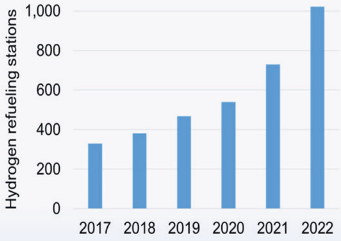

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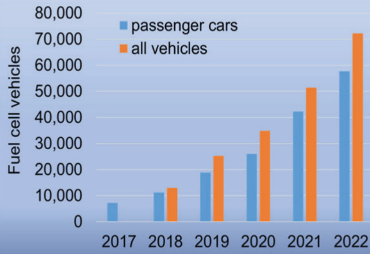

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IEA Technology Collaboration Programme
Advanced Fuel Cells

Deployment of Fuel Cell Vehicles in Road Transport and the Expansion of the Hydrogen Refueling Station Network: 2023 Update

Remzi Can Samsun and Michael Rex

ABSTRACT

This report aims to reflect the current deployment status of fuel cell vehicles for road transport and that of the hydrogen refueling station infrastructure as a result of a global data collection and analysis effort performed by the IEA Technology Collaboration Programme on Advanced Fuel Cells.

As in previous versions, the data was collected for the period until the end of December, in this case, of the year 2022, to provide an update for the beginning of 2023. Our data collection estimates a fuel cell vehicle fleet that surpassed the 70,000 unit mark being refueled by a network of more than 1000 hydrogen refueling stations. As in previous years, the collected data shows the dominance of the Republic Korea in the global fleet: More than 40% of the overall fuel cell vehicle population and half of fuel cell passenger car population is in this country. In addition, 90% of all fuel cell vehicles are in operation in only four countries and the fleet is dominated by passenger cars, which make up a share of 80%. The 2023 update also displays a very strong increase in the number of heavy-duty trucks in one year.

In terms of hydrogen refueling stations, China took the lead in 2022, followed by South Korea and Japan, resulting in 700 stations being located in Asia. Overall, the year 2022 witnessed the sharpest increase in the number of hydrogen refueling stations ever.

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1. INTRODUCTION

Fuel cells are presently gaining ever more attention for various transportation applications. This trend is mainly due to global efforts to achieve greenhouse gas-neutrality or net zero targets. Powered by hydrogen from renewable sources, fuel cell vehicles provide a fully zero-emission transportation solution. In fact, a fuel cell vehicle is always locally emission-free, independent of the hydrogen source, as the only emission from a hydrogen fuel cell vehicle is water. Thereby, fuel cell vehicles also contribute to reductions in local emissions and support electrification efforts in the transportation sector, especially in areas where battery–electric vehicles do not fulfill user requirements due to their limited ranges, long recharging times, and reduced payloads due to the battery weight.

But what is the present deployment state of fuel cell vehicles? Which countries lead the markets for them? In which vehicle categories do consumers have the possibility of buying a fuel cell vehicle? What is the present state of hydrogen refueling station infrastructure in different countries? To answer these questions, the Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) has collected data annually from its members since 2018 [1-5]. This publication summarizes the findings of the most recent data collection to serve as the 2023 update, as of the end of 2022. Building on the previous data collection results, the development trends are also presented and analyzed.

The results of the data collection on the deployment of fuel cell vehicles are presented in the next chapter. A detailed breakdown of the numbers pertaining to different vehicle categories, continents and countries will then be given. The third chapter will focus on hydrogen refueling station infrastructure on a continental- and country-based scale. The fourth chapter aims to provide more insights into the presented data with the help of various analyses. In this context, the global development of vehicle and station numbers over the last six years will be analyzed. Furthermore, the change in the shares from the last year will be highlighted in depth for those countries with the highest number of vehicles and stations. In addition, a combined analysis will offer insight in the number of vehicles per station in selected countries. Finally, the development trends will be analyzed for selected countries and thereby offer the most significant contribution to current state of fuel cell mobility.

2. FUEL CELL VEHICLES

The AFC TCP data survey indicates that worldwide, 72,193 fuel cell vehicles were on the road as of the end of 2022 [6-47]. 41% of the global fuel cell vehicle population was in the Republic of Korea. The United States was in second place, with 21% of the vehicles, followed by China (19%) and Japan (11%). As the waterfall diagram in Figure 1 clearly conveys, the major share of the international fuel cell vehicle fleet is already distributed across these four countries, making up 92% of the total. Of the remaining countries, Germany is the only one with more than 2000 vehicles. The United Kingdom, France and the Netherlands have more than 500 vehicles each. The next group consists of Belgium, Poland, Denmark, Australia, Norway, Canada, and Switzerland, with more than 100 vehicles. Meanwhile, the 50 vehicles mark is exceeded in India, Sweden, Italy, and Austria. The remaining countries, with less than 50 vehicles, are Iceland, Spain, the Czech Republic, Latvia, Luxemburg, Costa Rica, Portugal, Slovakia, Estonia, Finland, Brazil, and Lithuania, in descending order.

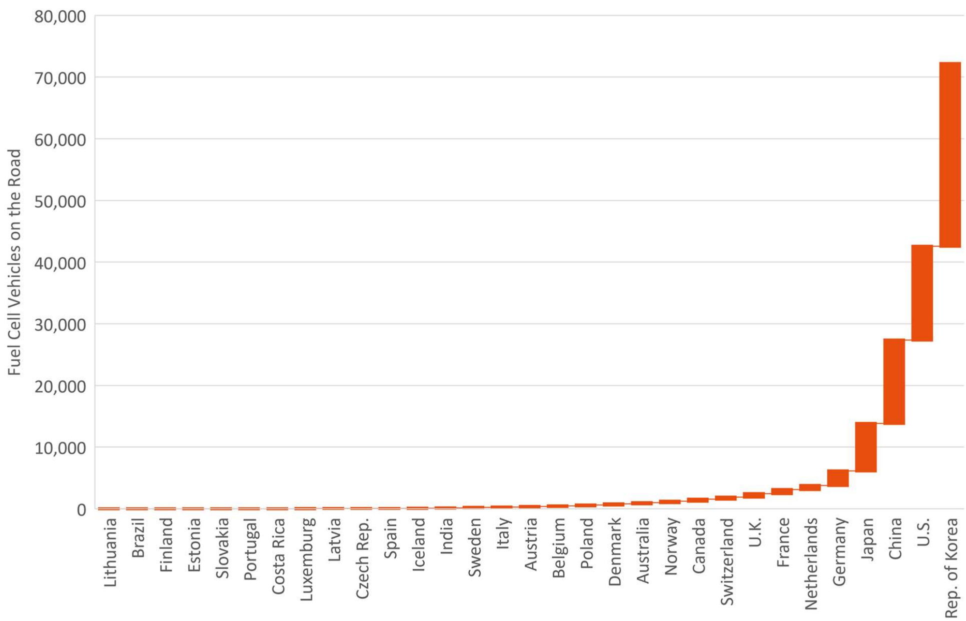

FIGURE 1. COUNTRY-BASED DISTRIBUTION OF FUEL CELL VEHICLES ON THE ROAD AT THE END OF 2022.

Five different vehicle classes, representing the fuel cell vehicle models available in the market, were defined for the survey. These classes are displayed in FIGURE 2. Passenger cars and vans make up the first category and differ from buses by the number seats, which are limited to eight plus the driver. The most prominent fuel cell vehicles belong to this category. In this publication, the term fuel cell–electric vehicle (FCEV) is only used for this vehicle class. The more general term, fuel cell vehicle (FCV), refers to all vehicle classes shown in FIGURE 2, including passenger cars. The buses in the next vehicle class also carry passengers but have more than eight seats in addition to the driver. Light commercial vehicles (LCVs) differ from passenger vehicles in their function of carrying goods instead of passengers, with the same weight limit of 3.5 tonnes as passenger cars. Additional commercial vehicles are medium- and heavy-duty trucks. The main difference between these truck types is their maximum mass. Whereas the mass of medium-duty trucks is limited by 12 tonnes in general and 10 tonnes for trailers and semi-trailers, the mass of heavy-duty trucks exceeds both thresholds in each category.

