# Chapter 1
# Technology and Market
## March 2022[1]

FUEL CELLS AND HYDROGEN OBSERVATORY

Co-funded by the European Union

Clean Hydrogen Partnership

[1] The FCEV registration and fleet data were amended on July 2022.

## Disclaimer

This report is based on data gathered for the Fuel Cells and Hydrogen Observatory by 31 December 2021. 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 Clean Hydrogen Joint Undertaking as part of the Fuel Cells and Hydrogen Observatory. Copies of this document can be downloaded from https://www.fchobservatory.eu/

The Fuel Cells and Hydrogen Observatory has been prepared for the Clean Hydrogen JU under a public procurement contract.

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Please note that this revised version of the report contains amended FCEV registration and fleet data.

# 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 open 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.

This module focusses on global fuel cell system shipments and on European FCH actors, vehicle registrations, refuelling stations, the hydrogen market and electrolyser 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 as the market itself evolves. This will enable the annual report to make year on year comparisons assessing market progress and identify strengths and trends. This is the third annual report on the FCHO and provides a snapshot of technology and market data in the period January 2021 – December 2021.

| | |
|---|---|
| **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. https://www.fchobservatory.eu/observatory/technology-and-market |
| **Scope:** | European electrolyser deployment data is presented<br>The report spans January 2000 – December 2021, with some additional commentary on 2022 onwards. |
| **Key Findings:** | The impact of COVID-19 greatly affected the number of new electrolysers commissioned in 2020 but a strong rebound in 2021 demonstrates how demand for this technology is growing:<br>Global Fuel Cell shipments **> 2.3 GW**<br>Europe Fuel Cell shipments up to **197.8 MW**<br>Europe HRS in operation **170**<br>FCEV registrations up **23% to 1,176** |

Following the effects of the global pandemic in 2020, the fuel cell and hydrogen industry has rebounded strongly. There was an 75.7% increase in the global number of fuel cell system shipments in 2021 totaling 2,330.4 MW. Asia continued to lead in shipment volumes, accounting for 65% of the total MW shipped internationally, while the US moved against its 2019-2020 trend with a 142% increase in total MW shipments. The number of shipments to Europe grew by 33% to 197.8 MW from 149 MW in 2020.

The transport sector leads growth among fuel cell applications, with 94% more units shipped globally and with deployments of 34,400 fuel cells. in total. Portable fuel cell application shipment increased by 48% whereas Stationary system application shipments decreased by 16%, with 47,800 units shipped.

After a period of slow growth in 2020, HRS deployment in Europe has rebounded strongly with 170 in operation by the end 2021, an 11% increase from 2020. 1,176 new FCEVs were registered in Europe in 2021, an increase of 23% from 2020, bringing the fleet size to 4,050.

After a sharp decline in the number of electrolysers commissioned in 2020 with only 2 units totaling 1.5 MW, 2021 saw 14 new units brought online in Europe with 27 MW of capacity. These number are expected to grow significantly over the coming years.

# 1. Introduction

The information in this report covers the period **January 2021 – December 2021**. 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 edition, data to the end of 2021 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. This year the report also includes data relating to electrolysers commissioned within Europe.

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. This annual report is an enrichment analysis of the data available on the FCHO, providing global context and insights on trends observed year-over-year.

Electrolyser systems commissioned for each calendar year within Europe are presented as both the number of units and the total system power rating in megawatts (MW). The data is further divided by:

- **Number of Electrolyser Units Commissioned**: The number of units brought online each year in Europe from 2000 until 2021.
- **Application**: Total systems commissioned are divided in Transport Fuel, Industry Feedstock, Steel Making, Industrial Heat, Power Generation, Export, Grid Injection and Sector Coupling.
- **Electrolyser Type**: Number for each of the different electrolyser types commissioned are provided.
- **Region of deployment**: Region where the electrolyser was commissioned.

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. 2021 Snapshot

## 2.1. Data Collection Methodology

The fuel cell shipment data at the end of 2020 as presented in the Technology & Market module of the Observatory is derived from E4tech's Fuel Cell Industry Review 2021[2]. 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 2021 and includes a forecast for the last quarter of the year, 2021f[3].

The industry survey was again conducted this year by E4tech as part of its scope for the Observatory.

