7%) and light- and medium-duty trucks (7.3%). The share of heavy-duty trucks is negligible as of end of 2019, however, this number is still monitored, since the application of fuel cells for the propulsion of heavy-duty trucks is considered as a very promising technology and there are important development efforts worldwide. To track the expected growth in this area, this vehicle category is included in the survey for the first time.

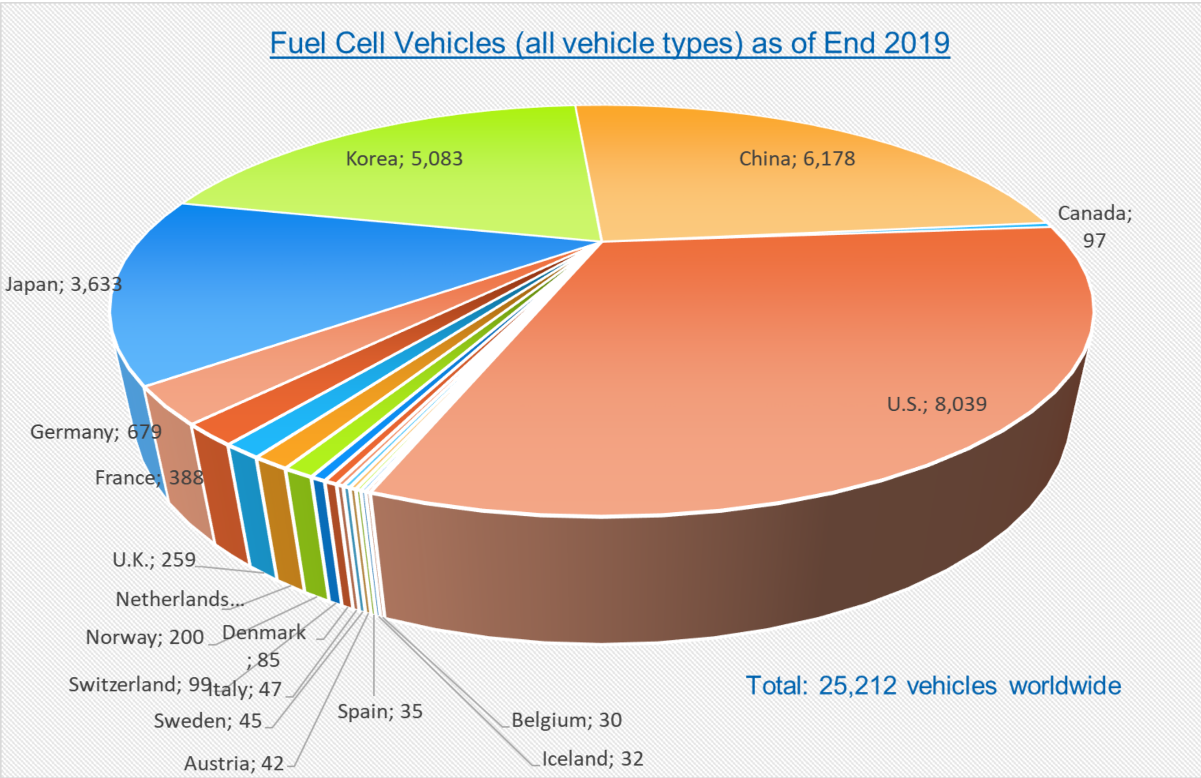

FIGURE 1: DISTRIBUTION OF FUEL CELL VEHICLES ON THE ROAD AS OF END 2019.

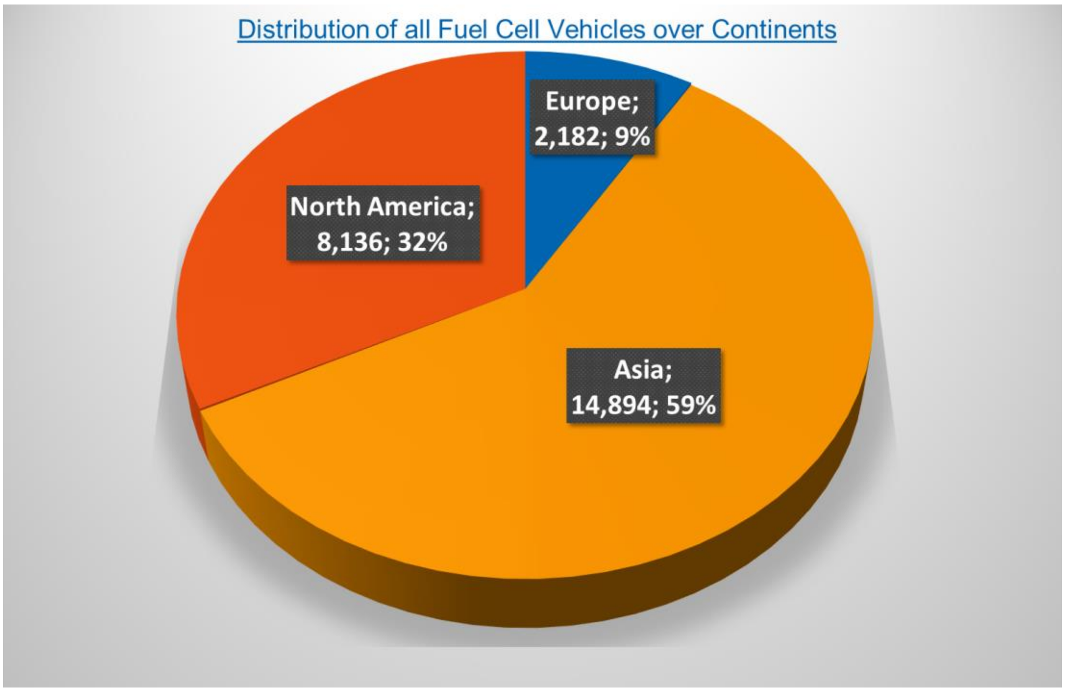

FIGURE 2: DISTRIBUTION OF ALL FUEL CELL VEHICLES OVER CONTINENTS AS OF END 2019.

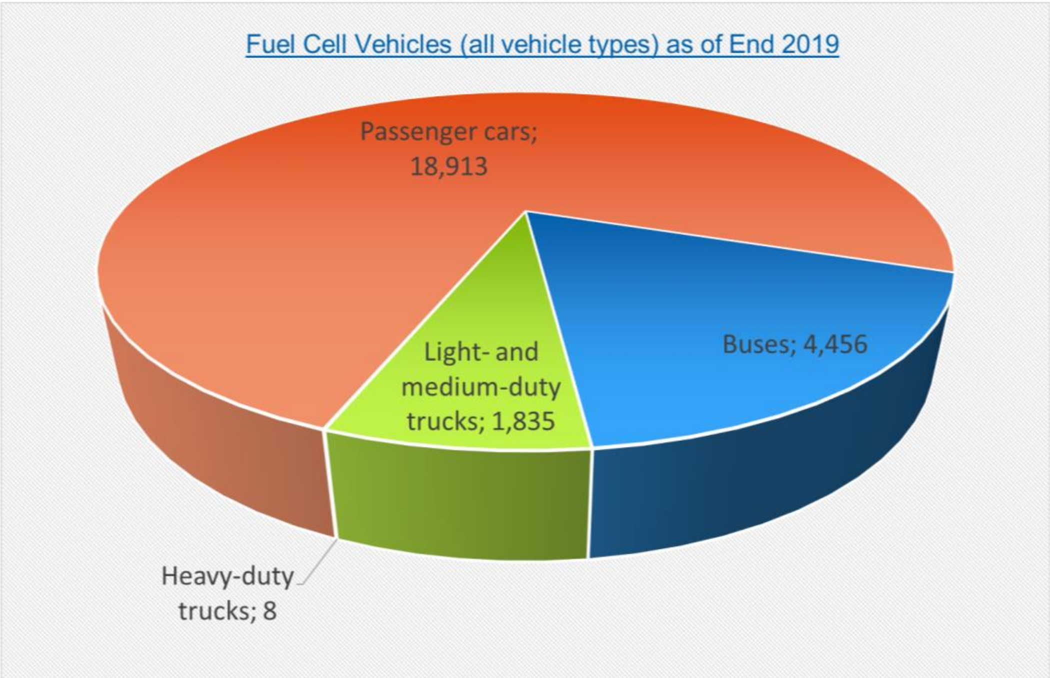

FIGURE 3: SHARE OF DIFFERENT VEHICLE TYPES IN THE TOTAL NUMBER OF FUEL CELL VEHICLES WORLDWIDE.

