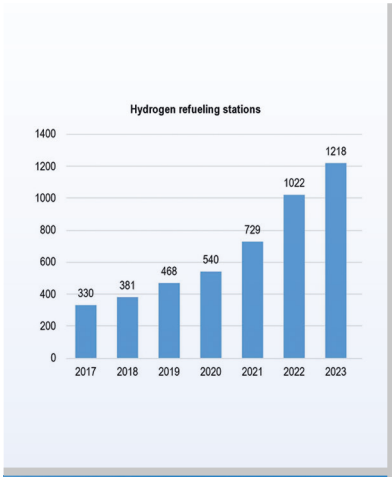

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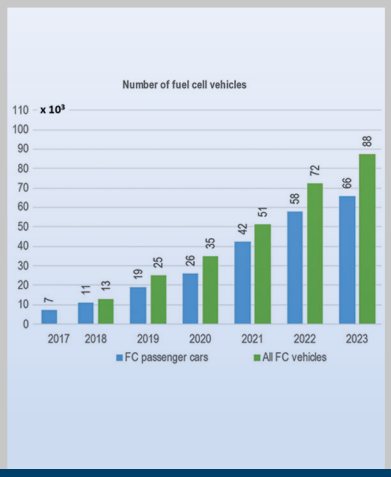

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Deployment of Fuel Cell Vehicles in Road Transport and the Expansion of the Hydrogen Refueling Station Network: 2024 Update

Thomas Grube and Michael Rex

Abstract

The objective of this report is to provide an overview of the current status of fuel cell vehicles for road transport and the hydrogen refueling station infrastructure, based on a comprehensive data collection and analysis initiative conducted by the International Energy Agency (IEA) Technology Collaboration Programme on Advanced Fuel Cells.

As in previous iterations, the data was collected for the period until the end of December, in this case, of the year 2023, to provide an update for 2024. Our data collection indicates that the fleet of fuel cell vehicles, which is now approaching 90,000 units, is being refueled by a network of over 1,200 hydrogen refueling stations. As in previous years, the data collected demonstrates that South Korea continues to lead the global fleet. This nation accounts for almost 40% of the total fuel cell vehicle population and half of the fuel cell passenger car population. Furthermore, 93% of all fuel cell vehicles are in operation in just four countries, with passenger cars dominating the fleet, accounting for 75% of the total. This year's update also shows a continued significant increase in the number of heavy-duty trucks. In terms of hydrogen refueling stations, China is again the leading nation, followed by South Korea and Japan, resulting in more than 800 stations in the Asian continent. Overall, the year 2023 witnessed another significant increase in the number of hydrogen refueling stations on record.

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1 Introduction

The potential of fuel cells is becoming increasingly evident in a variety of transportation applications. This surge in interest is primarily driven by global efforts to achieve greenhouse gas neutrality or net-zero targets. The utilization of hydrogen derived from renewable sources presents a fully zero-emission transportation solution in the form of fuel cell vehicles. Irrespective of the source of hydrogen, a fuel cell vehicle is invariably free of emissions on the local level, with the sole byproduct being water. Consequently, fuel cell vehicles play a significant role in reducing local emissions and supporting the electrification of the transportation sector. This is particularly advantageous in areas where battery electric vehicles (BEVs) are unable to meet the necessary requirements due to limitations in range, extended recharging times, and reduced payloads caused by the weight of the battery.

It is therefore pertinent to inquire as to the current status of fuel cell vehicle deployment. Which countries are at the vanguard of the markets for these vehicles? Which vehicle categories are currently available for consumer purchase? What is the current status of hydrogen refueling station infrastructure across different countries? To address these questions, the Advanced Fuel Cells Technology Collaboration Programme (AFC TCP) has been engaged in the annual collection of data from its members since 2018 [1–6]. This publication presents the findings from the most recent data collection, providing an update for 2024 based on data as of the end of 2023. Furthermore, the report examines and analyzes development trends based on the previous year's data.

The following chapter presents the latest data on the deployment of fuel cell vehicles. It includes a comprehensive and detailed analysis of the data, presenting a breakdown of the figures across various vehicle categories, continents, and countries. The third chapter is devoted to an examination of the hydrogen refueling station infrastructure at the continental and country levels. The fourth chapter provides a more detailed examination of the data through a variety of analytical techniques. This includes a global overview of vehicle and station numbers over the past seven years, as well as an in-depth investigation into the changes in these numbers over the previous year for countries with the highest counts of vehicles and stations. Additionally, a combined analysis will be conducted to examine the number of vehicles per station in selected countries. Finally, development trends for selected countries will be analyzed, offering valuable insights into the current state of fuel cell mobility.

2 Fuel cell vehicles

As indicated by the 2024 update of the AFC TCP data survey, the number of operational fuel cell vehicles reached 88,025 by the end of 2023. [7–41] With a 39% market share, South Korea leads the global fuel cell vehicle deployment, followed by China with a 23% share. The United States and Japan were identified as the third and fourth largest markets for FCEVs, with respective shares of 21% and 11%. Figure 1 elucidates that the international fuel cell vehicle fleet is concentrated in these countries, collectively representing 92% of the global FCEV fleet. Among the countries of Europe, Germany has the largest fleet, comprising more than 2,300 vehicles. France is the second European country with a fleet exceeding 1,000 vehicles, with the Netherlands, the United Kingdom, Switzerland, Norway, Denmark, Poland, and Belgium also having fleets of more than 100 vehicles. Additionally, fleets exceeding 100 vehicles are present in Canada, Australia, and India. In Austria, Italy, Spain, Sweden, Iceland, the Czech Republic, Latvia, and Luxembourg, fleets of 50-100 vehicles are operational. The list of countries with FCEVs is concluded with Costa Rica, Portugal, Slovakia, Estonia, Finland, Brazil, Bulgaria, Lithuania, and Romania, which have less than 10 vehicles and are listed in descending order.