Vehicle class	Explanation
Passenger cars	Fuel cell electric vehicles (FCEV) in the category light-duty vehicles (passenger cars and vans) with a maximum mass not exceeding 3.5 tonnes, no more than eight seats in addition to the driver seat. Examples: Toyota Mirai, Hyundai Nexo, Honda Clarity fuel cell, etc.
Buses	Fuel cell buses (FCB) for the carriage of passengers with more than eight seats in addition to the driver seat
Light commercial vehicles (LCV)	Vehicles for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes. Examples: Renault Kangoo & Master, Mercedes-Benz Sprinter, Volkswagen Crafter & Caddy, Ford Transit, etc.
Medium-duty (MD) trucks	Fuel cell trucks (FCT) having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes; trailers and semitrailers with a maximum mass exceeding 3.5 tonnes, but not exceeding 10 tonnes
Heavy-duty (HD) trucks	Fuel cell trucks (FCT) with a maximum mass exceeding 12 tonnes; trailers and semitrailers with a maximum mass exceeding 10 tonnes

FIGURE 2. VEHICLE CATEGORIES DEFINED FOR THE AFC TCP DATA COLLECTION.

As is displayed in Figure 3, passenger cars dominate the global fleet of FCVs, amounting to 80% thereof. In other words, every four of five registered FCVs belong to the category of passenger cars. Buses make up the second highest share in the pie chart, with 9%. In total, both truck categories, namely heavy- and medium-duty, even have a higher share of 10% in total with 5% in each truck category. The light commercial vehicles only have a share of 1%. It should be noted here that in some countries, the numbers of light commercial vehicles are included in the figures for passenger cars. However, this detail does not change the general trend displayed in Figure 3.

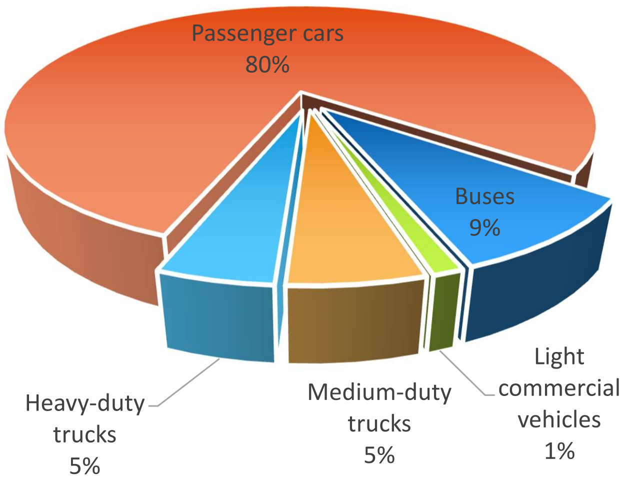

FIGURE 3. SHARES OF DIFFERENT VEHICLE CATEGORIES AS OF THE END OF 2022.

The distribution of the number of fuel cell vehicles to continents is presented in Figure 4. As in previous years, Asia is home to more than two thirds of the vehicles. North America follows, accounting for more than one fifth of all vehicles, whereas Europe makes up a lower share, with 7.7%. Australia only has a share of 0.3%.

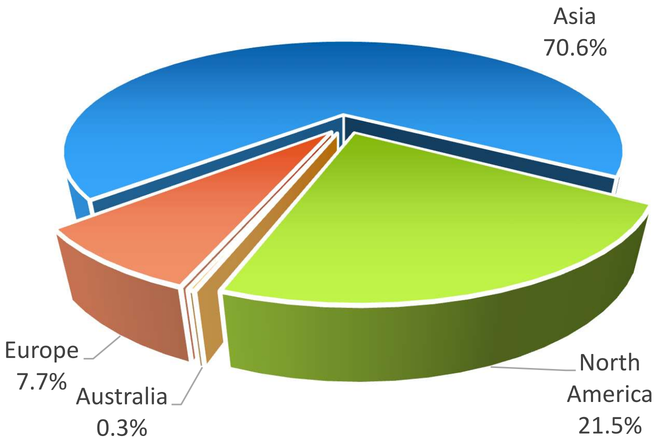

FIGURE 4. DISTRIBUTION OF FUEL CELL VEHICLES BY CONTINENT AS OF THE END OF 2022.

After taking a general look to all fuel cell vehicles, we will now provide more detailed insight into the distribution of different vehicle categories, starting with passenger cars. The total number of passenger cars operating on fuel cell technology was estimated at 57,651 as of the end of 2022. Figure 5 shows the distribution of these vehicles across different continents on the upper left side. Like all vehicles, almost two thirds of the passenger cars are in Asia. It must be noted here, however, that the share of passenger vehicles in Asia is 5.6% points lower than the Asian share of all vehicles. North America hosts more than every fourth passenger car, with a higher share compared to the distribution of all fuel cell cars. Europe still exhibits a low, yet slightly increased share of passenger cars compared to all vehicles. Australia's share is only 0.4%. Four further vehicles are registered on the remaining continents.

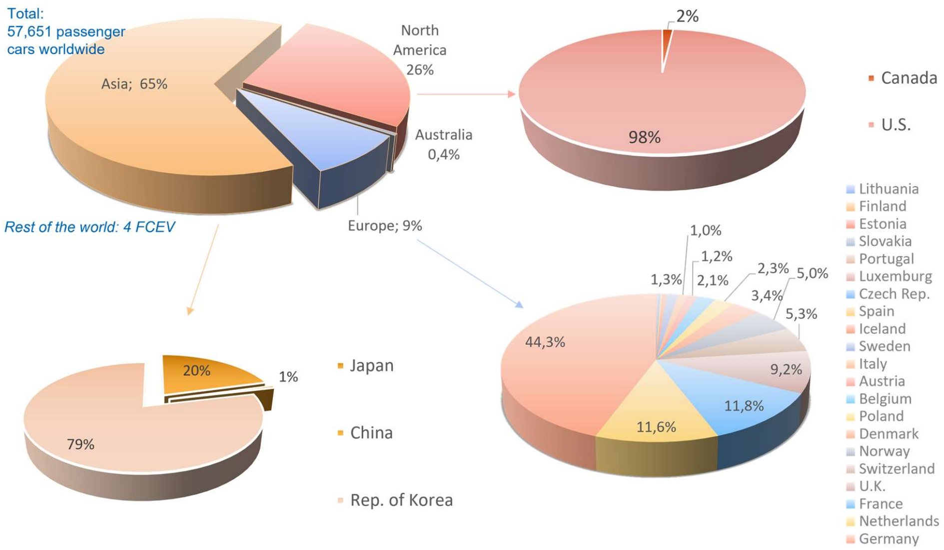

FIGURE 5. DISTRIBUTION OF FUEL CELL PASSENGER CARS ACROSS DIFFERENT CONTINENTS AND THEIR DETAILED ANALYSIS.

The bottom left chart presents the distribution of passenger cars in Asia. The Republic of Korea dominates the passenger car market in Asia with almost every four out of five cars, followed by Japan with every fifth car. It is also noteworthy that China appeared again in this chart after several years, although the Chinese contribution is presently low, at 1%.