After the total overview on all vehicles, we can now focus on passenger cars. As Figure 4 shows, most of the passenger cars are again in Asia (46%), followed by North America (43%) and Europe (11%). From the 8,093 FCEVs in North America, already 98.8% of the cars are in the U.S. with 7,997 cars as Figure 5 presents. Looking at the Asian market in Figure 6, we can recognize that the passenger car market is dominated by South Korea and Japan with a share of 99.2% together. It also becomes clear that from the 6,178 fuel cell vehicles in China (see Figure 1), only 74 vehicles are passenger cars showing a totally different trend than the rest of the world. It is, therefore, worthwhile to look at the Chinese market separately at the end. The European market is dominated by fuel cell passenger cars (FCEV) from Germany and France, as shown in Figure 7. Almost 50% of the European FCEV population are in these two countries. The U.K., the Netherlands, and Norway follow these countries and each have around 200 FCEV.

Looking at the 4,456 fuel cell buses in detail in Figure 8, it can be seen that the Asian market dominates the fuel cell bus market with 97%. From the 4,334 buses in Asia, already 4,297 are in China. If we look into the Chinese fuel cell market in detail with the help of Figure 9, it becomes clear that this market is dominated by buses and light- and medium-duty trucks. Also, the Chinese numbers dominate the worldwide numbers with 96.4% of the worldwide fuel cell bus fleet and the 98.5% of the worldwide fleet of fuel cell light- and medium-duty trucks being operated in China as of end of 2019. In comparison, only 0.4% of the worldwide FCEV (passenger car) fleet is in China.

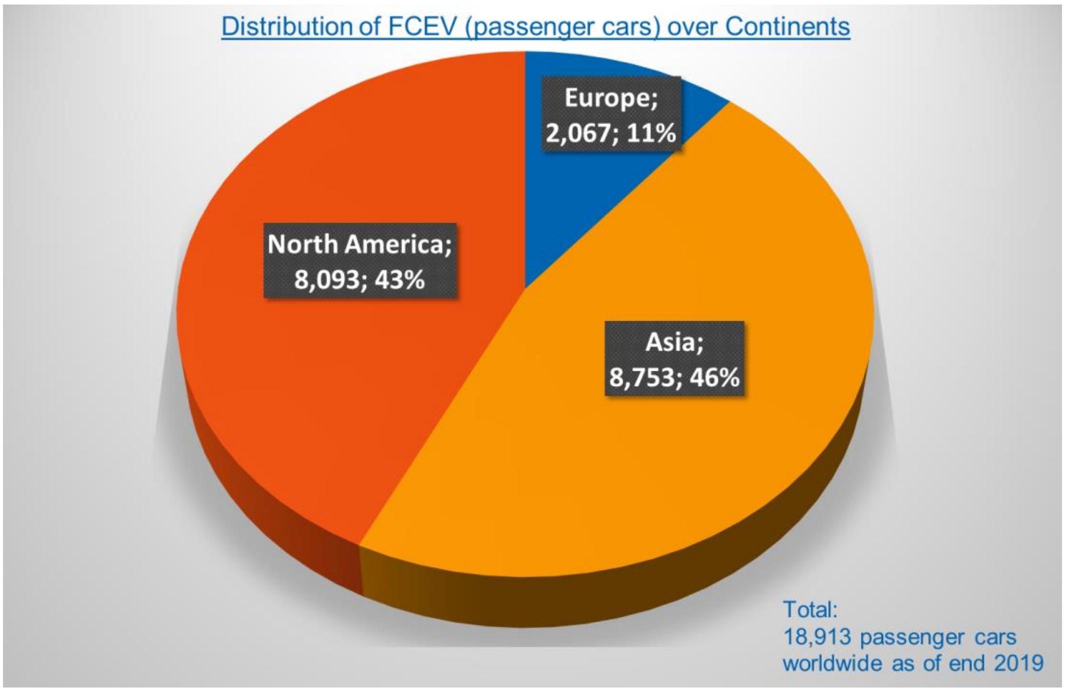

FIGURE 4: DISTRIBUTION OF PASSENGER CARS (FCEVS: FUEL CELL ELECTRIC VEHICLES) TO DIFFERENT CONTINENTS.