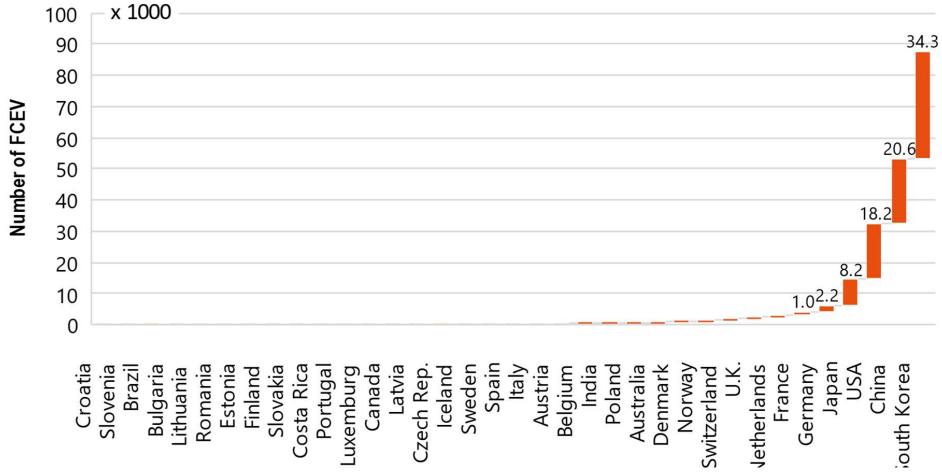

Figure 1. Country-based distribution of fuel cell vehicles on the road at the end of 2023.

The fuel cell vehicle segments, delineated for the purpose of presenting data on fuel cell electric vehicles in this survey, are illustrated in Figure 2. The initial category encompasses passenger cars and vans. The term "fuel cell–electric vehicle" (FCEV) is exclusively used in reference to passenger cars. The more generic term, "fuel cell vehicle" (FCV), encompasses all vehicle classes depicted in Figure 2, including passenger cars. Furthermore, fuel cell buses

(FCB) with more than eight seats, including the driver's seat, and typically significantly higher vehicle masses were considered. For the purpose of this study, light commercial vehicles (LCVs) with a vehicle mass limit of 3.5 tonnes, the same as passenger cars, are included in the third vehicle segment. The mass limits for medium- and heavy-duty trucks are higher, with a general limit of 12 tonnes for medium-duty trucks and 10 tonnes for trailers and semi-trailers. Heavy-duty trucks exceed both of these 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.

Figure 3 illustrates that passenger cars constitute the predominant category within the global fleet of fuel cell vehicles (FCVs), representing 75% of the total. This implies that for every three FCVs registered, two are passenger cars. Buses represent the second highest share at 9%, followed by heavy trucks at 8% and medium trucks at 5%. Light commercial vehicles account for only a significantly smaller share of 1%. It should be noted that for some countries, the numbers of light commercial vehicles are included within the passenger car segment. However, this detail would not alter the general distribution presented in Figure 3.

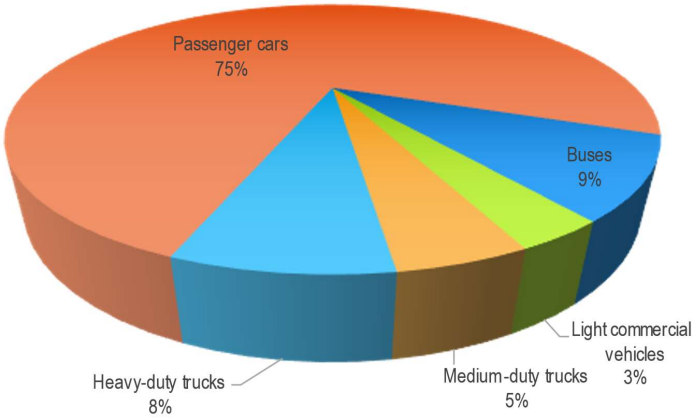

Figure 3. Shares of different vehicle categories as of the end of 2023.

Figure 4 illustrates the distribution of fuel cell vehicles across all vehicle segments and continents. As in previous years, the majority of fuel cell vehicles are located in Asia, representing nearly three-quarters of the global total. North America accounts for over one-fifth of the market, while Europe represents a smaller share at 7%. Australia has a negligible share of 0.3%. Latin America, with only seven fuel cell vehicles in total, has a similarly insignificant presence in the global market.

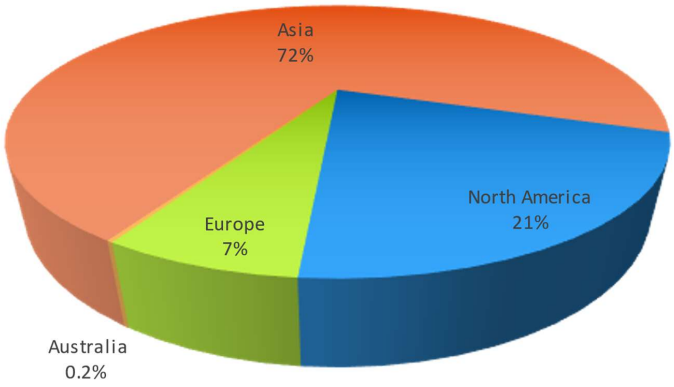

Figure 4. Distribution of fuel cell vehicles by continent as of the end of 2023.

Having initially considered the broader context of fuel cell vehicles, we now turn our attention to the specifics of their distribution across different vehicle categories, commencing with

passenger cars. The total number of fuel cell passenger cars was determined to be 66,065 by the end of 2023. Figure 5 illustrates the distribution across continents in the upper left quadrant. As is the case with all vehicles, approximately two-thirds of passenger cars are located in Asia. It is important to note, however, that the proportion of passenger vehicles in Asia is nine percentage points lower than the Asian share of all fuel cell vehicles. North America is home to more than a quarter of all passenger cars, representing a higher proportion than the distribution of all fuel cell vehicles. The proportion of passenger cars in Europe remains relatively low, although there has been a slight increase compared to the overall vehicle population. Australia accounts for a mere 0.3% of the total.

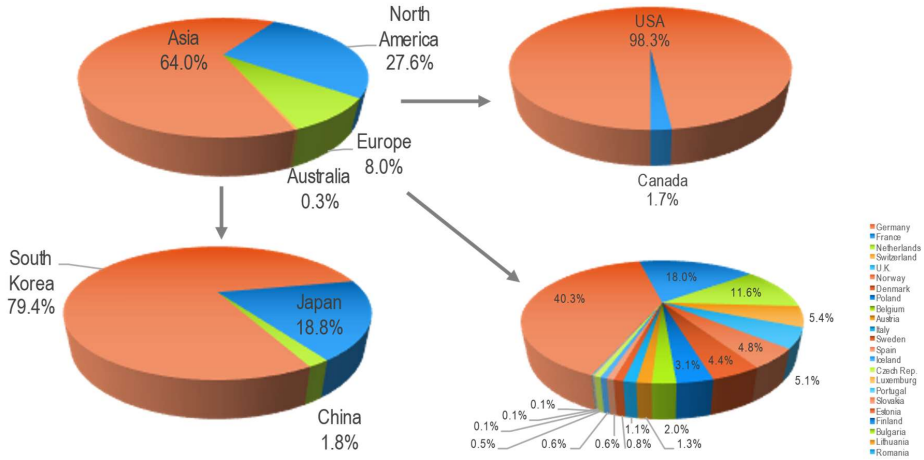

Figure 5. Distribution of fuel cell passenger cars across different continents and their detailed analysis.