The top right chart in Figure 5 clearly shows that the North American passenger car market is dominated by a share of 98% by the United States, mainly California. The remaining 2% of the vehicles are registered in Canada. The bottom right chart shows a very important trend in Europe. Despite the low share of fuel cell passenger cars in Europe, accounting for 9% of the worldwide fuel cell passenger car population, the vehicles are distributed across 21 different countries. Yet, almost half of the cars are in Germany. Moreover, the FCV passenger cars in Germany, the Netherlands, and France already represent more than every two out of three fuel cell passenger cars in Europe. The United Kingdom, Switzerland, and Norway also account for at least 5% of the fuel cell passenger cars in Europe.

Drawing on this continental insight, the country-based distribution of fuel cell passenger cars is displayed in the form of a waterfall diagram in Figure 6. The top four countries with the highest number of fuel cell passenger cars on their roads and, at the same time, hosting at least 2000 cars, are the Republic of Korea (51%; 29,337 FCEVs), the United States (26%; 14,979 FCEVs), Japan (13%; 7619 FCEVs), and Germany (4%; 2201 FCEVs).

Accordingly, the remaining countries host only 6% of the fuel cell passenger car fleet. Of those, France and the Netherlands are the only countries with more than 500 FCEVs, with 589 and 579 vehicles, respectively. The United Kingdom (458 FCEVs), Canada (303 FCEVs), Switzerland (266 FCEVs), and Norway (251 FCEVs) are other countries that have more than 250 FCEVs on their roads. The following group of countries consist of those with more than 100 FCEVs, namely China (240), Australia (197), Denmark (167), Poland (115), and Belgium (105). Sweden (65), Austria (60), and (52 FCEV) have more than 50 FCEVs. The remaining countries represented in Figure 6 are Iceland (27), Czech Republic (11), Spain (11), Luxemburg (5), Costa Rica (4), Portugal (3), Slovakia (3), Estonia (2) and, finally, Finland and Lithuania (1 FCEV each).

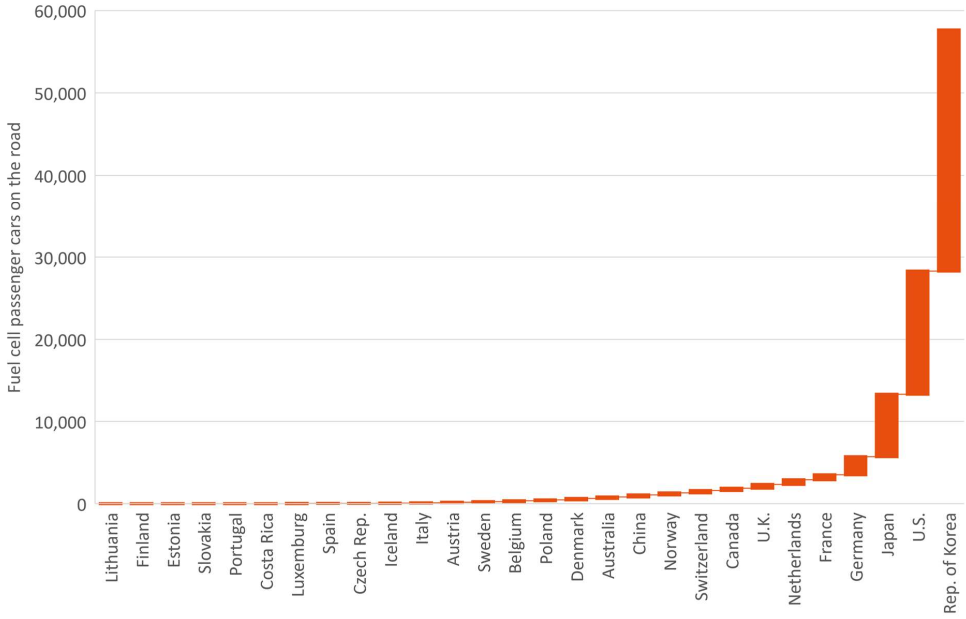

FIGURE 6. COUNTRY-BASED DISTRIBUTION OF FUEL CELL PASSENGER CARS ON THE ROAD AS OF THE END OF 2022.

The country-based distribution of fuel cell-based light commercial vehicles on the road is presented in Figure 7. The waterfall diagram clearly shows that this market is dominated by China, with 812 light commercial vehicles operating using fuel cell technology, out of 890 vehicles in total in this vehicle category. Such vehicles are also deployed in Germany (43 LCVs), the Netherlands (14), Switzerland (10), the United Kingdom (7), Denmark (3), and Belgium (1). It has already been noted that for some countries, the number of light commercial vehicles operating on fuel cell technology is already included in the number of passenger cars. One example of such cases is France.

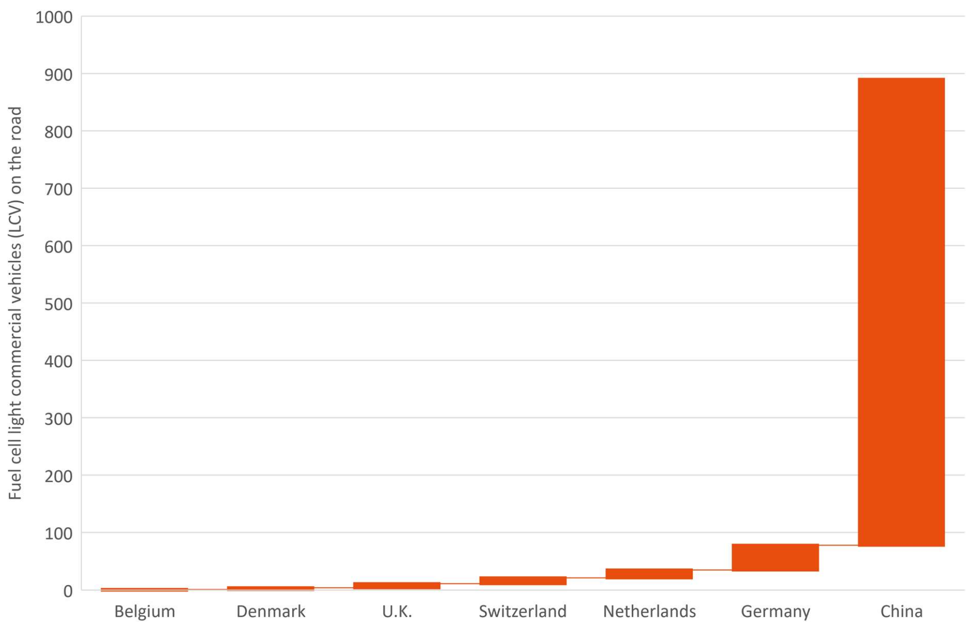

FIGURE 7. COUNTRY-BASED DISTRIBUTION OF FUEL CELL LIGHT COMMERCIAL VEHICLES ON THE ROAD AS OF THE END OF 2022.

The next waterfall diagram in Figure 8 shows the distribution of 6460 fuel cell buses (FCBs) across different countries. Most FCBs are in China, with 84% of the population spanning 5410 buses. Further countries with more than 100 FCBs are the Republic of Korea with 281, the United States with 211, and Japan with 124. The United Kingdom (98 FCBs), Germany (68), India (58), and the Netherlands (54) are other countries with more than 50 FCBs. The list continues with France (33), Austria (25), Switzerland and Italy (20 each), Canada, Norway, and Latvia (10 each), Spain (9), Luxemburg (5), Denmark and Belgium (4 each), Portugal and Sweden (2 each), and Brazil and Costa Rica (1 each). At the continental level, at least every nine out of ten FCBs are in Asia.