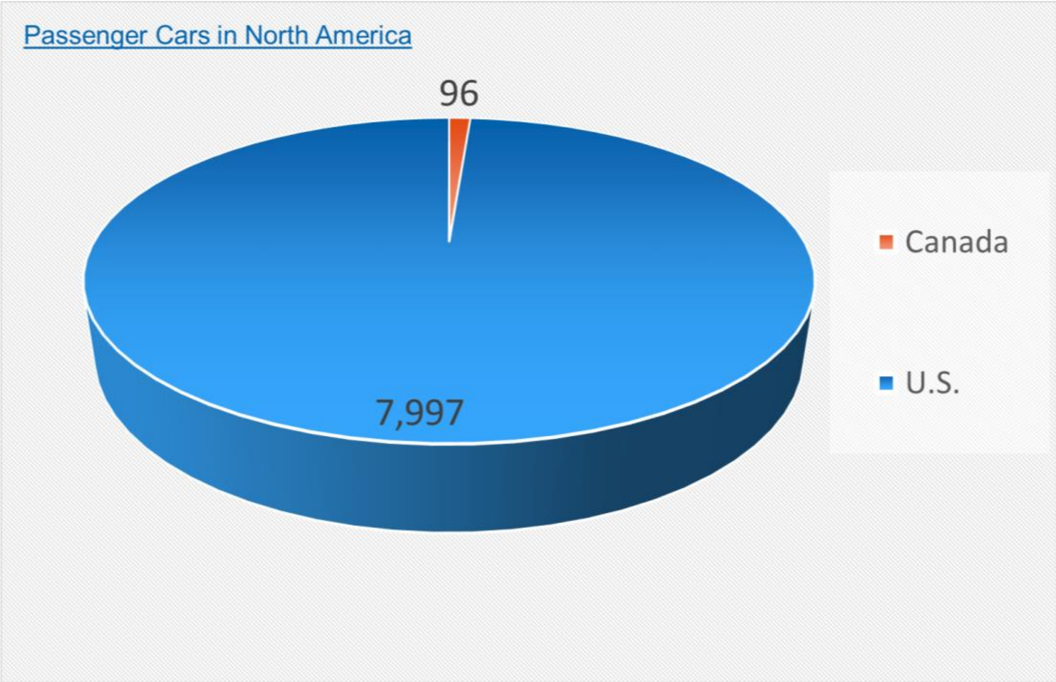

FIGURE 5: DISTRIBUTION OF PASSENGER CARS IN NORTH AMERICA

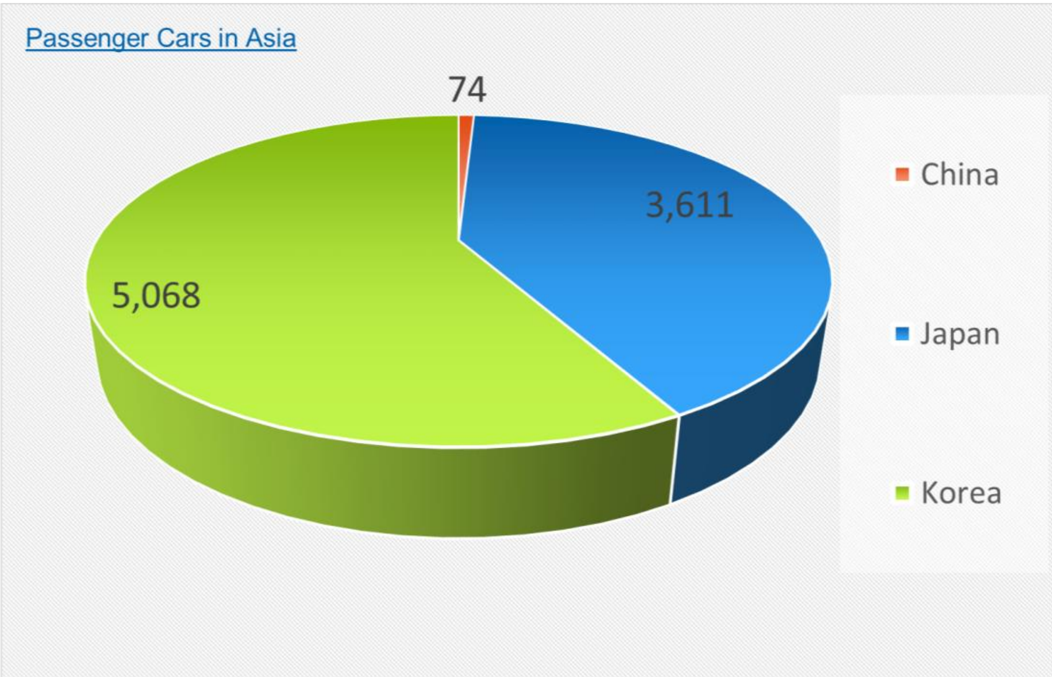

FIGURE 6: DISTRIBUTION OF PASSENGER CARS IN ASIA

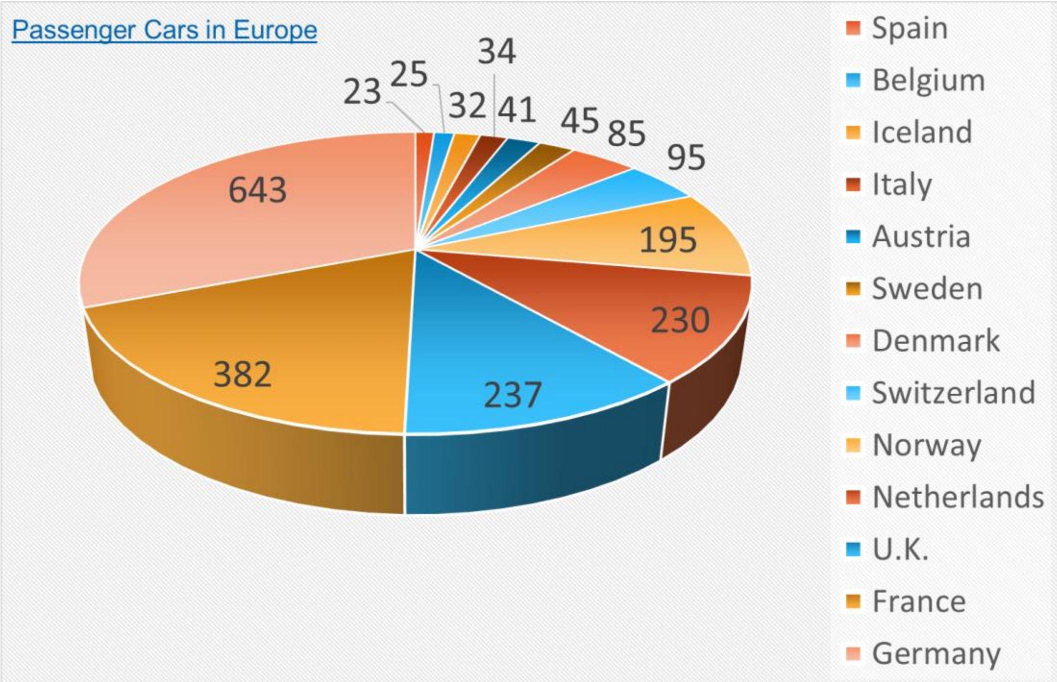

FIGURE 7: DISTRIBUTION OF PASSENGER CARS IN EUROPE

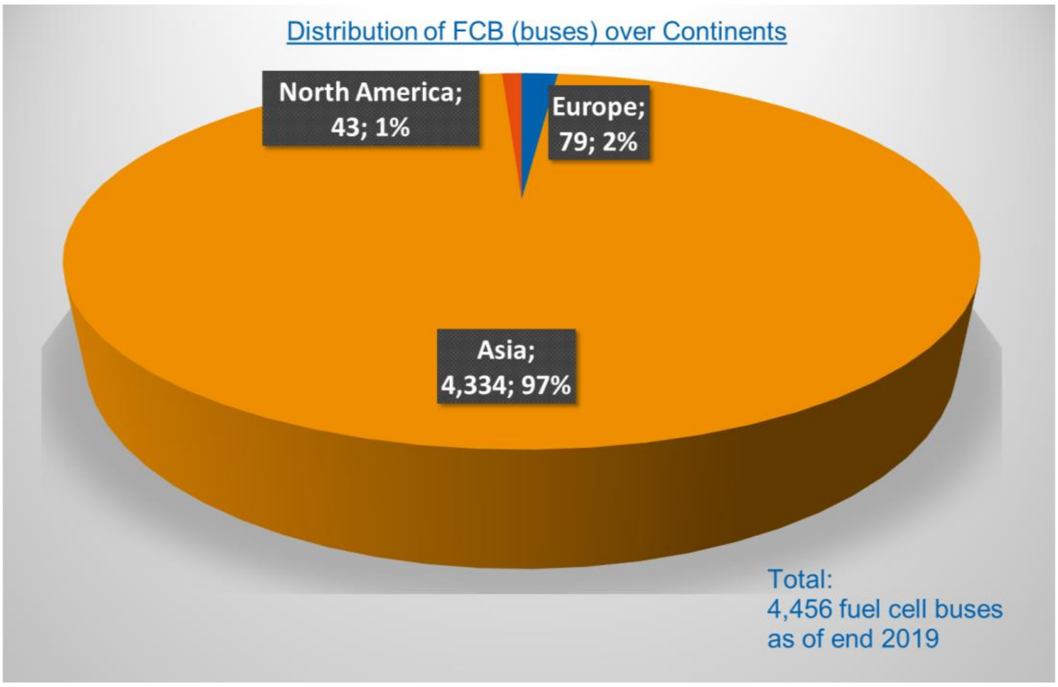

FIGURE 8: DISTRIBUTION OF FUEL CELL BUSES (FCB) OVER CONTINENTS.

