Chapter 1
Technology & Market
September 2020

FUEL CELLS AND HYDROGEN OBSERVATORY

This report is based on data gathered as part of the Fuel Cells and Hydrogen Observatory as at 31 December 2019. The authors believe that this information comes from reliable sources, but do not guarantee the accuracy or completion of this information. The Observatory and information gathered within it will continue to be revised. These revisions will take place annually and can also be done on a case by case basis. As a result, the information used as of writing of this report might differ from the changing data in the Observatory.

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This report was prepared for the Fuel Cells and Hydrogen 2 Joint Undertaking as part of the Fuel Cells and Hydrogen Observatory. Copies of this document can be downloaded from https://www.fchobservatory.eu/

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Executive Summary

The Fuel Cells and Hydrogen Observatory is an ambitious project to collect available valuable sector information in a single go-to source and make it available to all interested stakeholders. The technology and market module of the FCHO presents a range of statistical data as an indicator of the health of the sector and the progress in market development over time.

The module currently focusses on global fuel cell system shipments and on European FCH actors, vehicle registrations, refuelling stations and hydrogen market. The ambition over time is to broaden the scope of companies, technologies and markets and to widen the reach of geographies covered by the FCHO. This will enable the annual report to make year on year comparisons assessing market progress and identify strengths and trends. This first report provides a snapshot of technology and market data in the period January 2019 – December 2019.

Purpose:	*The technology and market module of the FCHO presents a range of statistical data as an indicator of the health of the sector and the progress in market development over time.*
Scope:	*Fuel cell shipment data is presented on a global basis. Other sections of the technology and market chapter (HRS data and FCEV data) are presented on a European basis.* *The report spans January 2019 – December 2019.*
Key Findings:	*Fuel cells and hydrogen continued to experience good growth in 2019:* *Global Fuel Cell shipments* ***> 1.1 GW*** *Europe Fuel Cell shipments up to* ***68.6 MW*** *HRS in operation or under construction 158* *FCEVs up* ***60% to 1,313****.*

Fuel cells and hydrogen continued to experience good growth in 2019, with interest in all parts of the world in new market applications and new geographical areas of activity emerging. Global fuel cell system shipments hit over a gigawatt for the first time in 2019, up 40% on the previous year. Asia took pole position from the US, accounting for 66% of the total MW shipped worldwide, whilst Europe continues to hold its own with 69 MW shipped, up from 41 MW in 2018.

The transport sector saw the most significant growth, up 40% on number of units shipped, coming from further expansion of deployed FCEVs; more than 15,000 vehicles of all types were shipped in 2019 globally. Material handling was an active sector with 5,000 units shipped. Stationary applications did not grow in 2019 but nevertheless remained significant with 51,700 units shipped.

2019 was a successful year for expansion of the HRS network in Europe. The number of HRS operating or in construction at the end of 2019 stood at 158, with a significant number of further stations at various stages of planning. Expanding networks were visible in other parts of the world most significantly in Asia. New fuel cell vehicle registrations increased by 608 in Europe to 1,919, whilst California remains out in front with more than 7,500 on the roads by the end of 2019.

Whilst the outlook for fuel cells across the spectrum of applications for 2020 held promise, the long-term impact of the coronavirus pandemic on global economies is not yet understood. However, as the world moves to assess its response, it is clear that hydrogen could have a critical role to play in enabling an

environmentally friendly economic recovery. The Commission's economic recovery plan 'Next Generation EU' highlights hydrogen as an investment priority to boost economic growth and resilience, create local jobs and consolidate the EU's global leadership.

July 2020 also saw the publication of the EU Hydrogen Strategy, laying out the strategy to decarbonise hydrogen production and to expand its use in sectors where it can replace fossil fuels. The European Clean Hydrogen Alliance was formed at the same time and will help to deliver on this strategy. In addition, with EU country strategies (Germany, France, Netherlands, Spain, Norway and Austria) recently published, the potential for successful development of a clean and globally competitive hydrogen industry in Europe has never been more achievable.

TABLE OF CONTENTS

1. Introduction

The information in this report covers the period ***January 2019 – December 2019****.*

The technology and market module of the FCHO presents a range of statistical data as an indicator of the health of the sector and the progress in market development over time.