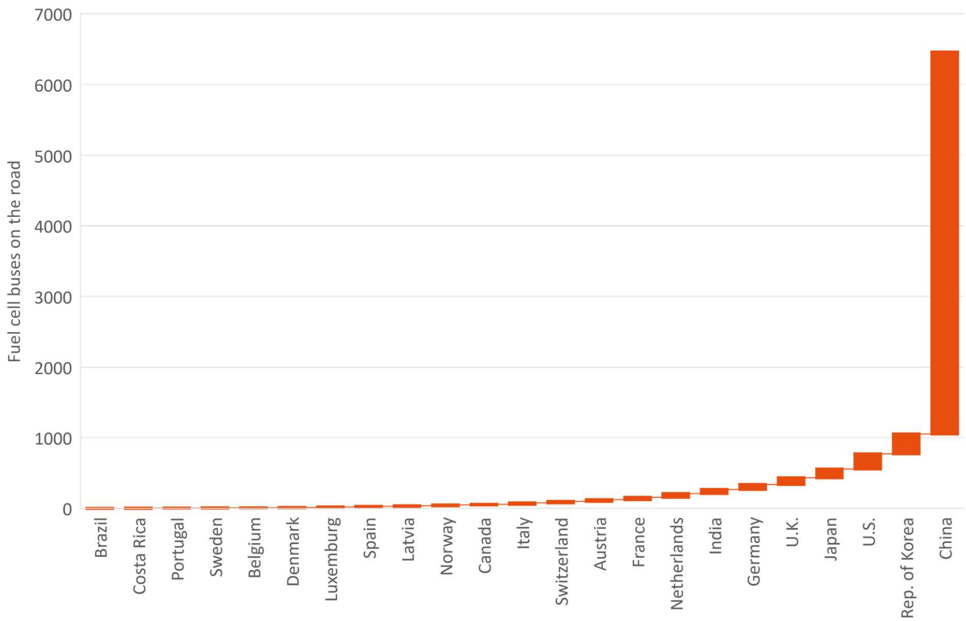

FIGURE 8. COUNTRY-BASED DISTRIBUTION OF FCBS ON THE ROAD AS OF THE END OF 2022.

As the next commercial vehicle category, the distribution of the 3871 medium-duty fuel cell trucks (MD-FCTs) in eight countries is displayed in Figure 9. As in the previous two diagrams pertaining to other commercial vehicle categories, the MD-FCT market is again dominated by vehicles registered in China, making up a share of 98% and 3790 trucks. The Netherlands (39 MD-FCTs) and Germany (28 MD-FCTs) are two countries in which more than 50 fuel cell MD-FCTs are in operation as well. Additional MD-FCTs are registered in Norway (6), the Republic of Korea (5) and France, the United Kingdom, and Denmark (1 each).

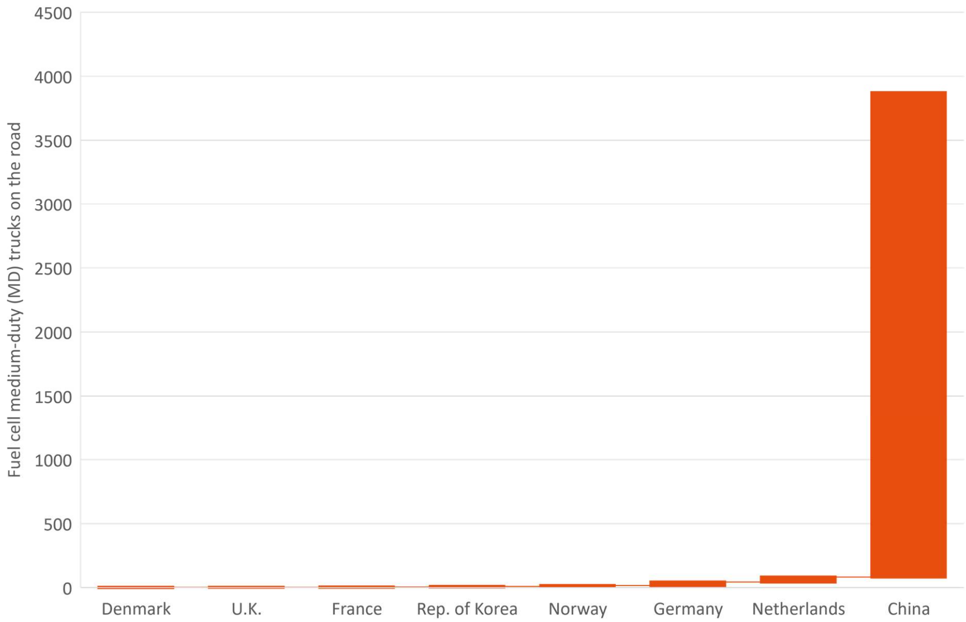

FIGURE 9. COUNTRY-BASED DISTRIBUTION OF MD-FCTS ON THE ROAD AS OF THE END OF 2022.

The last commercial vehicle category, namely heavy-duty fuel cell trucks (HD-FCTs), shows a similar picture to the previous three categories. As in the case of medium-duty ones, 98% of HD-FCTs are in use in China. This corresponds to 3252 of 3321 total trucks. Switzerland is in second place, with 48. For the United States, 10 HD-FCTs were recorded, 5 in Austria, and 2 in Sweden, Denmark, and Germany each.

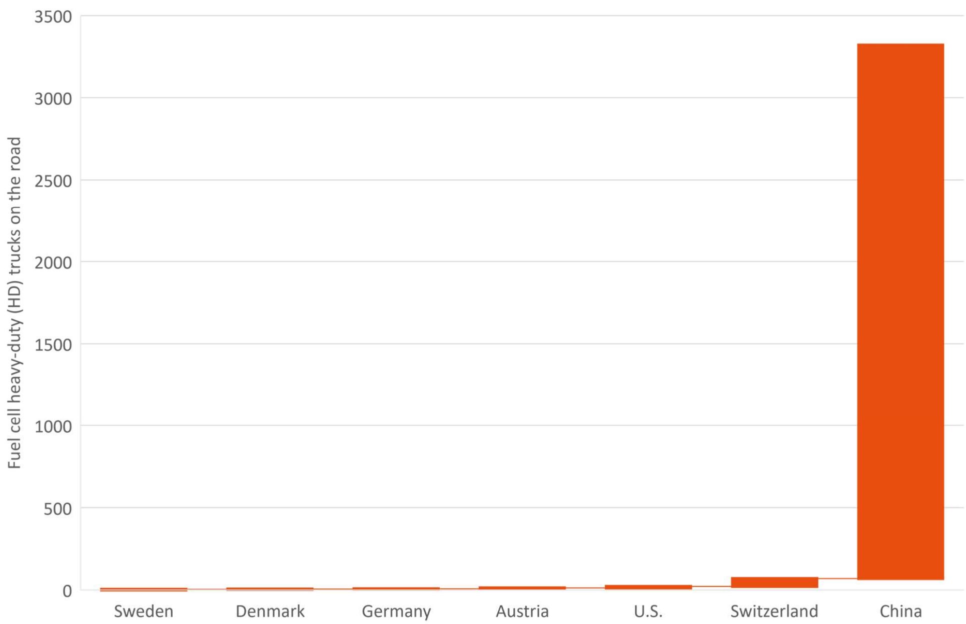

FIGURE 10. COUNTRY-BASED DISTRIBUTION OF HD-FCTS ON THE ROAD AS OF THE END OF 2022.

A complete breakdown of the vehicle numbers can be found in Table A1 in the Appendix.

3. HYDROGEN REFUELING STATIONS

As the second section of this publication, this chapter will focus on the AFC TCP survey results on the data collection regarding the worldwide state of hydrogen refueling station (HRS) infrastructure. 1022 hydrogen refueling stations were reported in operation as of the end of 2022 across 31 countries [23, 24, 32, 33, 36, 39, 42, 48-57]. This number includes both public and private stations. Thereby, the number of installed hydrogen refueling stations surpassed the 1000-station mark.