The chart in the lower left quadrant of Figure 5 depicts the geographic distribution of fuel cell vehicles in Asia. South Korea has a dominant position in the passenger car market in Asia, with a market share of nearly four out of every five cars, while Japan has a market share of approximately one in every five cars. It is also noteworthy that China reappears on this chart after a period of absence, although its current contribution is relatively modest, at approximately 2%.

As illustrated in the top right chart of Figure 5, the North American passenger car market is dominated by the United States, which accounts for over 98% of the market. California is a particularly prominent player in this market. The remaining 1.7% of vehicles are registered in Canada. The bottom right chart of Figure 5 illustrates an intriguing trend in the European market. Notwithstanding the relatively low proportion of fuel cell vehicles in Europe, which account for only 8% of the global fuel cell car population, these vehicles are distributed across 21 different countries, with Germany representing approximately 40% of this total.

Furthermore, the aggregate number of fuel cell cars in Germany, the Netherlands, and France already exceeds the total number of fuel cell passenger cars in two-thirds of European countries. Additionally, the United Kingdom, Switzerland, and Norway account for at least five percent of the fuel cell passenger cars in Europe.

In light of this continental insight, the country-based distribution of fuel cell cars is illustrated in the waterfall diagram presented in Figure 6. The four countries with the highest number of fuel cell cars, and which have at least 2000 such vehicles, are South Korea (51%; 33,591 FCEVs), the United States (27%; 17,940 FCEVs), Japan (12%; 7944 FCEVs), and Germany (3%; 2139 FCEVs).

Consequently, the remaining countries account for a mere 6% of the fuel cell passenger car fleet. It is notable that France, China, and the Netherlands have, among these, the highest number of fuel cell vehicles, with 955, 759, and 615, respectively. Canada, Switzerland, the United Kingdom, and Norway are the countries with FCEVs numbers exceeding 250 units, with 319, 289, 270, and 257 FCEVs, respectively. The following group of countries comprises those with more than 100 FCEVs: Denmark (232 FCEVs), Australia (197), Poland (165), and Belgium (107). Additionally, Austria (67) and Italy (58) have a greater than 50-unit FCEV presence. The remaining countries included in the survey are Sweden (44 FCEVs), Spain (33), Iceland (30), the Czech Republic (28), Luxembourg (5), Portugal and Costa Rica (4 each), Slovakia (3), Estonia and Finland (2 each), and finally, Bulgaria, Lithuania, and Romania (1 each), see Figure 6.

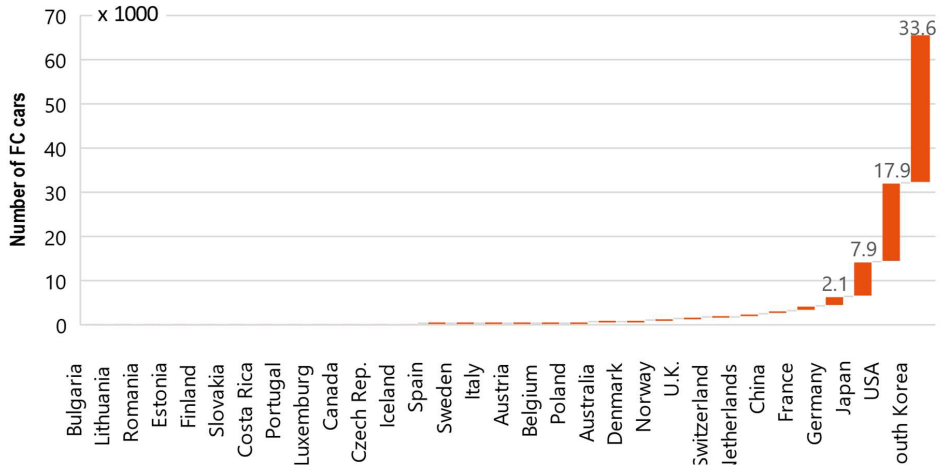

Figure 6. Country-based distribution of fuel cell passenger cars on the road by the end of 2023. FC: Fuel cell.

Figure 7 illustrates the geographical distribution of fuel cell-based light commercial vehicles (LCV) on the road. As illustrated in the waterfall diagram, China represents the dominant market for fuel cell-based light commercial vehicles (LCVs), with 2732 of these vehicles out of a total of 2936 in the category. Additionally, such vehicles are deployed in Germany (16 LCVs), the Netherlands (13), Switzerland (10), the United Kingdom (7), Denmark (2), and Belgium (1). It has been previously observed that for certain countries, the total number of light commercial vehicles utilizing fuel cell technology is incorporated into the overall figure for passenger cars. France provides an illustrative example of this phenomenon.

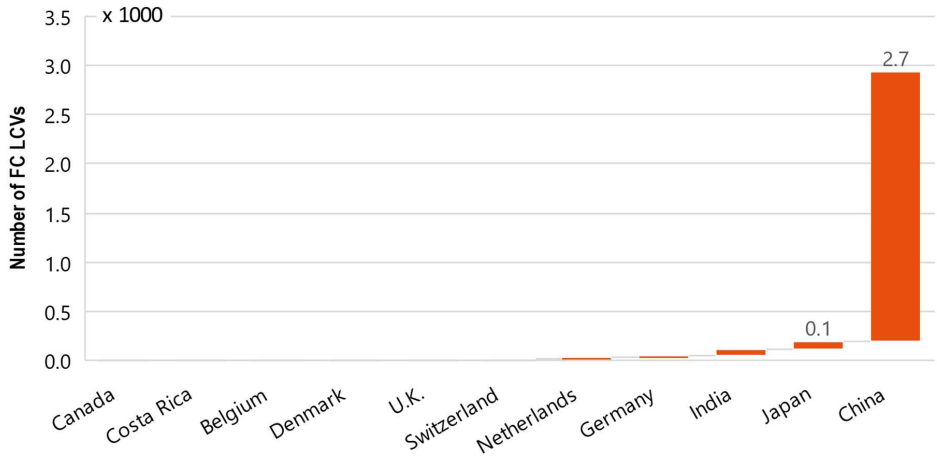

Figure 7. Country-based distribution of fuel cell light commercial vehicles on the road by the end of 2023. FC: Fuel cell; LCV: Light commercial vehicles.