Hydrogen Refuelling Station (HRS) data is derived from the European HRS Availability System[4]. The data is extracted and analysed to derive the number of HRS deployed in European member states at the end of 2020. 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[5]) which monitors vehicle deployments across a broad range of alternative fuels including hydrogen. This data is supplemented with desk research for non-EU markets.

Electrolyser deployment data was sourced from E4tech's internal hydrogen project database. The data has been gathered from a range of sources spanning industry players to project announcements and has been attempted to be as up to date and correct as possible.

## 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 total of those systems in megawatts, categorised 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.

[2] E4tech Fuel Cell Industry Review, fuelcellindustryreview.com
[3] 2020f is the data at end of 2020 using the forecasted numbers for the last quarter
[4] HRS Availability System, h2-map.eu
[5] 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

Following the impact of the COVID-19 pandemic in 2020 which saw the lowest growth levels in 5 years in the fuel cell sector, there was a large rebound in deployment numbers in 2021. The easing of supply chain delays coupled with a renewed focus on green solutions to rebuild economies saw Europe's annual deployment grow by 48.6 MW, or 32.6% in 2021. This is a similar level of growth to what was experienced in 2020 at 32%.

Asia saw an increase in deployments in 2021, with a 65% increase in MW observed following suppressed growth in 2020. With this increase in deployment, Asia remains the global leader for fuel cell capacity. As has been observed in previous years, the trend towards larger systems continues with the average system size increasing from 11.3 kW in 2020 to 14.1 kW in 2021 in Europe. Asia continued to deploy larger systems than Europe, averaging 15.9 kW in 2020 and 26.9 kW in 2021.

In North America, there was a reversal in the trend observed since 2019, where the total fuel cell deployments increased by 142% to 613 MW. This was coupled with an increase of 42.6% in the total number of units shipped.

Table 1: Units by Region of Deployment

| 1,000s units | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021f* |
|---|---|---|---|---|---|---|---|
| Europe | 8.4 | 4.4 | 5.1 | 7.7 | 10.7 | 13.2 | 14.0 |
| N America | 6.9 | 7.7 | 9.4 | 9.3 | 8.1 | 10.8 | 15.4 |
| Asia | 44.6 | 50.6 | 55.3 | 50.9 | 53.5 | 57.7 | 56.3 |
| RoW | 1 | 0.5 | 0.8 | 0.6 | 0.2 | 0.2 | 0.4 |
| **Total** | **60.9** | **63.2** | **70.5** | **68.5** | **72.50** | **81.7** | **86.1** |

* 2021f is the data at end of 2020 using forecasted numbers for the last quarter

Table 2: Megawatts by Region of Deployment

| MW | 2016 | 2017 | 2018 | 2019 | 2020 | 2021f |
|---|---|---|---|---|---|---|
| Europe | 27.4 | 38.9 | 41.2 | 113.0 | 149.2 | 197.8 |
| N America | 213.6 | 331.8 | 425.3 | 339.2 | 253.3 | 613.0 |
| Asia | 273.8 | 285.8 | 337.9 | 743.9 | 918.8 | 1,515.0 |
| RoW | 1.7 | 2.1 | 1.2 | 0.2 | 5.1 | 3.9 |
| **Total** | **516.5** | **658.6** | **805.8** | **1,196.3** | **1,326.4** | **2,330.3** |

### 2.2.1. Shipments by Application

2021 saw an 5.3% increase in the total number of units shipped over 2020 with 86,100 units or 2.33 GW shipped. Continuing the trend observed in recent years, the average capacity has increased to 27.1 kW/unit, a 66.7% increase in the average capacity observed in 2020.

Table 3: Global Shipments by Application

| 1,000s units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021f |
|---|---|---|---|---|---|---|
| Portable | 4.2 | 5.0 | 5.7 | 3.9 | 4.1 | 6.1 |
| Stationary | 51.8 | 54.9 | 51.9 | 52.2 | 56.8 | 47.9 |
| Transport | 7.2 | 10.6 | 10.9 | 16.4 | 20.8 | 32.1 |
| **Total** | **63.2** | **70.5** | **68.5** | **72.5** | **81.7** | **86.1** |

2021 saw an increase in the number of fuel cells deployed in portable applications, with a 48.8% increase in shipments in terms of units and a 40% increase in terms of capacity. This is a significant increase the growth observed in 2020 from 2019 (5.1% by units and 25% by capacity).