As is presented in the waterfall diagram in Figure 11, for the first time China (320 HRSs) took over the lead position, followed by the Republic of Korea (213) and Japan (164). Meanwhile, each of these countries have more than 100 HRSs and represent a huge share of 68% of global HRS infrastructure. There are three more countries that operate more than 50 HRSs, namely Germany (95), the United States (71), and France (58). The remaining 25 have between 1 and 12 stations and in total represent 10% of the worldwide HRS network.

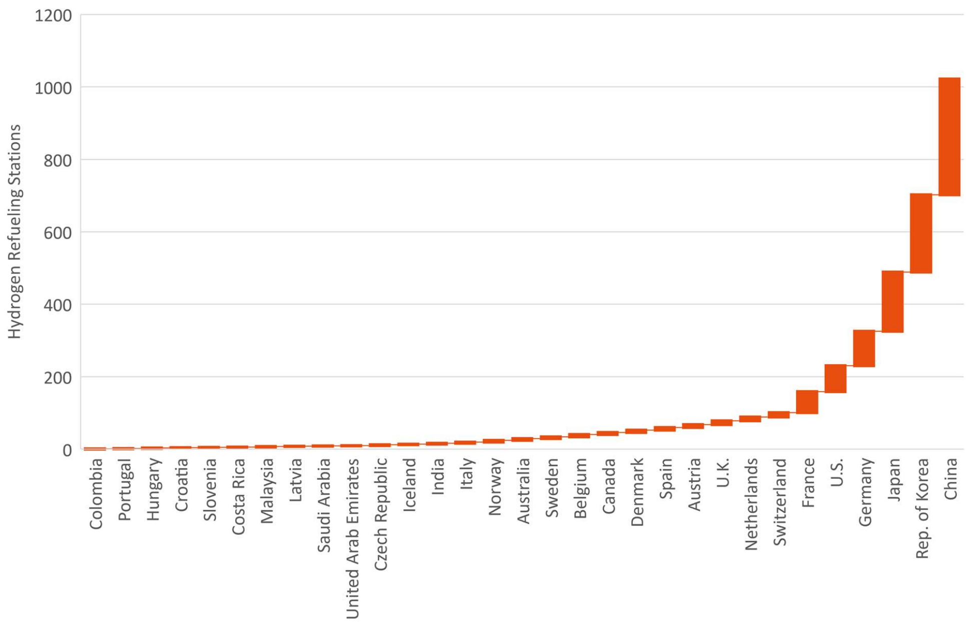

FIGURE 11. COUNTRY-BASED DISTRIBUTION OF HRSS WORLDWIDE AS OF THE END OF 2022.

Due to the very rapid development of the HRS network in China, the data sources could not confirm that all of the 320 HRS built by the end of 2022 in China are already under operation. For the remaining countries, the data reflects the stations that were not only built but also taken into operation. Therefore, the number of stations that were built until the end of 2022 is higher than the number of 1022 cited in this report. As China presently has the highest number of stations, we did not want to exclude the Chinese data from the analysis, despite the accompanying uncertainty.

As in the case of vehicles, this time, Figure 12 displays the distribution of 1022 HRSs across different continents and provides a detailed look into Asia, North America, and Europe. It must also be noted that 9 HRSs are located on other continents. Similar to the share of fuel cell vehicles (see Figure 4), Asia is in first place with 700 stations. The picture changes for Europe, which makes up 23% of the global HRS network and second place with 236 stations, mainly located in Germany and France. These two countries host two thirds of the stations in Europe. Like vehicles, many countries in Europe operate HRSs, which is important for the future development of hydrogen transportation on the continent. North America is in third place after Europe, with only 8% of global HRS infrastructure, with 92% of these stations being in the United States.

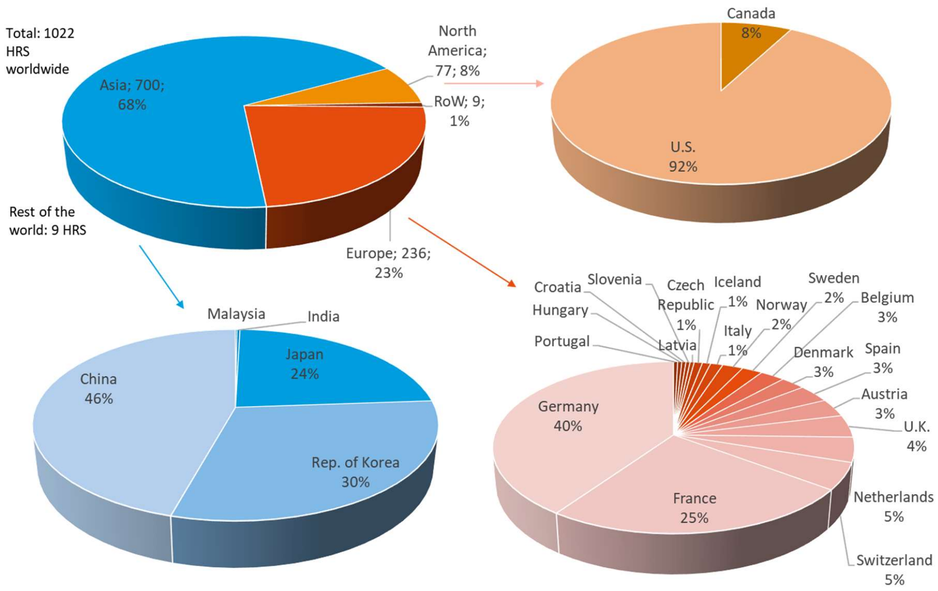

FIGURE 12. DISTRIBUTION OF HRSS TO DIFFERENT CONTINENTS AND THEIR DETAILED ANALYSIS.

A complete breakdown of the number of HRSs in each country can be found in Table A2 in the Appendix, together with further information on the stations.

4. Analysis

Following the brief presentation of the raw numbers on fuel cell vehicles and HRSs based on the annual AFC TCP data collection in previous chapters, this chapter will analyze development over the last six years.

The global development of the deployment numbers of FCVs between 2017 and 2022 is shown in Figure 13. In the first year, 2017, only the number of fuel cell passenger cars was estimated, as commercial vehicles had negligible amounts. For the remaining years, the analysis shows both the development of fuel cell passenger cars (FCEVs) and all FCVs, which also include passenger cars. In 2022, FCEVs exhibited an annual rate of increase of 37% in a single year. This rate is much slower than 2019, which saw the highest rate of increase, at 69%. In 2021, the rate of increase was also much higher, with 63%. A comparably low rate of increase was also observed in 2020 due to the Covid-19 pandemic.

Looking at the absolute increases in numbers, the FCEV fleet increased by 15,459 units in 2022. Furthermore, this number was lower than the increase in 2021, with 16,260 units. Until now, 2021 was the year with the highest absolute increase. However, the absolute increase in 2022 was the second highest. The slow increase rate in 2022 and the lower absolute increase in the stock can be explained by the chip crisis in the automobile sector, which resulted in the manufacturing capacities for FCVs not being fully exploited that year. Similarly, the total number of FCVs showed a moderate increase of 40% in 2022. In the previous year, the rate of increase was higher but comparable, at 48%. The highest rate of increase was observed in 2019, at 95% in one year. The rate of increase of 40% is similar to that for passenger cars, as the fleet is dominated by this vehicle category. At the same time, the slightly higher rate of increase indicates that the other vehicle types showed a much stronger rate of increase than passenger cars, and so they could raise the annual rate of increase despite their low share of 20% of the overall fleet.