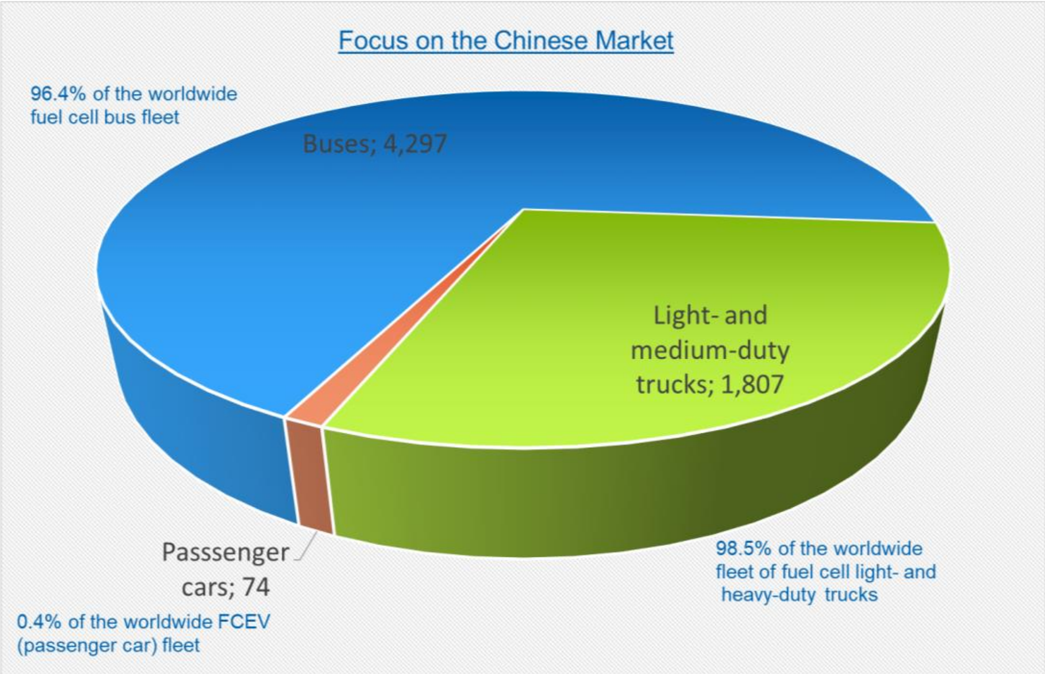

FIGURE 9: FOCUS ON THE CHINESE MARKET

Finally, Figure 10 monitors the development of the numbers of fuel cell vehicles worldwide since 2017 based on the AFC TCP surveys up to now. In 2017, the focus was given to the passenger cars, as the numbers on other vehicle types were low. In 2018, we differentiated for the first time between passenger cars and the total number of vehicles since we found out that the Chinese market was dominated by commercial vehicles unlike the rest of the world. The 2018 numbers for all vehicles given in Figure 10 are based on the number of vehicles in stock and not the numbers of registered vehicles for the Chinese market. The number of FCEV (passenger cars) already showed an increase of 56% at the end of 2018. At the end of 2019, this trend continued with a stronger increase of 69% for the passenger cars in one year. The number of all fuel cell vehicles showed an even stronger increase rate with 95% in 2019. The strong increase in the number of buses and light- and medium-duty trucks in China was decisive for this growth. Meanwhile, the discrepancy between the numbers in stock and the registrations do not exist in China.

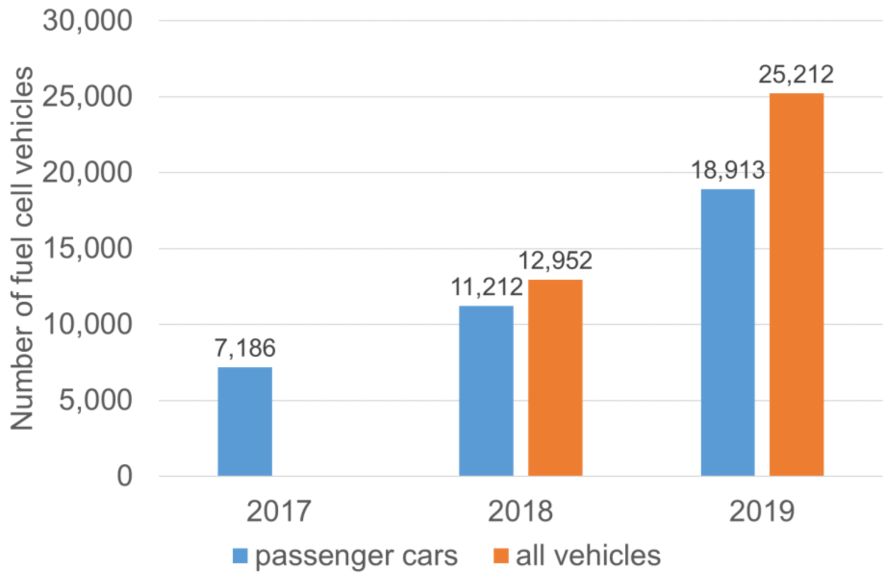

FIGURE 10: DEVELOPMENT OF THE NUMBERS OF FUEL CELL VEHICLES WORLDWIDE

2.2. INFORMATION ON SELECTED VEHICLES

In this section, technical data about selected passenger cars (FCEV) sold or leased at different countries are given based on the data from car manufacturers in Table 1:

FCEV	Toyota Mirai	Hyundai Nexo	Honda Clarity Fuel Cell	Mercedes-Benz GLC F-Cell
Fuel cell stack	370 cells in series 1.34 mm cell thickness 102 g cell weight 114 kW max. output 3.1 kW/l volume power density 2.0 kW/kg mass power density 37 l volume / 56 kg weight (cell+fastener)	95 kW 440 cells 3.1 kW/l power density @ 0.6 V 60% system efficiency	103 kW 358 cells 33 l volume 52 kg weight	
Battery	Nickel-metal hydride 34 cells in series 244 V nominal voltage 6.5 Ah capacity	Lithium-ion polymer 240 V voltage 40 kW power output 1.56 kWh output 95.3% charge / discharge efficiency	Lithium-ion 346 V voltage	Lithium-ion 13.5 kWh capacity
Electric motor / generator	permanent magnet, synchronous 113 kW max. power 335 Nm max. torque	permanent magnet motor 120 kW power output 395 Nm. max. torque	AC permanent magnet synchronous motor 130 kW power output 300 Nm max. torque	asynchronous machine 155 kW power output 365 Nm max. torque
Performance	179 km/h max. speed 9.6 s 0-62 mph acceleration	179 km/h max. speed 9.2 s 0-100 km/h acceleration 7.4 s 80-120 km/h acceleration -30 °C cold start temperature	165 km/h maximum speed 9.0 s 0-100 km/h acceleration	160 km/h maximum speed