Table 4: Global MWs shipped by Application

| MW | 2016 | 2017 | 2018 | 2019 | 2020 | 2021f |
|---|---|---|---|---|---|---|
| Portable | 0.3 | 0.6 | 0.7 | 0.4 | 0.5 | 0.7 |
| Stationary | 209.0 | 222.3 | 220.6 | 274.8 | 325.1 | 347.6 |
| Transport | 307.2 | 435.7 | 584.5 | 921.1 | 1,000.8 | 1,982.0 |
| **Total** | **516.5** | **658.6** | **805.8** | **1,196.3** | **1,326.4** | **2,330.3** |

2021 saw an increase in the number of fuel cells deployed in transport applications, with a 54% increase in shipments in terms of units and a 98% increase in terms of capacity. 32,100 vehicles of all types were shipped accounting for approximately 85% of the total MW of expected shipments by year end.

Stationary application shipments capacity saw reduced growth from 2020 with a 6.9% increase in MW of capacity. This was accompanied by a 15.7% decrease in the number of units shipped.

### 2.2.2. Shipments by Region of System Integration

Table 5: Global units shipped by region of system integration

| 1,000s units | 2016 | 2017 | 2018 | 2019 | 2020 | 2021f |
|---|---|---|---|---|---|---|
| Europe | 4.2 | 6.6 | 8.7 | 10.0 | 11.7 | 10.8 |
| N America | 6.3 | 8.4 | 6.6 | 6.7 | 11.1 | 15.0 |
| Asia | 52.5 | 55.3 | 53.1 | 55.7 | 58.9 | 60.3 |
| RoW | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **63.2** | **70.4** | **68.5** | **72.5** | **81.7** | **86.1** |

The numbers for shipments by region of system integration, depicting where stacks are integrated into final system, reveal that Asia is utilising 86.9% of the fuel cell system MW manufactured in 2021 and 70% of the units. This is a small increase from 84.2% of fuel cell MW in 2020 and a small decrease from 72% of units in that period. In North America, there was a small decrease from 2020 to 11.8% in the number of MW by system integration, but a significant increase to 17.4% of units, up from 14% in 2020. There was little change in the proportion of MW in Europe and a small drop in the proportion of units to 11.3%.

Table 6: Global units shipped by region of system integration

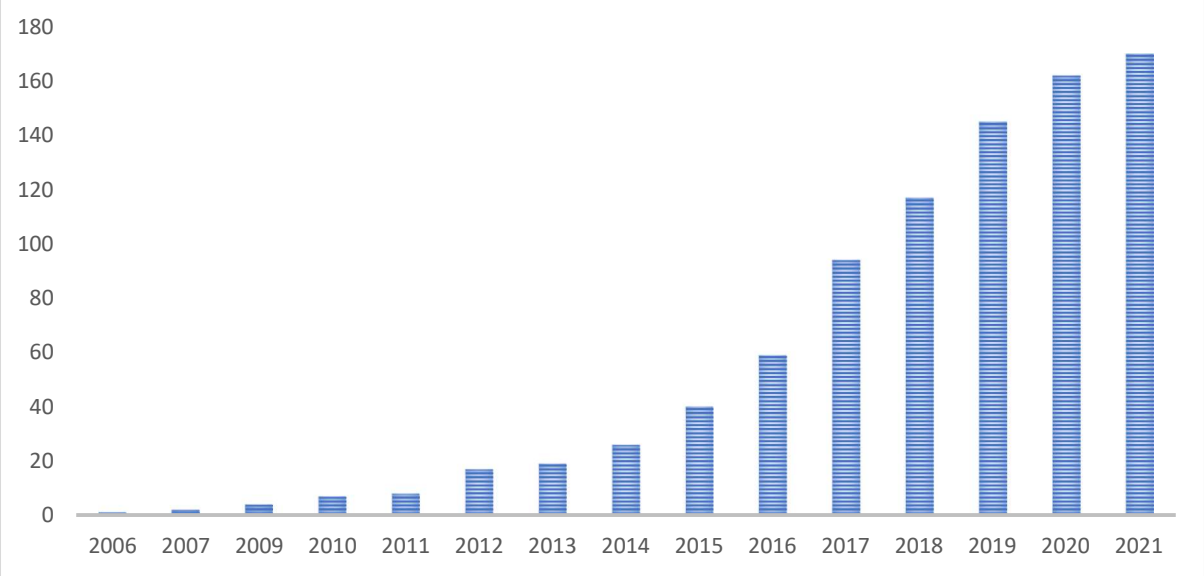
| MW | 2016 | 2017 | 2018 | 2019 | 2020 | 2021f |
|---|---|---|---|---|---|---|
| Europe | 6.7 | 8.2 | 11.0 | 13.8 | 20.4 | 30.3 |
| N America | 188.3 | 215.1 | 179.4 | 167.3 | 188.7 | 274.5 |
| Asia | 320.8 | 434.6 | 615.4 | 1,010.2 | 1,117.3 | 2,025.1 |
| RoW | 0.8 | 0.1 | 0.0 | 0.0 | 0.0 | 0.4 |
| **Total** | **516.5** | **658.0** | **805.8** | **1,191.3** | **1,326.4** | **2,330.3** |