A deeper analysis reveals a similar annual rate of increase of 36% for buses, whereas the MD FCTs showed almost no increase, with 7% in one year. For light commercial vehicles and HD FCTs, the annual increase rates were much higher than 100%, as the number of light commercial vehicles increased from 49 (2021) to 890 (2022) and heavy-duty vehicles from 852 (2021) to 3321 (2022).

Interestingly, 2022 saw the highest absolute increase, with 20,756 vehicles in one year. The highest absolute increase in previous years was in 2021, with 16,633 vehicles during the year. Due to the increasing number of vehicles in operation, a higher absolute increase in the numbers does not necessarily mean a higher annual increase rate. However, both the absolute and annual rates of increase are important parameters for tracking the deployment dynamics.

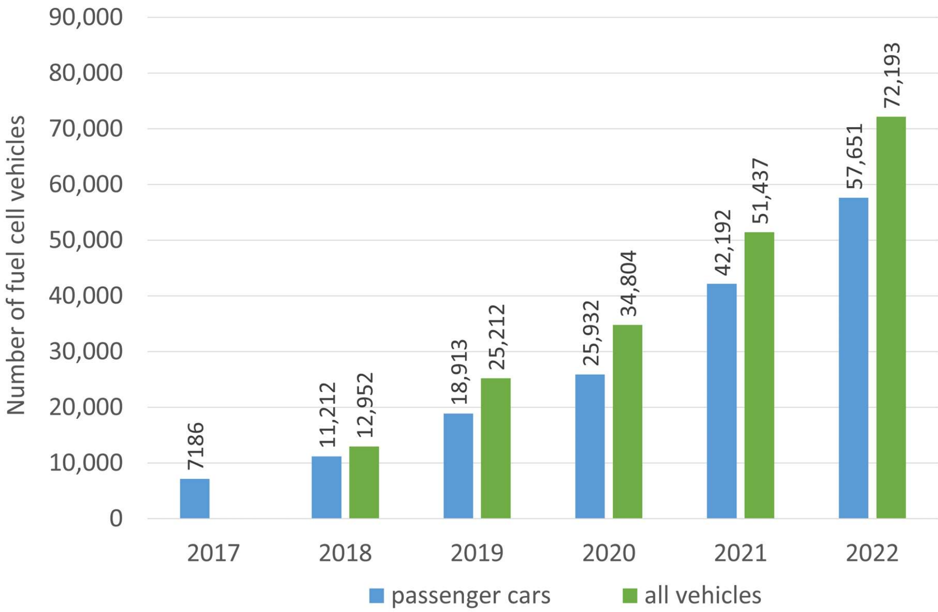

FIGURE 13. GLOBAL DEVELOPMENT OF THE DEPLOYMENT NUMBERS OF FCVS FOR 2017–2022.

Figure 14 compares the change in the shares of FCVs from 2021 to 2022 in the top five countries with more than 1000 FCVs on their roads as of the end of 2022. That year also saw a slight increase in the share of vehicles in the Republic of Korea and China, at 3% points each, leading to a reduction of 3% points for the United States and 2% points for China. The share of vehicles in the rest of the world decreased slightly, at 1% point and Germany kept its share at 3%. In total, the pie chart clearly shows that the ranking did not change in 2022.

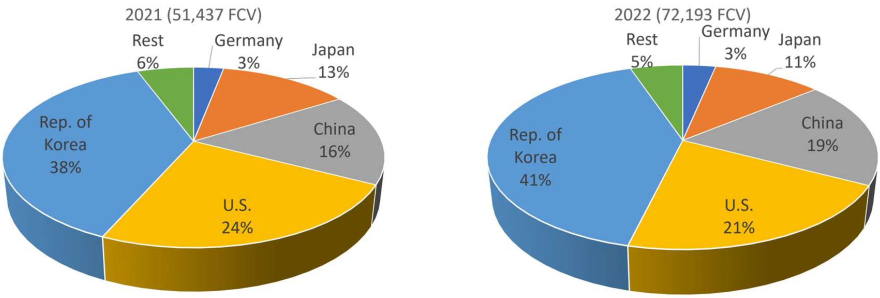

FIGURE 14. FCVS: CHANGE OF SHARES 2021–2022 IN THE TOP FIVE COUNTRIES WITH MORE THAN 1000 FCVS ON THE ROAD AS OF THE END OF 2022.

Similar to Figure 13 for FCVs, Figure 15 shows the worldwide development of the HRS network from 2017 to 2022 considering only stations that were built and ideally taken into operation. In 2022, the network experienced the sharpest annual expansion rate of 40%. This is a 5% points improvement over 2021, which was, up until now, the year with the highest ever annual increase. In absolute numbers, 2022 was also the year with the highest number of new stations, at 293 units. With this, it can be concluded that the strong development trend in 2021 continued in 2022. Figure 15 also shows that the almost linearly increasing trend in the first four years was broken in the meantime with a more dynamically increasing trend in the last two years. Thanks to this, the number of stations almost doubled in two years, with an increase from 540 in 2020 to 1022 in 2022.

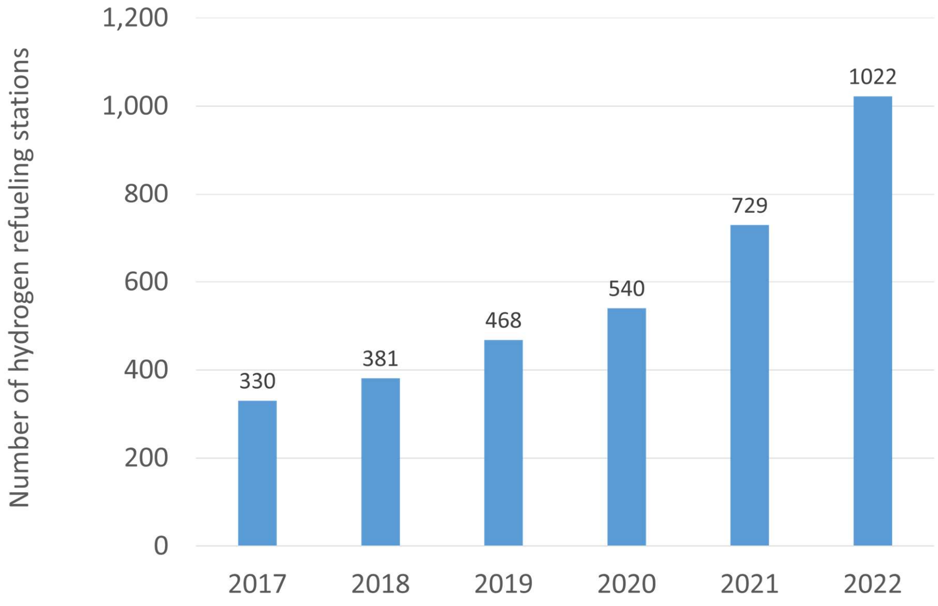

FIGURE 15. GLOBAL DEVELOPMENT OF HRSS FOR 2017–2022.

Figure 16 helps illuminate the development trends broken down to a country level. Similar to Figure 14 for vehicles, the pie charts compare the change in shares of hydrogen refueling stations from 2021 to 2022 in the top six countries with more than 50 stations as of the end of 2022. China took over the first place from Japan in 2022, with 195 new stations built, more than doubling its number of stations. The Republic of Korea retained second place, with an 87% increase in 2022. Japan is now in third place, showing no increase in 2022. Despite the opening of new stations in France (7), the United States, and Germany (each 4), their worldwide shares also diminished due to the strong increases in China and the Republic of Korea.