Fuel consumption / Driving range	0.76 kg/100 km combined 0.80 kg/100 km extra urban 0.69 kg/100 km urban	666 km WLTP 756 km NEDC	650 km NEDC	1 kg / 100 km hydrogen 478 km NEDC hybrid mode (50 km battery only)
Tank system	700 bar nominal working pressure 5.7 wt.% tank storage density approx. 5 kg fuel tank capacity Two tanks: 60 l front tank, 62.4 l rear tank	6.33 kg hydrogen 156.6 l overall capacity, 3 tanks, each 52.2 l	700 bar 5.46 kg hydrogen 141 l overall capacity, 2 tanks, 24 l and 117 l	700 bar 4.4 kg hydrogen
Weight	1,850 kg curb weight 2,180 kg gross vehicle weight	2,340 kg gross vehicle weight 1,814 – 1,873 kg curb weight	1,875 kg curb weight	
Exterior	4,890 mm overall length 1,815 mm overall width 1,535 mm overall height 0.29 drag coefficient	4,670 mm overall length 1,860 mm overall width 1,630 mm overall height 2,790 mm wheelbase 0.329 drag coefficient	4,915 mm overall length 1,875 mm overall width 1,480 mm overall height 2,750 mm wheelbase	4,671 mm overall length 2,096 mm overall width 1,653 mm overall height 2,873 mm wheelbase

TABLE 1: TECHNICAL SPECIFICATIONS OF TOYOTA MIRAI [16],[17], HYUNDAI NEXO [18],[19], HONDA CLARITY FUEL CELL [20],[21], MERCEDES-BENZ GLC F-CELL [22],[23].

2.3. SUBSIDY SCHEMES AND PURCHASE PRICES IN SELECTED COUNTRIES

As a new and promising energy conversion technology, the market introduction of fuel cell electric vehicles is supported by different incentives worldwide. In this section, selected possibilities are highlighted on a country basis. This information is complemented with purchase prices where possible.

In California [24],[25], the California Clean Vehicle Rebate Project (CVRP) supports buying or leasing battery electric, plug-in hybrid electric, and fuel cell electric vehicles. FCEVs receive USD 4,500 support. In addition, a federal tax credit of USD 8,000 is available. There are competitive leasing programs including fuel from different OEMs:

- Honda Clarity USD 369/month + tax; 3 years lease with $15,000 fuel allowance,
- Toyota Mirai USD 349/month + tax; 3 years lease with $15,000 fuel allowance,
- Hyundai Nexo ~ USD 550/month + tax; 3 years lease with $13,000 fuel allowance.

In Japan, the subsidies for FCEVs are JPY 2,020,000 (Toyota Mirai) to JPY 2,080,000 (Honda Clarity Fuel Cell) excluding subsidies from local governments [26]. The purchase price of a Toyota Mirai is JPY 7,409,600 [27] whereas Honda Clarity Fuel Cell has a purchase price of JPY 7,836,400 [28].

In Spain, FCEVs receive EUR 8,000 in Castilla la Mancha region, whereas other subsidies are possible in other regions [29]. The purchase prices are EUR 69,000 for Hyundai Nexo [30] and EUR 82,000 for Toyota Mirai [27].

In France, the FECVs received up to 2019 EUR 6,000 subsidy, whereas this amount is reduced to EUR 3,000 from 2020 [31].

In Austria, generally speaking, the same subsidies apply for FCEV as for BEV. They differ by the vehicle size; e.g., passenger cars receive a subsidy of EUR 3,000, but max 30% of the purchase price. Partly different funding is available for private individuals and companies/ organizations/ authorities: Maximum allowed purchase price for private individuals is EUR 50,000 gross list price and for companies EUR 60,000. The proof is required, that only hydrogen from renewable sources is used. Leasing a vehicle is also covered. A certain amount of money is available that is distributed by a first-come, first-serve approach. Half of the funding is provided by the federal government if, and only if, the car importer pays the second half. The number stated above refers to the entire funding. Some federal states increase public funding by up to 50% [32].

In Denmark, Hyundai Nexo and Toyota Mirai are available for purchasing, for prices between DKK 575,000 - 630,000 including VAT. The FCEVs have a tax exemption [33],[34].

Since 01.07.2019, Sweden has a bonus-malus policy where vehicles that emit zero carbon dioxide will qualify for a maximum bonus of EUR 6,000. From 01.01.2020, municipalities are allowed to introduce low emission zones, where only pure electric cars, fuel cell cars and gas cars that meet the emission standard Euro 6 can drive. High standards are also set for heavy vehicles. This zone only allows electric vehicles, fuel cell vehicles, plug-in hybrids and gas vehicles that meet the emission standard Euro 6 [35]. The purchase price of a Toyota Mirai was SEK 750,000 in 2015 [36].

In Switzerland, the drivers of fuel cell vehicles profit from exemptions. One exemption is from performance-related heavy vehicle charge (CHF 0.0228 tkm Euro 6). For example, for a 40 t heavy-duty truck driving 100,000 km/year saves CHF 91,200 per year. Another exemption is from petroleum tax (CHF 0.759 per liter). For an annual distance of 100,000 km and 32 l/km consumption, this results in CHF 24,300 per year. [37]

In Canada, the purchase prices vary slightly between Hyundai Nexo for CAD 73,000 and Toyota Mirai for CAD 73,800. The federal incentive amounts to CAD 5,000. In Quebec, the incentives vary between CAD 3,000 and CAD 8,000 depending on the vehicle MSRP (Manufacturer's Suggested Retail Price). In British Columbia, the incentives amount to CAD 3,000. [38]-[40]

In Germany, Hyundai NEXO (EUR 69,000) and Toyota Mirai (EUR 78,600) are available for purchase, whereas Mercedes GLC F-Cell can only be leased within a full-service model [41]. Hyundai NEXO is the only FCEV in Germany which is in the current list of eligible electric vehicles for the environmental bonus (Umweltbonus) published by the Federal Office for Economic Affairs and Export Controls BAFA. Above a netlist price of EUR 40,000, the environmental bonus for pure electric vehicles is EUR 5,000. Individuals, companies, foundations, corporations and associations to which a new vehicle is registered and who undertake to keep the vehicle for six months are eligible to apply. As of 29 February 2020, 113 fuel cell vehicles applied for subsidies with this program, all Hyundai with 94 NEXO and 19 ix35 Fuel Cell. [42] The environmental bonus is equally shared by the industry (car manufacturer) and the federal government [43]. A recent call from October 2019 as a part of the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP) focused on the promotion of fuel cell vehicles in fleets as a market activation strategy. With this incentive, investment grants covering up to 40% of the excess expenditures of purchasing a fuel cell vehicle (EUR 20,244 - 20,460 for Toyota Mirai / Hyundai Nexo) were possible for a total project volume of EUR 5 million [44].

On top of the environmental bonus, federal states also have additional funding schemes. For example, the federal state NRW supports companies, traders, clubs and associations with a location in this state with an additional bonus for commercial battery electric and fuel cell electric vehicles with the additional support of EUR 8,000 [45].

3. HYDROGEN REFUELING STATIONS

In this part, the results of the AFC TCP survey on hydrogen refueling stations are presented. As of end of 2019, the total number (public and private) of hydrogen refueling stations (HRS) worldwide reached 470. Most of the stations are located in Asia (212), followed by Europe (185) and North America (69). Japan is the country with the highest number of stations (113) followed by Germany (81) and the U.S. (64). China is in the fourth position (61) ahead of South Korea (34) and France (25). The biggest increase was observed for China, thanks to the mobile HRS implemented in this country in 2019. The information sources are given in [46]-[60]. All data is as of 31.12.2019 unless otherwise stated in the reference.