This includes statistical information on the size of the global fuel cell market including number and capacity of fuel cell systems shipped in a calendar year. For this first edition, data to the end of 2019 is presented where possible, alongside analysis of key sector developments. Fuel cell system shipments for each calendar year are presented both as numbers of units and total system megawatts. The data are further divided and subdivided by:

- ***Application****: Total system shipments are divided into Transport, Stationary and Portable applications*
- ***Fuel cell type****: Numbers are provided for each of the different fuel cell chemistry types*
- ***Region of integration****: Region where the final manufacturer – usually the system integrator – integrates the fuel cell into the final product*
- ***Region of deployment****: Region where the final product was shipped to for deployment*

The data is sourced directly from industry players as well as other relevant sources including press releases, associations and other industry bodies. In future editions, the aspiration is to include data related to other parts of the supply chain including electrolysers and component suppliers, as well as employment statistics for the sector.

Information is presented on the number of hydrogen refuelling stations (HRS) deployed since 2014 with detailed information on HRS in operation including pressure, capacity etc. In parallel, the observatory provides data on the registered fuel cell electric vehicles (FCEVs) on European roads, providing an indication of the speed of adoption of hydrogen in the transport sector.
All sections in the Technology & Market module are updated following an annual data collection and validation cycle and the Annual report is published the following Spring.

2. 2019 Snapshot

2.1. Data Collection Methodology

The fuel cell shipment data at the end of 2019 as presented in the Technology & Market module of the Observatory is derived from E4tech's Fuel Cell Industry Review 2019[1]. This data presents a snapshot of the size of the global fuel cell market and is a consolidated view of data collected by confidential survey with over 100 participants in the fuel cell and hydrogen supply chain. The survey was conducted through to the end of September 2019 and includes a forecast for the last quarter of the year, 2019f[2].

Going forward, this industry survey will be conducted by E4tech as part of its scope for the Observatory. Data will be collected and consolidated using a newly developed Market Data Platform. This platform allows additional data from a wider range of FCH supply chain actors to be gathered. E4tech will collate the data in the Market Data Platform and aggregate it to ensure confidentiality for those companies providing data. All actors in FCH supply chains are actively encouraged to create a profile for their company or business unit on the Market Data Platform.

Hydrogen Refuelling Station (HRS) data is derived from the European HRS Availability System[3]. The data is extracted and analysed to derive the number of HRS deployed in European member states at the end of 2019. Additional information on non-EU countries is sourced through desk research.

Information on Fuel Cell vehicle deployments in Europe is sourced from the European Alternative Fuels Observatory (EAFO[4]) which monitors vehicle deployments across a broad range of alternative fuels including hydrogen. This data is supplemented with desk research for non-EU markets.

2.2. Fuel Cell Shipments

The FCHO provides detailed statistics on a number of indicators for the market development of the fuel cell space. Annual data is presented on system shipments and the sum total of those systems in megawatts, sub-divided by application, region and fuel cell type as described below. Shipment numbers are rounded to the nearest 100 units and megawatt data to the nearest 0.1 MW. Where power ratings are quoted, these refer to the electrical output unless stated otherwise. In general, the nominal, not peak, power of the system is used, with the exception of transport. Because continuous power depends heavily on system design and how it is used, peak power is reported for transport units.

The reported figures refer to shipments by the final manufacturer, usually the system integrator. In transport the vehicle is counted when shipped from the factory. This is because the shipments of stacks or modules in a given year can be significantly different from the shipment of final units (e.g. vehicles) in the same timeframe. We use stack and module shipment data to enable correlation of numbers between years. The regional split in the data is provided both in terms of where the systems have been integrated and where they are shipped to. Where possible, we do not include shipments for toys and educational kits.

[1] E4tech Fuel Cell Industry Review, fuelcellindustryreview.com
[2] 2019f is the data at end of 2019 using the forecasted numbers for the last quarter
[3] HRS Availability System, h2-map.eu
[4] European Alternative Fuels Observatory, eafo.eu

The data is presented using the following definitions:

- *Shipments by region of deployment, depicting where systems are shipped to for final deployment,*
- *Shipments by region of system integration, depicting where stacks are integrated into final system such as a vehicle or CHP system, and*
- *Shipments by application, depicting the number of systems by application area (transport, stationary etc)*

2.2.1. Shipments by Region of Deployment

2019 was a undoubtably a good year for the global fuel cell sector, experiencing heathy and significant year-on-year growth (see Table 1); importantly for the first time exceeding 1 GW deployed, somewhat of an industry milestone. Europe has grown consistently in recent years, with 2019 hitting ***68.6 MW*** *deployed, a* ***60% increase*** *albeit from a low base relative to other parts of the world. Asia continues to be out in front in terms of capacity, effectively doubling their deployed MW 2019.*