Figure 8 illustrates the geographical distribution of 8148 fuel cell buses (FCBs) across various countries. The majority of FCBs are located in China, with 81% of the population represented by 6632 buses. Additionally, countries with over 100 FCBs include South Korea (651 FCBs), Germany (178), Japan (149), and the United States (101). Additionally, the United Kingdom (98 FCBs), the Netherlands (65), France (59), India (58), and Norway have a minimum of 50 FCBs each. The list continues with Spain and Latvia (22 FCBs each), Switzerland (20), Italy (13), Austria (8), Luxembourg (5), Denmark and Belgium (4 each), Sweden and Portugal (2 each), and Canada, Brazil, and Costa Rica (1 each). At the continental level, at least nine out of ten FCBs are located in Asia.

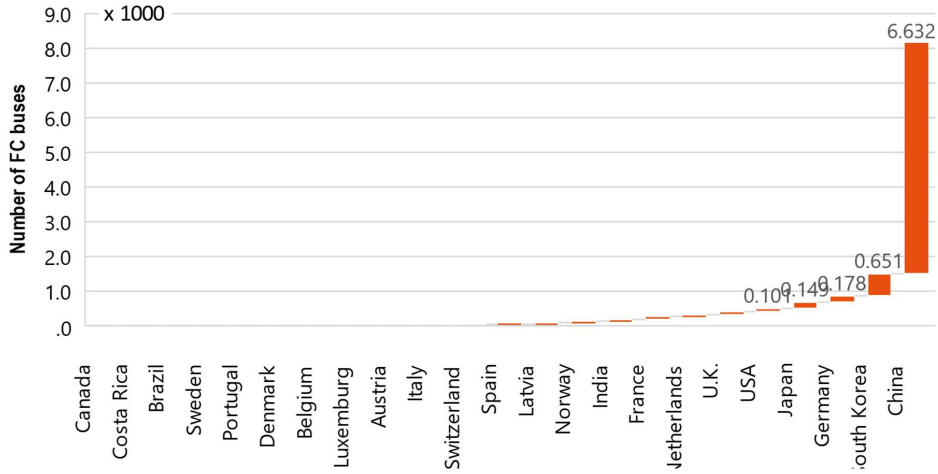

Figure 8. Country-based distribution of fuel cell buses on the road by the end of 2023. FC: Fuel cell.

Figure 9 illustrates the distribution of the 4122 medium-duty fuel cell trucks (MD-FCTs) across seven countries. Once more, this market is dominated by vehicles registered in China, which account for 95% of the total and 3901 trucks. The two countries with the highest number of MD-FCTs in operation are Switzerland (77 MD-FCTs) and the United Kingdom (52). Furthermore, fuel cell MDTs are present in Norway (41 FC-MDTs), the Netherlands (35), and South Korea (16).

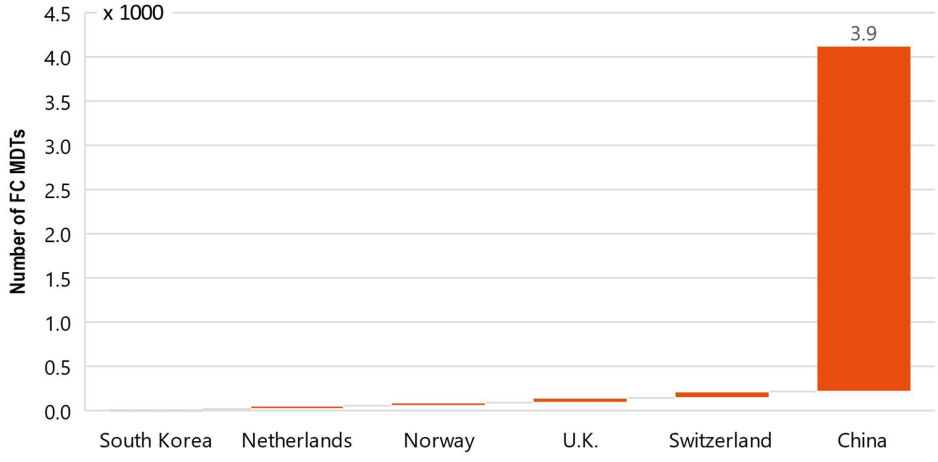

Figure 9. Country-based distribution of medium-duty fuel cell trucks on the road as of the end of 2023. FC: Fuel cell; MDT: Medium duty truck.

In regard to the final commercial vehicle category, namely heavy-duty fuel cell trucks (HD-FCTs, Figure 10), a comparable pattern was observed to that of the preceding three categories. As with the medium-duty category, the majority of these vehicles are located in China, with 6548 out of 6,757 vehicles, representing a 97% share. The United States occupies the second position with 170 vehicles, followed by Germany (30), France (6), Sweden (2), and Austria (1).

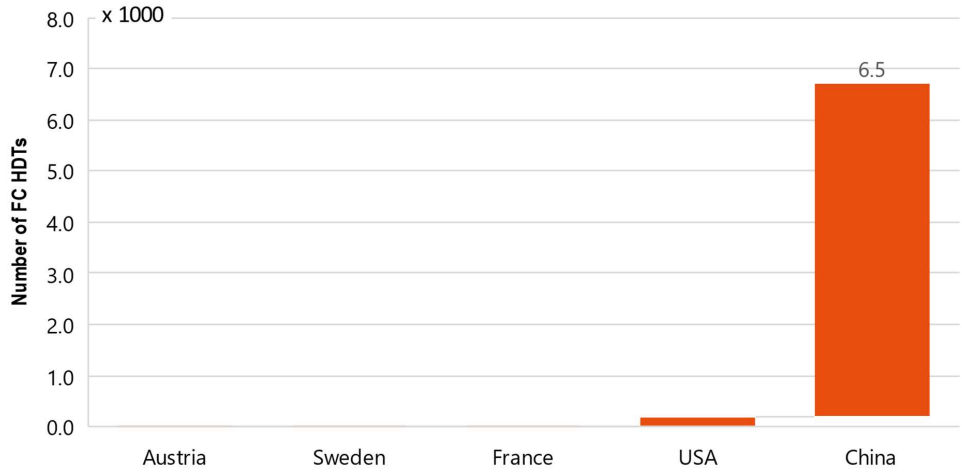

Figure 10. Country-based distribution of HD-FCTs on the road as of the end of 2023.

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

3 Hydrogen refueling stations

This section presents the findings of the AFC TCP survey on the global status of hydrogen refueling station (HRS) infrastructure. As of the conclusion of 2023, 1218 hydrogen refueling stations were documented to be operational across 28 countries. [11–13], [15–26], [28–36], [38–47] This figure encompasses both public and private stations, which now exceed 1200 in number.