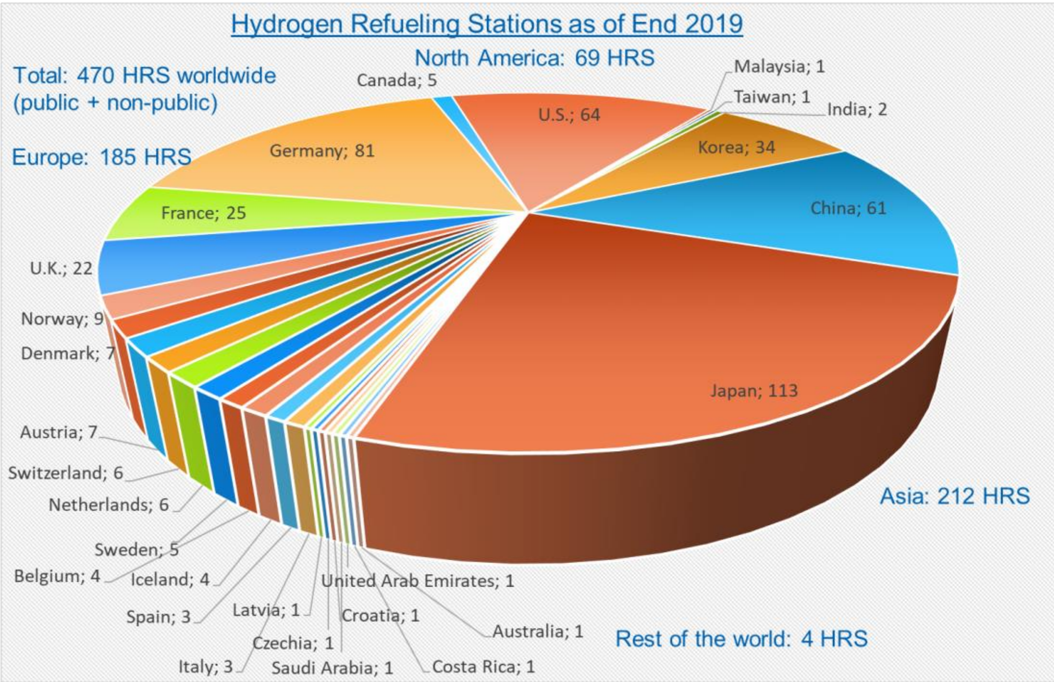

FIGURE 11: OVERVIEW OF PUBLIC AND NON-PUBLIC HYDROGEN REFUELING STATIONS (HRS) WORLDWIDE AS OF END 2019.

The three countries with the highest numbers of publicly available hydrogen refueling stations have not changed and Japan (113), Germany (81) and the U.S. (48) are still the top three countries in this category. With these numbers, the publicly available HRS in these three countries (242) represent more than half of the total HRS (public and private) worldwide.
The total number of HRS worldwide showed an increase of 23% in the last year. Thus, the increase is stronger than the 15% observed in the year before.
Based on the HRS numbers presented in this section and the vehicle numbers in the previous section, the number of fuel cell vehicles per hydrogen refueling station can be calculated for the top six countries having the highest numbers of HRS. The assumption for this simple, theoretical analysis lays in a fictive allocation of each registered vehicle to a station. As Figure 12

shows, in South Korea, the U.S. and China, the number of vehicles per HRS is higher than 100. The extreme case is in Korea, where each HRS is theoretically used by 149.5 fuel cell vehicles. In Japan, France and Germany, the rate is lower than 35 vehicles per HRS. This time, the extreme case is in Germany, where every HRS is theoretically used by 8.4 fuel cell vehicles.

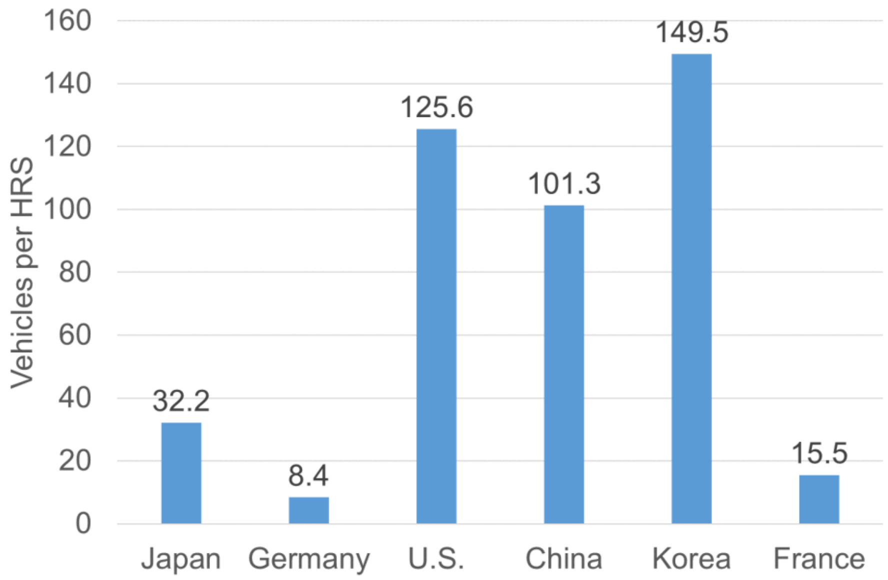

FIGURE 12: ANALYSIS OF THE NUMBER OF FUEL CELL VEHICLES PER HYDROGEN REFUELING STATION (HRS) IN THE TOP SIX COUNTRIES WITH THE HIGHEST NUMBER OF HRS AS OF END 2019.

For the AFC TCP survey, it was difficult to differentiate between public and private (non-public) stations sharply. Since the available data is not sufficient to make a distinction for every possible station, the partly available numbers are not highlighted here.

Similarly, it is hard to describe the tanking pressure of each station. Most of the stations for passenger cars are designed for 700 bar. Stations for buses typically use 350 bar. A snapshot of the HRS Availability Map of the FCH JU / European Commission showed 139 public HRS stations in Europe, from which 124 stations deliver 700 bar for passenger cars, 40 stations 350 bar for passenger cars and 16 stations 350 bar for buses. It is clear that many stations offer more than one possibility [61].

Priem analyzed 45 HRS in Europe funded by the FCH 2 JU [62]. This analysis shows that 9x 350 bar stations operate with delivered hydrogen, 6x 350 bar stations with onsite produced hydrogen, 3x 700 bar stations with delivered hydrogen, 10x 700 bar stations with onsite produced hydrogen, 6x dual stations (350 / 700 bar) with delivered hydrogen, 5x dual stations with onsite produced hydrogen, 5x stations at other pressure levels with trucked-in hydrogen and 1x other station with onsite produced hydrogen.

FCH JU presents the state-of-art and future targets, called key performance indicators (KPIs) for hydrogen refueling stations on their webpage. Selected indicators are presented in Table 2. The international state-of-art is based on the year 2017. A full list of indicators, based on the multi-annual work plan can be found in the source [63].

Parameter	Unit	State-of-art 2017	FCH 2 JU target 2020	FCH 2 JU target 2030
Lifetime	years	10	12	20
Energy consumption	kWh / kg	10	5	3
Availability	%	95	96	99
Mean time between failures	days	20	48	168
CAPEX	EUR 1,000 / (kg/day)	7	4 – 2.1	2.4 – 1.3
Cost of renewable hydrogen	EUR / kg	12	11	6

TABLE 2: SELECTED PARAMETERS FOR STATE-OF-ART AND FUTURE TARGETS FOR HYDROGEN REFUELING STATIONS FOR FCH JU PROJECTS [63].