Table 1. Megawatts by Region of Deployment

MW	2015	2016	2017	2018	2019f*
Europe	27.7	27.4	38.9	41.2	68.6
N America	108.4	213.6	331.8	425.3	384.1
Asia	159.7	273.8	285.8	337.9	676.7
RoW	2.3	1.7	2.1	1.2	0.2
Total	**298.1**	**516.5**	**658.6**	**805.8**	**1,129.6**

** 2019f is the data at end of 2019 using forecasted numbers for the last quarter*

2.2.2. Shipments by Application

Whilst 2019 saw a steady 3% increase in the total number of units shipped over 2018, the capacity figures indicate a shift to larger systems, with ***over 70,000 units or 1.1 GW*** *shipped this year, up significantly on prior year capacity.*

Table 2: Global Shipments by Application

1,000s units	2015	2016	2017	2018	2019f
Portable	8.7	4.2	5.0	5.7	3.9
Stationary	47.0	51.8	54.9	51.9	51.7
Transport	5.2	7.2	10.6	10.9	15.3
Total	**60.9**	**63.2**	**70.5**	**68.5**	**70.9**

Transport applications continued to grow, ***up by 40%*** *in terms of number of units and* ***up by 55%*** *up in MW from the prior year. Fuel cell vehicles made up more than* ***80% of the Total MW*** *shipped with two companies, Hyundai and Toyota collectively accounting for two thirds of this supply. Other noticeable factors were the numbers for fuel cell trucks and buses in China, with an estimate of over 1,500 units*

shipped, as well as the emergence of a number of specialist fuel cell vehicles including commercial vans and refuse trucks onto the EU market.

Table 3: Global MWs shipped by Application

MW	2015	2016	2017	2018	2019f
Portable	0.9	0.3	0.6	0.7	0.6
Stationary	183.6	209.0	222.3	220.6	221.2
Transport	113.6	307.2	435.7	584.5	907.8
Total	**298.1**	**516.5**	**658.6**	**805.8**	**1,129.6**

*In total more than **15,000 vehicles** of all types were shipped globally, accounting for more than **900 MW** of the total 1.1GW expected by year end.*
In addition, shipments into material handling applications continue to be a strong contributor with over 5,000 units shipped, one third of the total vehicle unit shipments.

*Stationary applications shipments are flat compared with prior year, stable at 51,700 units and 220 MW capacity, however the sector still dominates as the largest in terms of all units shipped at **73%** of the global total. As previously, the Japanese Ene-farm programme has a major impact with nearly 45,000 of the total 70,000 units going into Japanese homes.*
Number of units shipped into portable applications showed a decline in 2019 but the MW numbers suggest a shift to slightly larger capacity systems. Nevertheless, the overall MW shipments is low.

2.2.3. Shipments by Region of System Integration

Table 4: Global units shipped by region of system integration

1,000s units	2015	2016	2017	2018	2019f
Europe	8.0	4.2	6.7	8.8	9.5
N America	6.5	6.3	8.4	6.6	6.7
Asia	46.1	52.5	55.4	53.2	54.8
RoW	0.2	0.2	0.0	0.0	0.0
Total	**60.9**	**63.2**	**70.5**	**68.5**	**70.9**

*The numbers for shipments by region of system integration, depicting where stacks are integrated into final system, reveal that Asia is not only leading deployment of fuel cells (ca. **60% of total megawatts)** but is also home to nearly **85%** of fuel cell system megawatts manufactured in 2019. Again a large part this is due to Toyota's and Hyundai's fuel cell passenger car manufacturing, but also a significant amount of stationary fuel cells made in Japan and Korea.*

Outside Asia, notable fuel cell manufacturing activity is found in the US and Canada, ranging from SOFC for stationary use to PEMFC for forklift truck applications. California is the most important region of fuel cell car adoption for Toyota and Hyundai outside their respective domestic markets in Japan and Korea. As there is no fuel cell car model available from US OEMs, this region is a net importer of fuel cell systems, despite strong players in stationary fuel cell systems and in PEMFC stacks and components.