As illustrated in Figure 11, China (406 HRSs) is in the leading position, followed by South Korea (286) and Japan (174). Each of these countries has a hydrogen refueling station fleet comprising more than 100 stations, representing an impressive 71% of the global HRS fleet. Additionally, three countries have more than 50 HRSs each: Germany (89 HRSs), France (52), and the United States (55). The remaining 22 countries have between one and 34 stations, representing a cumulative share of 12% of the worldwide hydrogen refueling stations.

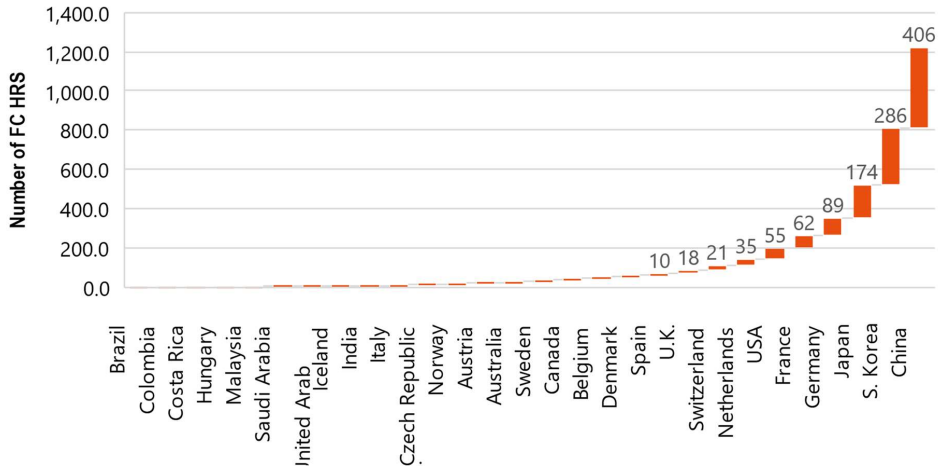

Figure 11. Country-based distribution of HRSs worldwide as of the end of 2023.

Given the accelerated expansion of the HRS network in China, it has not been possible to ascertain with certainty that all 320 HRSs constructed by the end of 2022 in China are currently operational. With regard to the remaining countries, the data set reflects not only the stations that have been constructed but also those that have commenced operation. Consequently, the total number of stations constructed by the end of 2023 is greater than 1218 reported in this study. Given that China currently has the highest number of stations, we opted to retain the Chinese data in the analysis, despite the accompanying uncertainty.

Figure 12 illustrates the geographic distribution of 1218 HRSs across various continents, with a particular focus on Asia, North America, and Europe. As illustrated in Figure 4, which depicts

the distribution of fuel cell vehicles, Asia occupies the leading position, with 871 stations. The situation in Europe is somewhat different. Europe accounts for 23% of the global HRS network and is in second place with 276 stations. These are mainly located in Germany, France, and the Netherlands. These three countries are home to over two-thirds of the stations in Europe. As was the case for vehicles, numerous countries in Europe operate HRSs, which is a crucial factor in the prospective deployment of hydrogen-based transportation on the continent. North America occupies the third position after Europe, yet it accounts for a mere 5% of the global HRS infrastructure. 89% of these stations are situated in the United States.

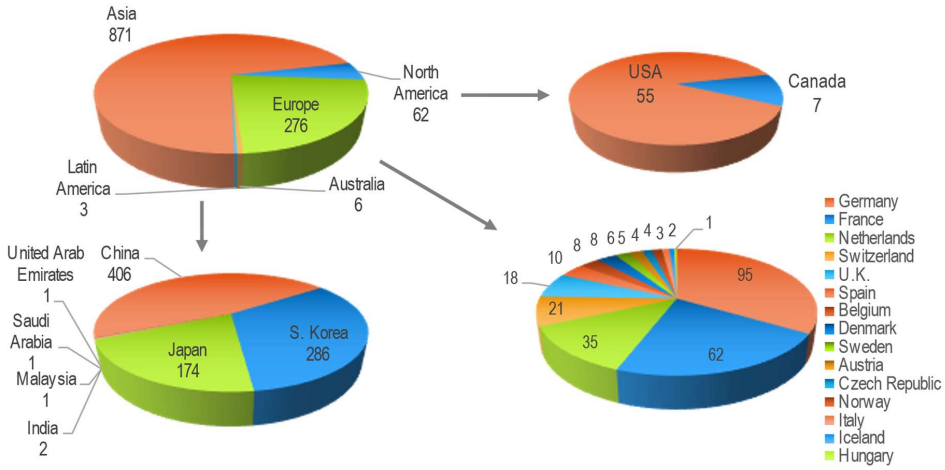

Figure 12. Distribution of HRSs to different continents and their detailed analysis.

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

In the following section, the presented analysis examines the deployment of fuel cell vehicles and hydrogen refueling stations over the past years, based on the annual AFC TCP data collection. This analysis will be conducted following the presentation of the survey results on the numbers of fuel cell vehicles and hydrogen refueling stations, which were based on the aforementioned data collection.

Figure 13 illustrates the global deployment of fuel cell vehicles (FCVs) between 2017 and 2023. In the initial year of the study, 2017, the data set only included an estimation of the number of fuel cell passenger cars. The quantities of commercial vehicles were minimal. For the subsequent years, the analysis encompasses both fuel cell passenger cars and all fuel cell vehicles, including those designed for passenger transportation. In 2023, the number of fuel cell cars exhibited an increase of 15% compared to the 2022 level. This rate is markedly lower than the value observed in 2019, which represented the highest increase among all years under consideration at 69%. The mean annual growth rate is 46%.

A review of the absolute figures reveals an increase of 8411 fuel cell passenger cars in 2023. This figure is considerably lower than the increase observed in 2022, which was 15,459 units. Thus far, the highest absolute increase has been observed in 2021, with 16,260 additional vehicles. The relatively low absolute and relative increase observed in 2023 can be attributed to a number of factors, including the continued limited exploitation of manufacturing capacities for fuel cell cars, which has been influenced by the chip crisis in 2021 and 2022. Additionally, the preference for battery-electric cars as the preferred solution for zero-emission passenger cars may have contributed to this trend. Similarly, the total number of fuel cell vehicles across all segments exhibited a moderate increase of 22% in 2023. In the preceding year, the rate of increase was markedly higher, at 40%. The highest observed increase rate was recorded in 2019, at 95% over the course of a single year. The mean increase rate between 2019 and 2023 was 49%. A more detailed examination of the data reveals an increase of 26% for buses in 2023 compared to the previous year, following a 36% increase in 2022. In contrast, light-, medium- and heavy-duty vehicles achieved an annual increase of 71% in 2023, coming from 79% in 2022.