## 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 is displayed on the portal and 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[6]. The HRS-AS database tracks the onstream availability of public HRS stations in Europe. It does not include private HRSs.

Figure 1: Cumulative number of HRS operational at the end of 2021
Source: HSR-AS

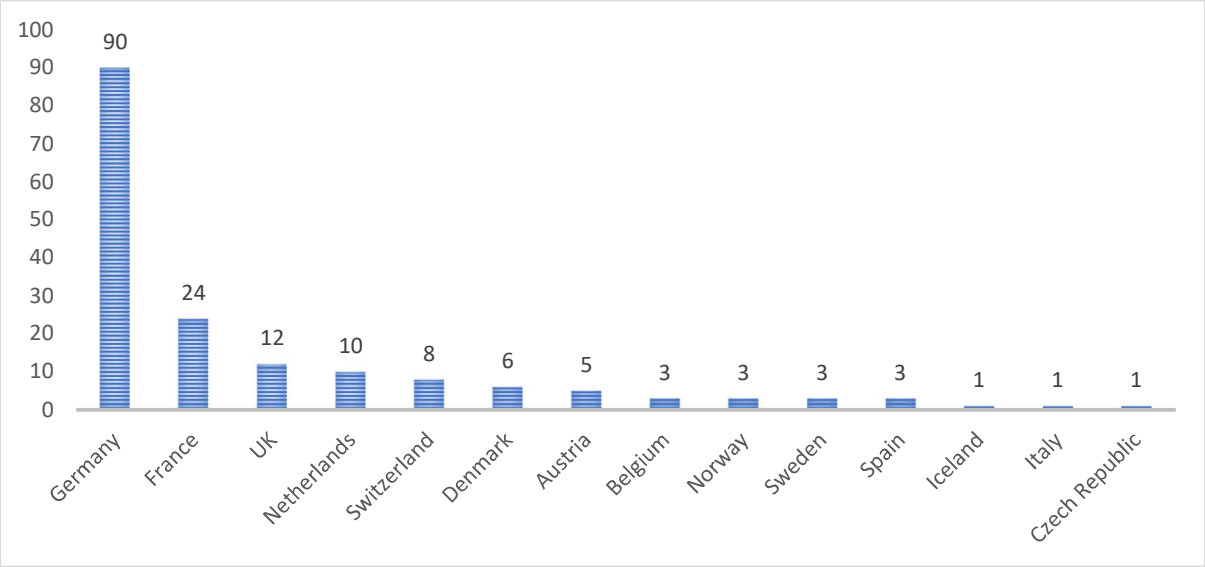



Growth in hydrogen refuelling infrastructure slowed down further in 2021, continuing the trend following the impact of COVID-19 observed in 2020. With a total of 8 new stations added in 2021 and the closure of stations in the UK and Austria, the total number of stations in operation by the end of

[6] The database used to complete the analysis is not an exhaustive list of HRS in the Europe, but rather was used to show a representative view of HRS roll out progress.

2021 was 170. However, there may be an increase in the number of HRS openings in 2022, as 5 additional stations have come in to in operation at the time of publication.