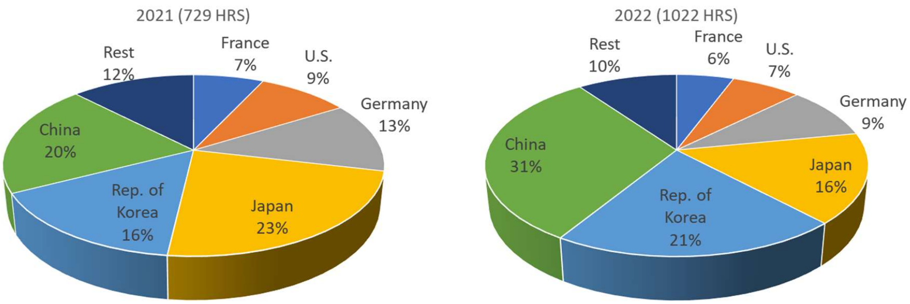

FIGURE 16. HRSS: CHANGE OF SHARES 2021–2022 IN THE TOP SIX COUNTRIES WITH MORE THAN 50 STATIONS AS OF THE END OF 2022.

As in previous years, we combined the number of FCVs and the HRSs in the top six countries with more than 50 stations for the fictive analysis shown in Figure 17. Here, the number of vehicles in these countries was divided by the number of stations without considering the geographical location of the stations and the registration location of the vehicles. The calculated number of vehicles per station in each of the six countries is presented, starting with China as the country with the highest number of stations and ending with France with the lowest amongst the top six countries. According to Figure 17, the hydrogen refueling stations in the United States served the highest number of FCVs, with 214 vehicles per station. The Republic of Korea was in second place, with 139 vehicles per station. In all other countries, the number of vehicles per station was under 50. Japan is in third place, with 47 vehicles per station, followed closely by China with 42 per station. For Germany, the number drops to 25 and for France, to 11.

Higher numbers are required to secure the economical operation of the stations. The ideal number of vehicles changes according to daily consumption per vehicle and the vehicle category, as discussed in last year's report. Comparing these numbers with those from last year, we see an increase for the United States, Germany, Japan, and France [1]. In China and the Republic of Korea, the numbers decreased. In these two countries, HRSs showed a stronger annual rate of increase compared to that of vehicle numbers in 2022. In the remaining four countries, the rate of increase of vehicles was stronger.

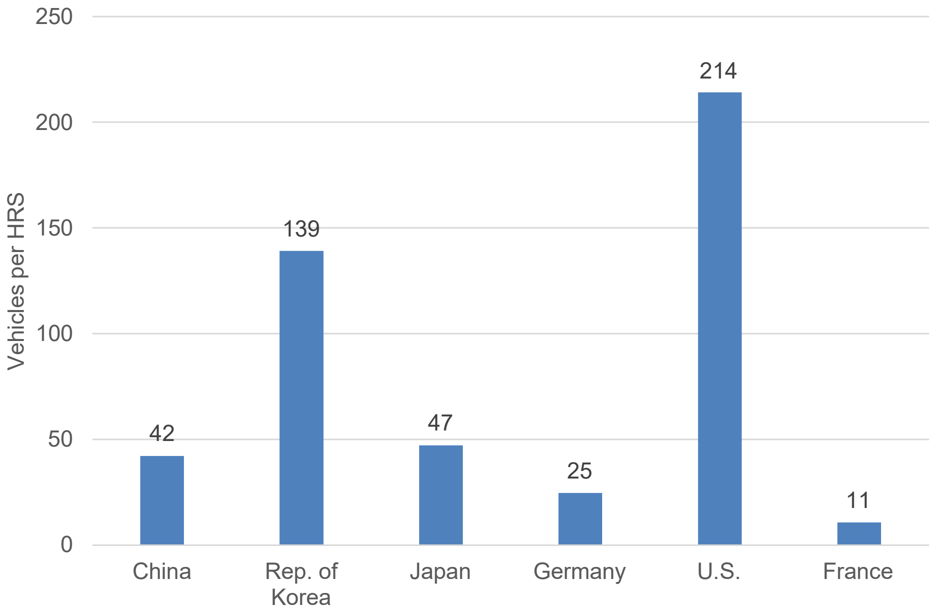

FIGURE 17. ANALYSIS OF FCVS PER STATION IN THE TOP SIX COUNTRIES WITH MORE THAN 50 HRSS IN OPERATION AS OF THE END OF 2022. (CHINA: HIGHEST NUMBER OF HRSS; FRANCE: LOWEST NUMBER AMONGST THE TOP SIX COUNTRIES).

Finally, Figure 18 displayed the development trends for the deployment of FCVs and the HRS infrastructures for the leading four countries with the highest number of FCVs on their roads as of the end of 2022. For the sake of a better comparison, an identical scaling of the axes was preferred for each country and comparison category. For the United States (top left), we can observe an almost linear increase in the number of FCVs and a linear but very moderate increase in the number of HRSs over the last six years. In this period, the number of FCVs increased from 3531 to 15,200 in the United States, whereas the number of HRSs grew from 61 to 71.

In the case of Japan (top right), we see a similar trend for HRSs to that of vehicles in the United States, which is linear. In the same period, the number of refueling stations increased from 92 to 164. The trend for vehicles can be represented by a polynomial function that is not very strong, as the number of vehicles increased from 2300 to 7743.

China (bottom left) saw a similar, linearly increasing trend for FCVs, as the number increased from 51 in 2017 to 13,504 in 2022. A much stronger, second-degree polynomial trend was observed for HRSs in the country, as their number increased from 6 to 320 within six years.

Finally, the Republic of Korea showed a similar trend to Chinese stations for both categories. The dynamic trends can again be explained by second-degree polynomial functions. From 2017 to 2022, the number of FCVs increased from 100 to 29,623 in this country, in parallel to an increase in HRSs from 11 to 213.

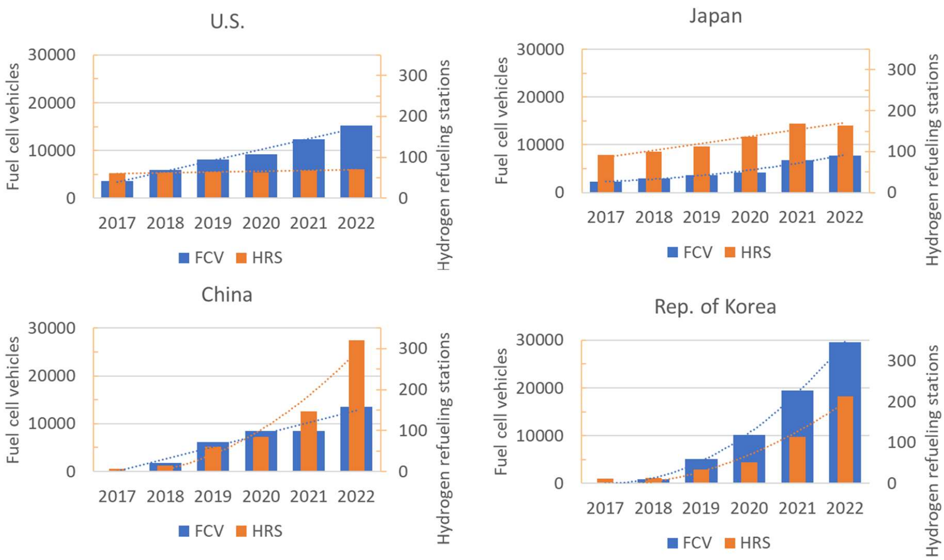

FIGURE 18. DEVELOPMENT TRENDS FOR FCV DEPLOYMENT AND HRS INFRASTRUCTURE IN THE FOUR COUNTRIES WITH THE HIGHEST NUMBER OF FCVS ON THE ROAD AS OF THE END OF 2022.