For all 113 public HRS in Japan, the storage pressure is 820 bar and the dispensing pressure is 700 bar. Moreover, cost figures are available from Japan. The CAPEX for 2018 average for off-site hydrogen production at 300 Nm^3/h capacity was JPY 310 million. The OPEX for 2017 average was JPY 32 million for the same parameters. [56]
CAPEX of new, high capacity stations is approximately EUR 1 million including installation in Denmark [64].

4. ANNOUNCED TARGETS, VISIONS AND PROJECTIONS

In the final section of this report, a selection of announced targets, visions and projections are highlighted on a country or region basis. In the end, an overview is given using a timeline in Figure 13.

- Korea [65],[66]
  - 2022: 81,000 vehicles (79,000 passenger cars and 2,000 buses) / 310 stations
  - 2040: 6.2 million vehicles (5,900,000 passenger cars, 120,000 taxis, 60,000 buses, 120,000 trucks) / 1,200 stations
  - 2,000 buses by 2022 and 41,000 by 2040.
  - The government expects the hydrogen economy to become the driving force of innovation growth in 2040, generating 43 trillion won in added value annually and 420,000 new jobs.
- Japan [67]
  - 2020: 40,000 passenger cars / 100 buses / 160 stations
  - 2025: 200,000 passenger cars / 320 stations
  - 2030: 800,000 passenger cars / 1,200 buses / 900 stations
  - Make hydrogen stations independent by the second half of the 2020s

- Europe [68]-[77]
    - Minimum of 747 hydrogen stations are targeted in 2025.
    - Hydrogen Mobility Europe project is planning to place more than 1,400 fuel cell cars in customers' hands and deploy more than 45 hydrogen stations across Europe until 2020.
    - JIVE projects are planning to put 291 FC buses on the road by 2023.
    - France: 2023: 5,000 vehicles and 100 stations; 2028: 20,000-50,000 vehicles and 400-1,000 stations
    - Germany: 2020: 100 stations; 2025: 400 stations. 14 passenger trains start operation from 2021, 27 additional passenger trains by 2023.
    - Spain: 2020: 500 vehicles, 20 stations
    - Switzerland: 50 heavy-duty vehicles in 2020, 1,600 in 2025.
    - Hydrogen Europe 2030 vision: 5 million cars, 15,000 buses, 95,000 trucks, 4,500 HRS in 2030.
    - Hydrogen Roadmap Europe: The ambitious scenario of FCH 2 JU estimates 45 million passenger cars, 6.5 million LCVs, 1.7 million trucks and 250,000 buses powered by hydrogen for the year 2050.
- U.S. [78],[79]
    - California Air Resources Board estimates a total of 26,900 FCEVs in California by 2022 and 48,000 by 2025 based on projections provided by auto manufacturers.
    - 200 stations are anticipated by the end of 2025 in California.
    - California Fuel Cell Partnership 2030 vision: 1,000,000 vehicles, 1,000 stations
- China [80]
    - 2020: 5,000 vehicles / 100 stations
    - 2025: 50,000 vehicles / 300 stations
    - 2030: 1,000,000 vehicles / 1,000 stations
- Hydrogen Council vision [81]
    - 2030: 1 in 12 cars in Germany, Japan, South Korea and California powered by hydrogen; globally 10-15 million cars and 500,000 trucks.
    - 2050: Hydrogen powers more than 400 million cars, 15-20 million trucks, and around 5 million buses

FIGURE 13: SELECTION OF ANNOUNCED TARGETS, VISIONS AND PROJECTIONS.

5. CONCLUSION

This report gives a brief overview of the status of the numbers of fuel cell vehicles and hydrogen refueling stations worldwide. According to AFC TCP data collection results, the number of fuel cell vehicles including passenger cars, buses, light- and medium-duty trucks and heavy-duty trucks amounted to 25,212. Moreover, 470 hydrogen refueling stations were in operation at the end of 2019. More than half of the vehicles are operated in Asia. Passenger cars dominate the total number with a share of 75%. From that, 46% of the vehicles are registered in Asia. A focus on the Chinese market showed a strong increase in the number of buses on the road from 421 in 2018 to 4297 in 2019. Similarly, the number of light- and medium-duty trucks (commercial vehicles) increased from 412 to 1807. With these numbers, China strongly dominated both markets worldwide. The numbers for the passenger cars and hydrogen refueling stations showed an increase of 69% and respectively 23% in 2019, both numbers representing a stronger increase rate than 2018. The total number of vehicles showed a much stronger increase of 95%.

A combined analysis of the number of vehicles and stations for the top 6 countries having the highest number of hydrogen refueling stations showed that in Korea, the U.S. and China the number of cars per station is more than 100, whereas this number is lower than 35 for Japan,

France and Germany. Korea and Germany show both extremes in this analysis, with 149.5 cars per station in Korea and 8.4 in Germany.
The report also showed big differences between the available national and regional incentives for purchasing a fuel cell vehicle. In many countries, the same incentives apply for battery electric vehicles and fuel cell electric vehicles. The available exemptions in Switzerland enable significant savings for heavy-duty transportation with fuel cells. Switzerland will be one of the countries in focus for the next years since a fleet of 1,600 heavy-duty trucks is planned until 2025 here. Analyzing the announced roadmaps, targets and visions for Korea, Japan, China, Europe, California and the worldwide vision of Hydrogen Council for 2050, we can conclude that hydrogen and fuel cells have a strong potential to play a critical role for a sustainable mobility.

6. Acknowledgement and Disclaimer

Data collection by the Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) Executive Committee Members, coordinated by the core group (L. Antoni, N. Garland, J. Han, M. Rex and R.C. Samsun).
The authors are deeply grateful to all Executive Committee Members of the AFC TCP who delivered data for this report. Special thanks go to Canada, whose membership was not yet finalized during the preparation of this report. Special thanks to the FCH 2 JU Programme Office for supplying European data.
The results from data collection on FCV and HRS are originally provided to IEA Global EV Outlook 2020 publication.
The presented data intends to give an overview of the status and perspectives, was prepared using available sources. AFC TCP does not claim that the data provided is complete.
AFC TCP functions within a framework created by the International Energy Agency (IEA). The activities of the AFC TCP are coordinated by the IEA's Working Party on Energy End-use Technologies (EUWP). Views, findings and publications of the AFC TCP do not necessarily represent the views or policies of the IEA Secretariat or of its individual member countries.
Publication date: June 2020

7. References

[1] Austria (FCEV): Statistik Austria, as of 30.11.2019 https://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/strasse/kraftfahrzeuge_-_bestand/index.html
[2] Austria (FCB): https://www.postbus.at/en/das-unternehmen/innovationen/wasserstoffbusse.html
[3] Canada (FCEV): HIS Markit Catalyst for Insight
[4] Canada (FCB): IPHE Country Update from October 2019
[5] China: China Association of Automotive Manufacturers
[6] Denmark: http://brintbiler.dk/
[7] France: H2 Mobility France
[8] Germany: Kraftfahrt Bundesamt, Flensburg, 2020