In consideration of fuel cell vehicles across all segments, the year 2023 witnessed a decline in comparison to the absolute vehicle number increase observed in 2022, which represents the overall maximum of the 2017-2023 period with 20,756 vehicles. In 2023, the number of fuel cell vehicles increased by 15,823. As the number of vehicles in operation continues to grow, it is important to note that an increase in the absolute number of vehicles does not necessarily

correspond to a higher annual increase rate. Nevertheless, both the absolute and annual rates of increase are crucial parameters for monitoring the deployment dynamics.

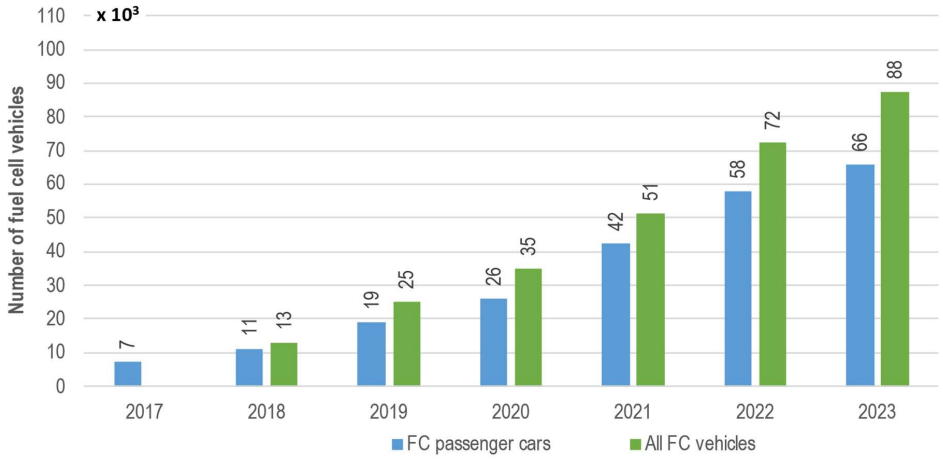

Figure 13. Global development of the deployment numbers of FCVs for 2017–2023.

Figure 14 presents a comparison of the fuel cell vehicle market shares between 2022 and 2023 for the top five countries. In that year, there was also a slight increase in the proportion of vehicles in China, by 4 percentage points, while there was a reduction of 2 percentage points for the United States and 2 percentage points for Japan. The vehicle shares in Germany, France, and the remainder of the world were found to be stable. The pie chart demonstrates that China has overtaken the United States to assume the second position, with South Korea remaining in the lead.

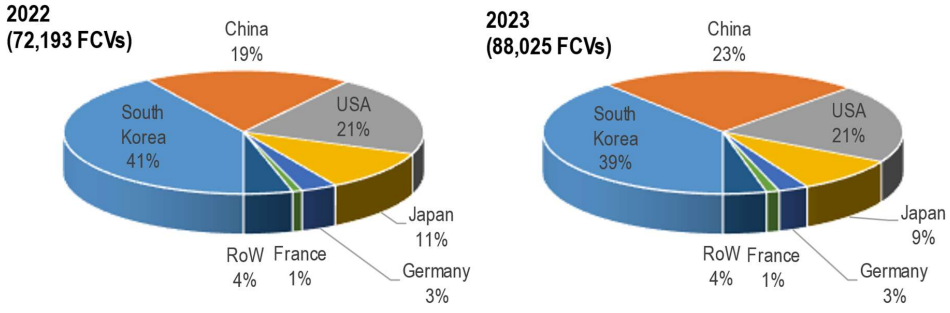

Figure 14. Change of fuel cell vehicle shares across all segments between 2022–2023 for the top six countries as of the end of 2023.

Figure 15 illustrates the global expansion of the hydrogen refueling station infrastructure between 2017 and 2023. In 2023, the network exhibited a diminished annual expansion rate

of 19% in comparison to the 2022 value of 40%. In terms of absolute numbers, 2023 was the year in which the second highest number of new stations was established, amounting to 196 units. The upward trajectory persists, albeit at a diminished rate. Figure 15 also illustrates that the trend resumes a more linear increase. As a result, the number of stations has increased by more than 100% over the past five years, rising from 540 in 2020 to 1218 in 2023.

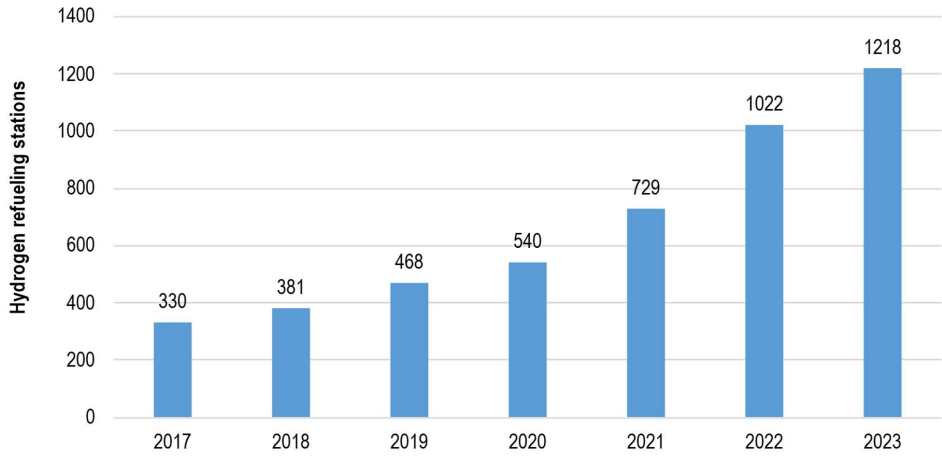

Figure 15. Global development of HRSs for 2017–2023.

Figure 16 illustrates the development trends at the country level. As with Figure 14, which depicts vehicle data, the pie charts illustrate the proportion of hydrogen refueling stations in 2022 and 2023 for the six countries with the highest number of stations by the end of 2023. China retains the top position with 406 HRSs, while South Korea occupies the second rank with 286 stations. Japan has ascended to the third position, with a modest increase of ten new stations in 2023. In contrast to the opening of four new stations in France, the HRS fleet in the United States and Germany experienced a net decrease of 16 and six stations, respectively. While this finding for the USA might indicate a more consistent trend towards fewer stations, it should be noted that some German HRSs are currently closed for refurbishment in order to serve heavy trucks and buses. It is reasonable to anticipate that the station will reopen and that the HRS fleet will be extended in the coming years.