Despite the positive development trends, more progressive development is required for both categories. In last year's publication [1], we presented a detailed discussion of the announced targets and projections for the deployment of FCVs and the infrastructure expansion of HRSs. We also combined the realized and targeted numbers for the four countries analyzed here in order to show the required development trends for the next years, which could mostly be represented by third-degree polynomials. As was foreseen in last year's publication, the expected deployment rates for providing the first step for a steeper increase rate in order to achieve future targets could not be registered for 2022, increasing pressure for the future.

However, there are several exceptions that speak against this general trend. As previously mentioned, the number of light-duty FCVs and the heavy-duty trucks showed a very strong rate of increase in 2022, with 1716% and 289%, respectively. If the numbers continue to increase with the same trends in the coming years, these vehicle categories can make a significant contribution to achieving the set targets. On the refueling side, China showed a 118% increase, which is very close to the 127% target we had calculated for 2022 for this country. With this progress, the 2025 target of 1000 refueling stations is still in sight for China. For the Republic of Korea, the 310 HRS target for 2022 could not be achieved, despite the strong rate of increase of 87% in 2022. The 2025 target with 450 stations is still realistic, with 213 stations already in operation at the end of 2022. Japan is also not far away from the 2025 target, with 320 stations, as already more than half of these stations are in operation; however, as the expansion did not continue in 2022, it is questionable whether the 2025 target can be achieved.

5. CONCLUSIONS

This publication provides an update on the global deployment status of FCVs in road transport, together with an overview of the present HRS infrastructure as of the end of 2022. The number of FCVs has surpassed 70,000 units. Moreover, the number of HRSs has surpassed 1000 units. More than 40% of the overall FCV population and 50% of FCEV population are in the Republic of Korea. In addition, our data collection shows that more than 90% of all FCVs are registered in four countries: the Republic of Korea, the United States, China, and Japan in descending order.

The FCV fleet is dominated by passenger cars, which make up 80% of it. 94% of these vehicles are in four countries: the Republic of Korea, the United States, Japan, and Germany. On a continental basis, more than 70% of all vehicles and 65% of passenger cars are on Asian roads. China dominates the numbers for commercial vehicles; 84% of buses, 98% of trucks, and 91% of light commercial vehicles are in this country. 2022 also saw a very strong increase in the number of heavy-duty trucks and light commercial vehicles.

China took over the lead for HRSs for the first time in 2022, followed by the Republic of Korea and Japan; Asia alone hosts 700 HRSs.

Our analysis shows that the annual rate of increase for passenger cars was much slower than in 2019 and 2021. In addition, the absolute increase was lower than that in 2021. For all FCVs, the annual rate of increase was also moderate, but the absolute increase was the highest in 2022. Concerning the expansion of the HRS infrastructure, 2022 exhibited the strongest ever increase. As of the end of 2022, the United States and the Republic of Korea are the only countries in which the number of vehicles per station is higher than 100.

Looking at the four countries with the highest numbers of FCVs on their roads, we can observe a strong non-linear increasing trend for the Republic of Korea and a non-linear but not strong trend for Japan. Concerning HRSs, strong non-linear trends can be observed for China and the Republic of Korea. Despite the positive development trends for the deployment of FCVs and refueling infrastructure, a more progressive development trend is required for both vehicles and their refueling infrastructure. Such promising trends were observed for light commercial vehicles and heavy-duty trucks as vehicle categories, and for refueling stations in China and the Republic of Korea.

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The presented data is intended to provide an overview of the current status and perspectives and was prepared using the available sources. The AFC TCP does not claim that the data provided is complete.

The AFC TCP functions within a framework created by the IEA. The activities of the AFC TCP were coordinated by the IEA's Working Party on Energy End-use Technologies (EUWP). The 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.

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8. APPENDIX

TABLE A1. BREAKDOWN OF THE NUMBERS OF FCVS ON THE ROADS ON A COUNTRY AND VEHICLE CATEGORY BASIS. SOURCES AND EXPLANATION OF CATEGORIES: SEE CHAPTER 2.

Country	FCEV (passsen-ger cars)	Buses	Light commer-cial vehi-cles	Medium-duty trucks	Heavy-duty trucks	Total (FCV)
Lithuania	1					1
Brazil		1				1
Finland	1					1
Estonia	2					2
Slovakia	3					3
Portugal	3	2				5
Costa Rica	4	1				5
Luxemburg	5	5				10
Latvia		10				10
Czech Rep.	11					11
Spain	11	9				20
Iceland	27					27
India		58				58
Sweden	65	2			2	69
Italy	52	20				72
Austria	60	25			5	90
Belgium	105	4	1			110
Poland	115					115
Denmark	167	4	3	1	2	177
Australia	197					197
Norway	251	10		6		267
Canada	303	10				313
Switzerland	266	20	10		48	344
U.K.	458	98	7	1		564
France	589	33		1		623
Netherlands	579	54	14	39		686
Germany	2201	68	43	28	2	2342
Japan	7619	124				7743
China	240	5410	812	3790	3252	13504
U.S.	14979	211			10	15200
Rep. of Korea	29337	281		5		29623
Worldwide	**57651**	**6460**	**890**	**3871**	**3321**	**72193**

TABLE A2. BREAKDOWN OF THE NUMBERS OF HRSS IN OPERATION ON A COUNTRY BASIS. SOURCES: SEE CHAPTER 3.

Country	Number of HRS	Number of public HRS (if available)	Notes	HRS locations
Colombia	1	1	350 bar	
Portugal	1		350 bar	
Hungary	1		dual	
Croatia	1	1	30 bar, for bicycles	
Slovenia	1	1	dual, passenger cars	
Costa Rica	1	1	350 bar, 700 bar	
Malaysia	1		dual; cars and buses	
Latvia	1	1	dual	
Saudi Arabia	1		700 bar	
United Arab Emirates	1		700 bar	
Czech Republic	2	2	1x 350 bar, 1x 700 bar	
Iceland	2	2	700 bar	
India	2		350 bar	
Italy	3	2	2 dual, 1x 350 bar	
Norway	5	5	1 dual, 4 700 bar	
Australia	5		4x 700 bar, 1 dual	
Sweden	5	5		https://vatgas.se/fakta/utbyggnad-av-vatgastank-stationer-tanka-vatgas-vatgastankstationer/
Belgium	6	6	3 dual, 2x 700 bar, 1x 350 bar	
Canada	6	5	700 bar for light-duty	https://www.nrcan.gc.ca/energy-efficiency/transportation-alternative-fuels/electric-charging-alternative-fuelling-stationslocator-map/20487#/find/nearest?coun-

				try=CA&fuel=HY&hy_nonre-tail=true
Denmark	6	6		https://brintbiler.dk/tank-stationer/
Spain	8	2		
Austria	8	8	Both forms of 350/700 bar available in the country	
U.K.	10		700 bar	
Nether-lands	11			
Switzerland	12	12		
France	58		18 HRS 700 bar, 48 HRS 350 bar, 6 HRS 200 bar	https://vighy.france-hydro-gene.org/chiffres-cles/
U.S.	71	52	350 bar and 700 bar	https://afdc.en-ergy.gov/fuels/hydrogen_lo-cations.html
Germany	95	95	Mainly 700 bar, 7 dual (350/700)	https://h2.live/en
Japan	164	164	All: 700 bar	http://fccj.jp/hystation/in-dex.html#hystop
Rep. of Ko-rea	213	199		
China	320		Number of HRSs built at the end of 2022; unclear if all stations were operating. The number also takes the 22 stations that were dismantled into consid-eration.	
Worldwide	**1022**			

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