[9] Belgium, Iceland, Italy, Netherlands, Norway, Switzerland, UK (FCEV): OEM data provided by FCH2 JU Programme Office
[10] Belgium, Iceland, Italy, Netherlands, Norway, Switzerland, UK (FCB): FCH2 JU Database
[11] Japan: METI
[12] Republic of Korea: IPHE Country update, January 2020.
[13] Spain: DGT
[14] Sweden: Hydrogen Sweden
[15] U.S.: California Fuel Cells Partnership, Data from Baum and Associates
[16] https://media.toyota.co.uk. Access date 09.03.2020
[17] https://www.toyota-europe.com. Access date 09.03.2020
[18] https://www.hyundaiusa.com/us/en/vehicles/nexo/compare-specs. Access date 09.03.2020
[19] https://www.hyundai.news/eu/press-kits/all-new-hyundai-nexo-technical-specifications/. Access date 09.03.2020
[20] https://hondanews.eu/eu/en/cars/media/pressreleases/106336/2017-honda-clarity-fuel-cell-press-kit. Access date 09.03.2020
[21] https://owners.honda.com/vehicles/information/2018/Clarity%20Fuel%20Cell/specs#mid^ZC4F7JGNW. Access date 09.03.2020
[22] https://www.daimler.com/produkte/pkw/mercedes-benz/glc-f-cell.html. Access date 09.03.2020
[23] https://media.daimler.com/marsMediaSite/de/instance/ko/Mercedes-Benz-GLC-F-CELL-Elektromobiles-Doppelherz-Batterie-und-Brennstoffzelle.xhtml?oid=41475770. Access date 09.03.2020
[24] Cory Shumaker: Moving California Forward. Hydrogen and Fuel Cell Initiative in California. Presentation at the 8th European Fuel Cell Technology & Applications Piero Lunghi Conference - EFC19, Naples, Italy. December 9-11 2019.
[25] California Fuel Cell Partnership. https://cafcp.org/cars#cars_makes_models. Access date 10.03.2020
[26] Next Generation Promotion Center
[27] Toyota
[28] Honda
[29] CLM Region
[30] Hyundai
[31] French annual financial law
[32] www.umweltfoerderung.at/betriebe/foerderungsaktion-e-mobilitaet-fuer-betriebe-2019-2020.html. Access date 11.03.2020
[33] https://katalog.hyundai.dk/NicChristiansenGruppen/Hyundai/Specifikationer/nexo/?page=1 Access date 11.03.2020
[34] https://www.toyota.dk/new-cars/mirai/index.json Access date 11.03.2020
[35] Swedish Energy Agency
[36] https://teknikensvarld.se/ny-toyota-mirai-kommer-nasta-ar/ Access date 11.03.2020
[37] Swiss Federal Office of Energy
[38] https://www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html. Access date 11.03.2020

[39] https://vehiculeselectriques.gouv.qc.ca/english/rabais/ve-neuf/programme-rabais-vehicule-neuf.asp. Access date 11.03.2020
[40] https://www.cevforbc.ca/. Access date 11.03.2020
[41] H2 Mobility, https://h2.live/fahren Access date 09.03.2020
[42] BAFA, Elektromobilität (Umweltbonus) Zwischenbilanz zum Antragsstand vom 20. Februar 2020
[43] https://www.bundesregierung.de/breg-de/aktuelles/umweltbonus-1692646. Access date 10.03.2020
[44] https://www.ptj.de/lw_resource/datapool/systemfiles/cbox/5236/live/lw_bekdoc/aufruf_2019_08_bmvi_nip_pkw_191002.pdf. Access date 10.03.2020
[45] https://www.elektromobilitaet.nrw/foerderprogramme/elektrofahrzeuge/. Access date 10.03.2020
[46] Australia, Costa Rica, Croatia, Taiwan, U.A.E, India, Malaysia, Latvia, Saudi Arabia: h2stations.org, an info service of Ludwig-Bölkow-Systemtechnik GmbH and TÜV SÜD.
[47] Austria (HRS overall): http://h2tankstellen.cleanenergypartnership.de/
[48] Austria (HRS in Thalheim): Fronius; https://www.fronius.com/de/solarenergie/info-center/news/wasserstoff-als-energietraeger-111018
[49] Austria (HRS in Graz): HyCenta; http://www.hycenta.at/anlage/#top
[50] Canada: NRCan
[51] China: http://news.emoney.cn/hangye/3728879.shtml
[52] Denmark: http://brintbiler.dk/
[53] France: AFHYPAC
[54] Germany: H2 Mobility, https://h2.live/ Access date January 6, 2020
[55] Belgium, Czech Reb., Iceland, Italy, Netherlands, Norway, Switzerland, UK: Provided by FCH2 JU Programme Office, HRS availability study / FCH JU internal database
[56] Japan: METI, as of 06.02.2020
[57] Republic of Korea, IPHE County Update, January 2020.
[58] Spain: https://h2-map.eu/
[59] Sweden: Hydrogen Sweden
[60] U.S. Department of Energy - Energy Efficiency and Renewable Energy,
Alternative Fuels Data Center: Alternative Fueling Station Counts by State, as of 7.1.2020
[61] HRS Availability Map with availability data from the E-HRS-AS. FCH JU – European Commission. Access date 11.03.2020.
[62] Thierry Priem. Deployment of Hydrogen Refueling Stations in Europe. FCVC 2019, Topical Meeting on HRS. 27.09.2019, Rugao, China.
[63] https://www.fch.europa.eu/soa-and-targets Access date: 11.03.2020
[64] Nel Hydrogen
[65] Korean Government Announces Roadmap to Become the World Leader in the Hydrogen Economy by FuelCells Works, January 17, 2019 https://fuelcellsworks.com/news/korean-government-announces-roadmap-to-become-the-world-leader-in-the-hydrogen-economy/ Access date 06.02.2019
[66] National goals, compiled by KIST. February 2019
[67] Ministry of Economy, Trade and Industry, Japan
[68] French National Hydrogen Plan

[69] Commission Staff Working Document: Detailed Assessment of the National Policy Frameworks Accompanying the Document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Towards the Broadest Use of Alternative Fuels - an Action Plan for Alternative Fuels Infrastructure under Article 10(6) of Directive 201/94/EU, Including the Assessment of National Policy Frameworks under Article 10(2) of Directive 2014/94/EU. Brussels, November 8, 2017

[70] Fuel Cells and Hydrogen Joint Undertaking (FCH JU); Hydrogen Mobility Europe, https://h2me.eu/ Access date 10.03.2020.

[71] Joint Initiative for hydrogen Vehicles across Europe 2. http://www.fch.europa.eu/project/joint-initiative-hydrogen-vehicles-across-europe-2 Access date 28.02.2018.

[72] Presentation by K. Bonhoff, WHEC 2018, Rio de Janeiro, Brazil, June 21 2018

[73] Press release of Rhein-Main Verkehrsverbund from 19.07.2019

[74] Spanish Trade, Tourism and Energy Ministry

[75] Hyundai Hydrogen Mobility: Hyundai and H2 Energy sign Joint Venture Contract, 26.08.2019

[76] Hydrogen Europe: Hydrogen, Enabling a Zero Emission Europe. Technology Roadmaps Full Pack, September 2018.

[77] Hydrogen Roadmap Europe: A Sustainable Pathway for the European Energy Transition, Fuel Cells and Hydrogen 2 Joint Undertaking, 2019

[78] The California Fuel Cell Revolution. A Vision for Advancing Economic, Social, and Environmental Priorities. By the California Fuel Cell Partnership, July 2018

[79] 2019 Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development. CARB, July 2019

[80] Hydrogen Fuel Cell Vehicle Technology Roadmap, developed by the Strategy Advisory Committee of the Technology Roadmap for Energy Saving and New Energy Vehicles and SAE China, October 2016. English version.

[81] Hydrogen scaling up. A sustainable pathway for the global energy transition, Hydrogen Council, November 2017.