Table 5: Global units shipped by region of system integration

MW	2015	2016	2017	2018	2019f
Europe	4.8	6.7	8.2	11.0	13.1
N America	171.0	188.3	215.7	179.4	157.2
Asia	121.6	320.8	434.6	615.2	958.8
RoW	0.7	0.8	0.1	0.0	0.0
Total	**298.1**	**516.5**	**658.6**	**805.6**	**1129.2**

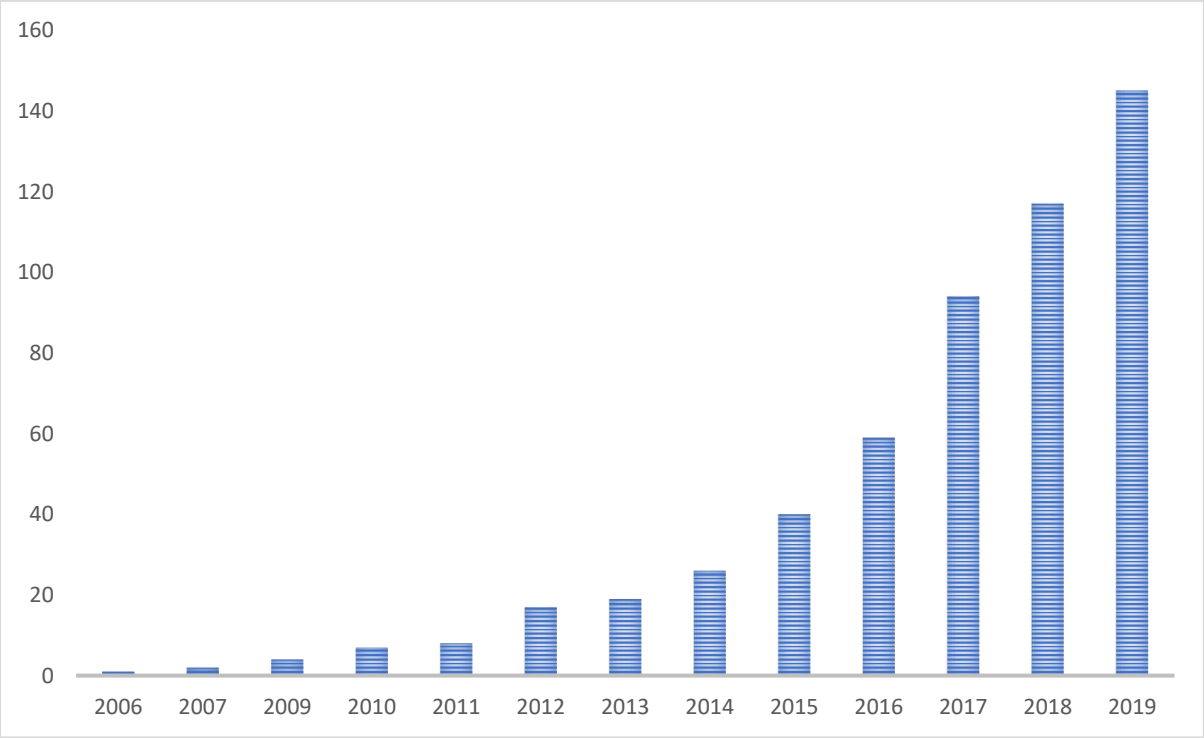
In Europe, fuel cell system manufacturing remains low in comparison to other regions and the activity is spread across a pool of companies active in different fuel cell technologies and applications, often driven by demonstration projects or early commercialization such as micro-CHP in Germany. However, several globally leading fuel cell component suppliers are based in Europe and participate in the market growth elsewhere.

3. Hydrogen Refuelling Stations

The HRS module within the FCHO provides a range of information on technical characteristics including for example, station opening times, station operator, refuelling options (pressure) available as well as a live station availability update. This information on the portal is derived from the HRS Availability System (HRS-AS) in real time.

This analysis provided here draws upon the supporting database compiled for the HRS-AS, supplemented by additional desk research to provide a picture of hydrogen refuelling station deployments in Europe.