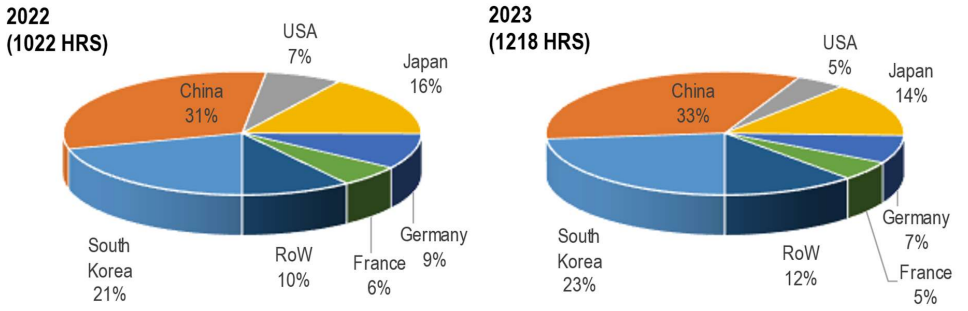

Figure 16. HRSs: Change of Shares 2021–2022 in the top six countries with more than 50 stations as of the end of 2022.

As in previous years, the number of FCVs and HRSs in the top six countries with more than 50 stations were combined for the fictive analysis illustrated in Figure 17. In this instance, the number of vehicles in each country was divided by the number of stations, without consideration of the geographical location of the stations or the registration location of the vehicles. The calculated number of vehicles per station in each of the six countries is presented, commencing with China, which has the highest number of stations, and concluding with France, which has the lowest number of stations amongst the top six countries. As illustrated in Figure 17, the hydrogen refueling stations in the United States served the highest number of FCVs, with an average of 214 vehicles per station. The Republic of Korea was in second place, with an average of 139 vehicles per station. In all other countries, the number of vehicles per station was less than 50. Japan occupies the third position, with an average of 47 vehicles per station, closely followed by China with an average of 42 vehicles per station. The number declines to 25 for Germany and to 11 for France.

To ensure the economic viability of the stations, a higher number of vehicles served per station is necessary. The optimal number of vehicles is contingent upon the daily consumption per vehicle and the vehicle category, as previously discussed in the preceding year's report. A comparison of these figures with those from the previous year reveals an increase for the United States, Germany, Japan, and France. In China and the Republic of Korea, the figures declined. In these two countries, the annual rate of increase of HRSs was more explicit than that of vehicle numbers in 2022. In the remaining four countries, the rate of increase in vehicle numbers was more pronounced.

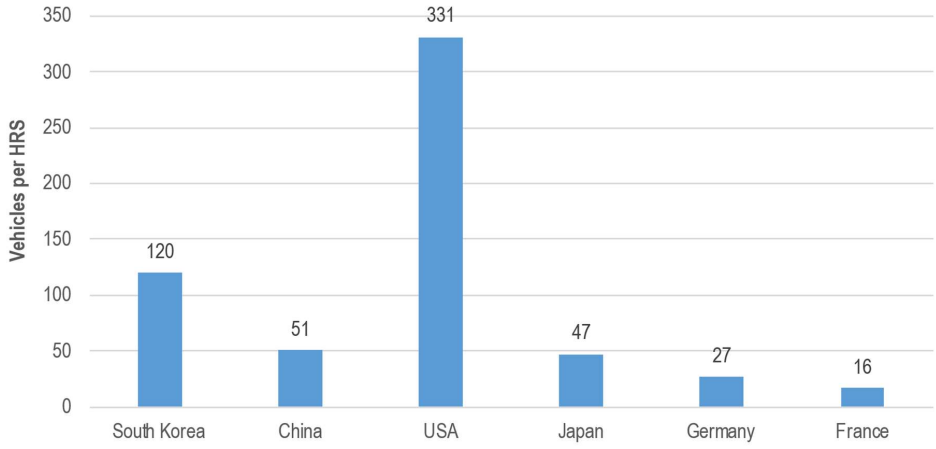

Figure 17. Analysis of FCVs per station in the top six countries with more than 50 HRSs in operation as of the end of 2022. (China: Highest number of HRSs; France: Lowest number amongst the top six countries).

Figure 18 provides a summary of the recent development trends of the FCV and HRS infrastructures deployment in the four countries with the highest number of FCVs by the end of 2023. To facilitate comparison, a uniform scaling axis was employed for each country and category. In the case of the United States (Figure 18, top left), the linear trend in FCV fleet development continued, with projections extending to 2023. In contrast, the relatively modest increase in the number of HRSs observed between 2017 and 2023 has reached a plateau, with a notable decline in the latest data point for 2023. From 2017 to 2023, the number of FCVs in the United States increased from 3531 to 17,940, while the number of HRSs decreased from 61 to 55.

In the Republic of Korea (Figure 18, top right), the rapid increase in both FCV and HRS numbers has slowed somewhat, but remains at a high level. From 2017 to 2023, the number of FCVs and HRSs increased markedly, from 100 to 34,285 and from 11 to 286, respectively.

With regard to Japan (Figure 18, bottom left), it is possible to identify divergent trends in the numbers of both FCVs and HRSs. While the fleet of FCVs expanded to 8288 vehicles from 7743 the previous year, The number of hydrogen refueling stations has remained relatively constant compared to the previous year, with 174 stations currently in operation.

China (Figure 18, bottom right) exhibited a pronounced increase in both FCVs and HRS. Specifically, the number of FCVs increased from 51 in 2017 to 20,572 in 2023. Moreover, the number of HRS units increased markedly, from 6 to 406, over the same period.