Figure 2: Number of HRS operation by country in March 2022
Source: HSR-AS



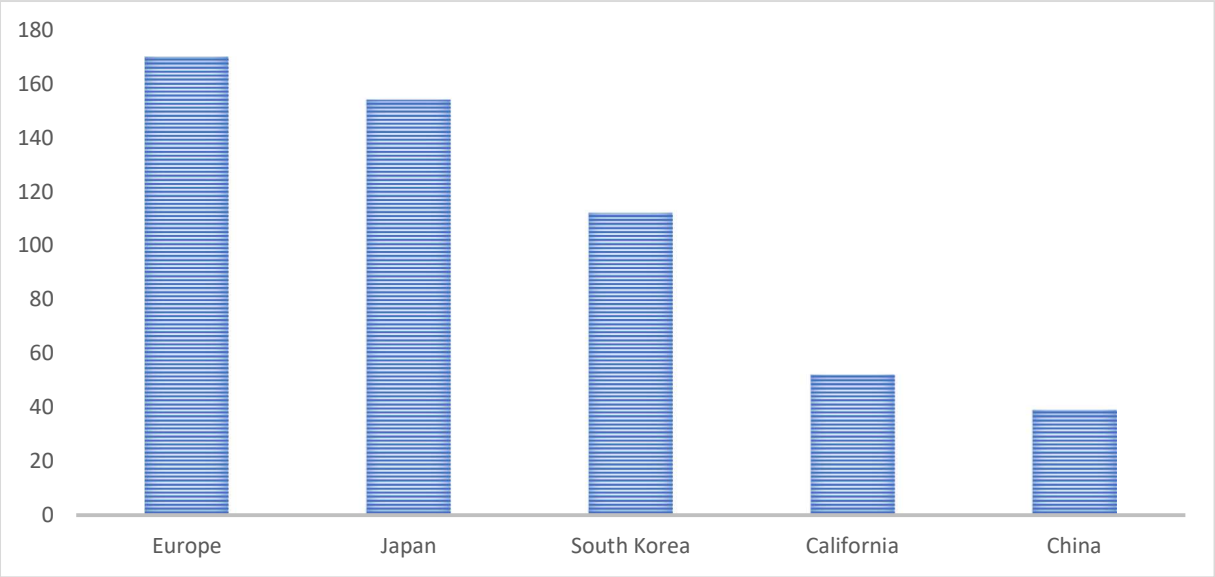

In Europe, Germany leads with 90 operational stations, but with only a small increase since 2020 and still some way off its goal of 100 HRS in operation. This is followed by France with 24 which corresponds to a 26% increase in the number of stations since 2020. The Netherlands saw significant growth in the number of HRS in operation growing by 100% to 10 stations. Switzerland also saw 300% growth from 2020 with 8 stations in operation. Beside the increases in the number of HRS in these four countries, there were no other additional HRS brought into operation in 2021.

Japan remains the global leader with a total of 154 stations operational in May 2022, adding 21 new HRS since the end of 2020. South Korea saw great expansion in the number of HRS, with 112 operational, an increase of 69 new stations.

The number of stations operational in California increased from 42 in 2020 to 52 by May 2022. A significant ramp up is required in order to reach the target of 200 stations by 2025.

The number of HRS operational in China increased by 2 to 39. This number is expected to grow substantially with the new that as part of China's 14$^{th}$ five-year plan, Sinopec plans of open 1,000 stations.

Figure 3: Number of HRS operation by Country in March 2022
Source: HSR-AS, The Fuel Cell Industry Review 2021, California Fuel Cell Partnership