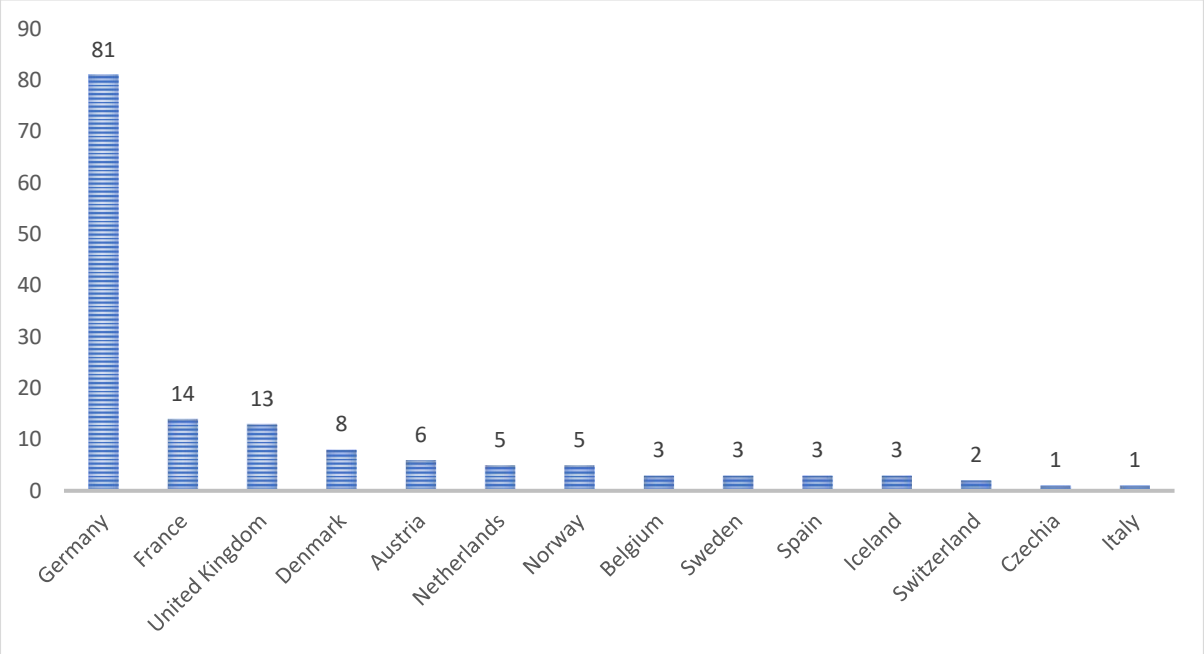
Figure 1: Cumulative number of HRS operational at end 2019
Source: HRS-AS



*Hydrogen refuelling infrastructure expanded globally in 2019 with significant new deployments in Germany, Japan, Korea, California and China. The total European stations in operation or under construction stood at **155** with significantly more in the planning stage at year end.*

*In Europe, Germany led the way with **89 stations** operating or under construction, including **28 new stations** becoming operational in 2019.*

Figure 2: Number of HRS operational by Country at end 2019
Source: HRS-AS



*The early part of 2020 is expected to show a sharp ramp up in deployments in France, Netherlands and Germany, with Germany hitting its 2020 target of **100 HRS**. Continued momentum is needed, alongside suitable levels of vehicle deployments, if individual country targets are to be reached for example, Germany's target of 400 HRS by 2025.*

*In Japan approximately **30 new HRS** were deployed in 2019 taking the total to **130** indicating that Japan is on course to hit its 2020 target of 160 stations and potentially the target of 310 stations by 2022. In Korea, the accelerated roll-out of NEXOs was complemented by a doubling of its hydrogen infrastructure capacity to approximately **30 HRS** operating. It has a national target of 310 stations by 2022.*

*California added relatively few stations between the end of 2018 and early December 2019; operational stations grew from 30 to **44**, which suggests a slow-down in deployment when considering the 100 station state target for 2020.*

***28 Hydrogen refuelling stations** were in operation in China, up from 18 operational in 2018.*
The ongoing utilization of these stations remains a factor in the rate of deployment. There is a range of utilization profiles across the regions impacted by the relative availability of FCEVs.