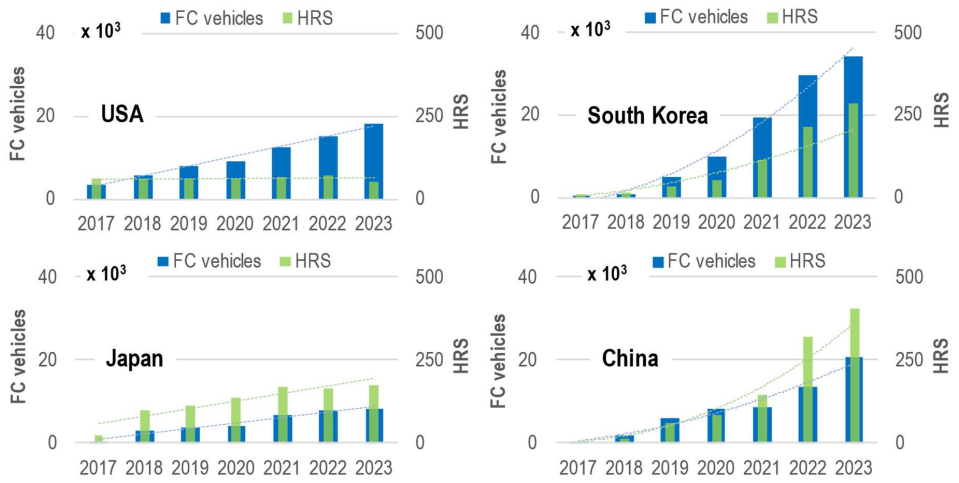

Figure 18. Development trends for FCV deployment and HRS infrastructure in the four countries with the highest number of FCVs on the road as of the end of 2022.

The available data indicate that the growth in the number of fuel cell vehicles and hydrogen refueling stations continues. However, the strong developments observed during the 2019-2021 period has slowed down, with the exception of China. It is crucial to acknowledge the notable transition towards the implementation of commercial fuel cell vehicles and the corresponding refueling infrastructure. The number of heavy- and light-duty fuel cell vehicles (FCVs) exhibited a marked increase from 2022 through 2023, with a growth rate of about 330% and 200%, respectively. The number of fuel cell passenger cars and buses exhibited an increase of 19% and 26%, respectively. All values are based on data from the present report and are compared with data from the previous year's report. [1] With regard to the development of refueling stations, the growth was relatively modest, with an increase of only 19%. The decline in sales of passenger vehicles can be attributed to the rapid growth in the market for battery electric vehicles (BEVs), which have become a priority for many major original equipment manufacturers (OEMs) in the deployment of alternative fuel vehicles. Should fuel cell vehicles be expected to play a significant role in the decarbonization of transportation, it would be necessary to significantly increase efforts in this regard.

5 Conclusions

The purpose of this report is to present an update on the global deployment status of fuel cell electric road vehicles and the respective hydrogen refueling infrastructure. The total number of fuel cell vehicles (FCVs) across all road vehicles segments is now approaching 90,000, while the number of hydrogen refueling stations (HRSs) exceeds 1200 units. With regard to all vehicle categories under consideration, the largest share of FCVs is concentrated in South Korea, representing approximately 40% of the total. In addition to the FCV fleets in China, the USA, and Japan, over 90% of all FCVs are registered in only four countries. In consideration of the individual vehicle segments, passenger cars continue to constitute the predominant share, representing 75% of the total vehicle fleet. This is followed by the rapidly growing segment of heavy trucks, buses, and medium and light commercial vehicles. A total of 93% of fuel cell passenger cars are registered in only four countries: the Republic of Korea, the United States of America, Japan, and Germany. On a continental basis, more than 70% of all vehicles and 64% of passenger cars are located on Asian roads. In the context of commercial vehicles, China is the dominant player in the current deployment landscape, with 81% of buses, 97% of heavy trucks, 95% of medium-duty trucks, and 93% of light commercial vehicles. The substantial growth in the number of heavy-duty trucks and light commercial vehicles observed in 2022 persisted throughout 2023.

With regard to the global HRS stock, China occupies the leading position with a share of one-third of all stations, followed by South Korea and Japan with 24% and 14%, respectively.

As was observed in our 2023 analysis, the annual rate of increase for passenger cars was again slower than in previous periods. This trend may be attributed to the rapid deployment of battery-electric vehicles. In essence, this trend redirects transportation-related fuel cell applications toward vehicle segments with high energy turnover, namely heavy-duty and long-distance transport.

In consideration of the deployment of hydrogen infrastructure, the year 2023 exhibits a comparatively less pronounced degree of development in comparison to the preceding year, 2022. Nevertheless, the total number of hydrogen refueling stations has increased by 19% in comparison to the 2022 level. Nevertheless, the United States and the Republic of Korea are the only countries with a vehicles-per-station ratio exceeding 100.

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The data presented in this work is intended to provide an overview of the current status and perspectives and was prepared using 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.

Region	Country	Passenger cars	Buses	Light commercial	Medium-duty trucks	Heavy-duty trucks	Total
Asia	China	759	6632	2732	3901	6548	20,572
Asia	India		58	58			116
Asia	Japan	7944	149	95			8188
Asia	South Korea	33,591	651		16		34,258
Australia	Australia	197					197
Europe	Austria	67	8			1	76
Europe	Belgium	107	4	1			112
Europe	Bulgaria	1					1
Europe	Croatia	0	0				0
Europe	Czech Rep.	28					28
Europe	Denmark	232	4	2			238
Europe	Estonia	2					2
Europe	Finland	2					2
Europe	France	955	59			6	1020
Europe	Germany	2139	178	16		30	2363
Europe	Iceland	30					30
Europe	Italy	58	13				71
Europe	Latvia		22				22
Europe	Lithuania	1					1
Europe	Luxemburg	5	5				10
Europe	Netherlands	615	64	13	35		727
Europe	Norway	257	53		41		351
Europe	Poland	165					165
Europe	Portugal	4	2				6
Europe	Romania	1					1
Europe	Slovakia	3					3
Europe	Slovenia	0					0
Europe	Spain	33	22				55
Europe	Sweden	44	2			2	48
Europe	Switzerland	289	20	10	77		396
Europe	U.K.	270	98	7	52		427
Latin America	Brazil		1				1
Latin America	Costa Rica	4	1	1			6
North America	Canada	319	1	1			321
North America	USA	17,940	101			170	18,211
	Worldwide	66,062	8148	2936	4122	6757	88,025

Table A2. Breakdown of the numbers of HRSs in operation on a country basis. Sources: See chapter 3.

Region	Country	HRS number
Asia	China	406
Asia	India	2
Asia	Japan	174
Asia	S. Korea	286
Asia	Saudi Arabia	1
Asia	United Arab Emirates	2
Australia	Australia	6
Europe	Austria	5
Europe	Belgium	8
Europe	Czech Republic	4
Europe	Denmark	8
Europe	France	62
Europe	Germany	89
Europe	Hungary	1
Europe	Iceland	2
Europe	Italy	3
Europe	Netherlands	35
Europe	Norway	4
Europe	Spain	10
Europe	Sweden	6
Europe	Switzerland	21
Europe	U.K.	18
Latin America	Brazil	1
Latin America	Colombia	1
Latin America	Costa Rica	1
North America	Canada	7
North America	USA	55
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