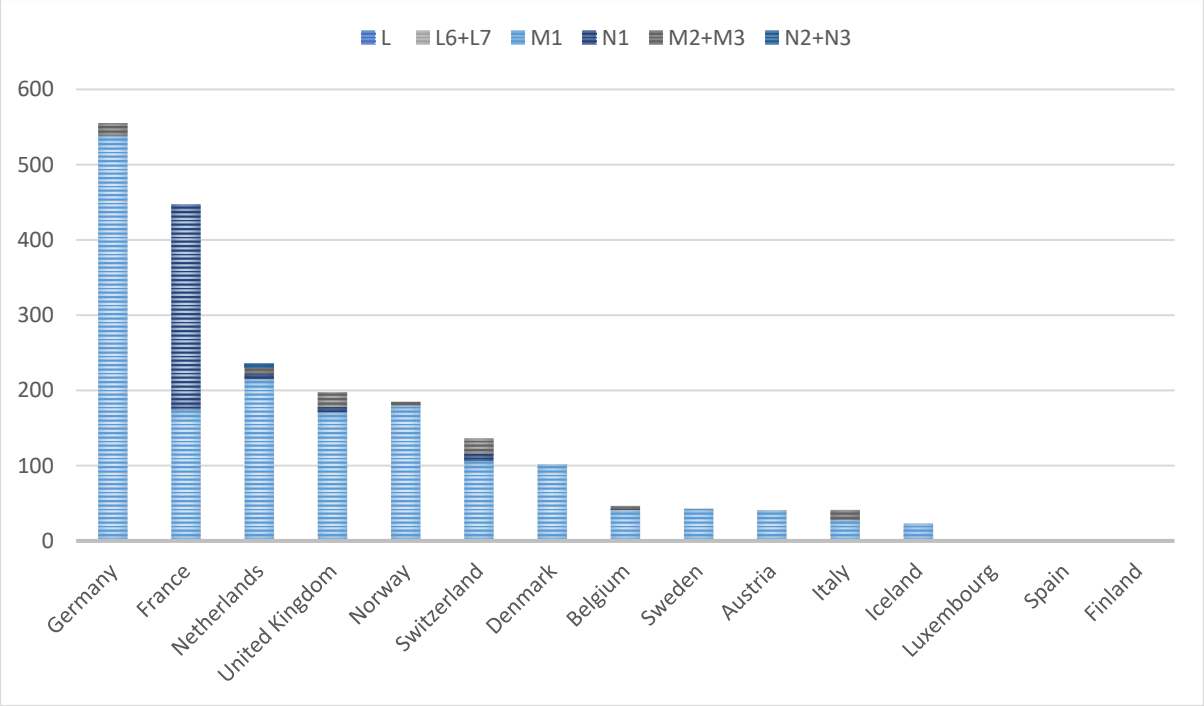
4. Fuel Cell Vehicles

The fuel cell vehicle data is sourced from EAFO who use national (usually governmental) registration bodies, where they exist, to collate the data. Where no recognised national organisation exists to collect this data, desk research supplements the efforts. In this analysis 'net new registrations' excludes vehicles that have been exported or that have been decommissioned from service. The full list of relevant EAFO sources for country can be found at eafo.eu.

*Europe saw a **44% growth** in new registrations of fuel cell passenger cars in 2019 up to **1,991 vehicles**, from a base of 1383. Toyota and Hyundai remain dominant, with Hyundai launching a new passenger FCEV NEXO at the end of 2018[1], new sales of which are reported to have been better than the more established Mirai. A new Mirai is expected to be launched in 2020, in line with Toyota's announcements on increasing production capacity. New European registrations of Honda's Clarity remain in the 10s of vehicles in Europe, meaning it is the third placed OEM but a long way behind the top two. Daimler kept a low profile in 2019 whilst BMW announced its concept FCEV, the i Hydrogen NEXT, continuing the cooperation with Toyota in fuel cell technology which started in 2013, but at the same time indicating that it will be some time before the company offers its customers a production car powered by hydrogen. Light duty vehicles are combined with the passenger vehicle registrations in this analysis and are made up exclusively of Renault Kangoo vans.*

*Elsewhere, California continues to lead the way with more than **7,500 passenger vehicles** sold or leased as of November 2019 (with 44 retail refuelling stations operational at that date). Japan had sold or leased **3,521 FCEVs** of 1 November 2019.*

Figure 3: Net number of FCEVs registered by country at end 2019
Source: EAFO



Three new fuel cell buses were registered in Denmark and a further three in the Netherlands in 2019. The eight fuel cell buses deployed in Pau, France at the end of the year are expected to appear in 1Q2020 numbers. Whilst the number of new registrations is relatively small, almost all bus deployments in Europe are part of larger scale demonstration projects supported by a number of EU funding and national government initiatives. There were announcements in 2019 on a number of planned initiatives to deploy new bus fleets of significant size which are appearing in the 2020 numbers as the respective projects progress. These include JIVE and JIVE2 (a total of 290 FC buses) and H2Bus (600 FC buses in the first phase, another 400 thereafter).

Elsewhere as of 1 May 2020, California had 42 hydrogen buses in operation, with a further 7 buses and 4 shuttles under development. 22 fuel cell buses were operating in Japan on 1 Nov 2019.

In the EU, interest in hydrogen for heavy goods vehicles has increased significantly in 2019. Hyundai announced the expected deployment of the first fifty H2 XCIENT fuel cell trucks in Switzerland and a number of projects focused on hydrogen in heavy duty, are expected to commence (H2Haul and H2Share). The impact of these developments will be discussed in the 2020 report.