# 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.

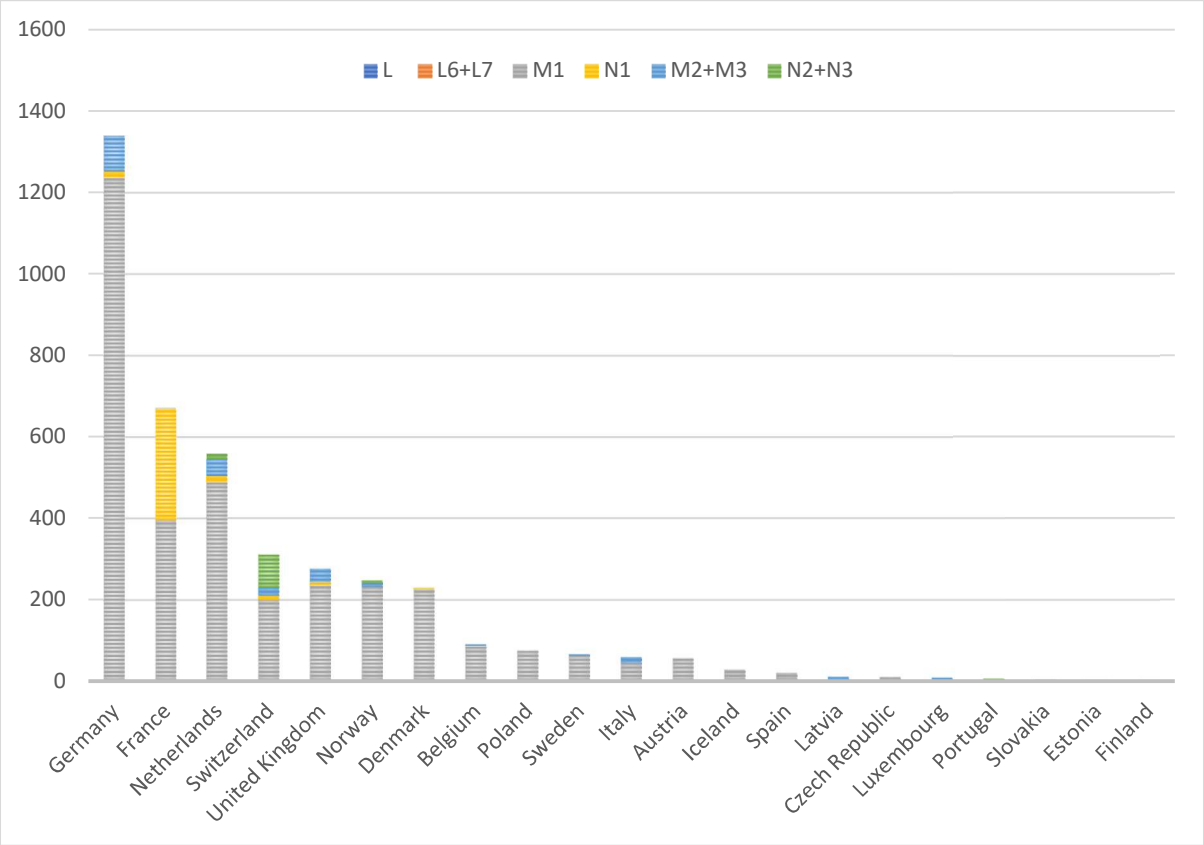
2021 saw a continuation of the trend observed in 2020, with continued growth in fuel cell passenger cars with 1,034 new registrations, up 22% from 851 vehicles registered in 2020. Germany saw a 70% increase in new FCEV registrations with 531 vehicles of all reported categories, followed by the Netherlands and Switzerland with 147 and 126 new vehicles respectively. Switzerland saw a 103% increase in FCEV registrations, from 62 registrations in 2020.

2021 saw the highest number of fuel cell vehicles to date, with almost twice the number of global sales. Continuing the trend from previous years, Toyota and Hyundai continue to dominate the FCEV market. Hyundai's 2018 released NEXO continued to prove popular and Toyota updated their offering with a new Mirai model released in 2021. Hyundai also unveiled new fuel cell car models; the Vision FK sports car and the Genesis GV80 SUV concept. Honda discontinued the production of their Clarity, though the car will remain available for lease throughout 2022. Daimler is currently focusing it its efforts in fuel cells on trucks rather than cars, with a joint venture between Daimler Truck and Volvo Group working on heavy duty trucks. BMW started testing its iHydrogen NEXT concept car in Europe and presented the iX5 Hydrogen vehicle at the IAA Mobility 2021 motor show in Munich. Jaguar Land Rover began development of a fuel cell prototype vehicle based on the Land Rover Defender. Chinese manufacturers Great Wall unveiled it hydrogen energy strategy and plans to deploy its first fuel cell SUV in 2022., and SAIC is expected to scale up production of its Maxus EUNIQ 7.

South Korea continues to lead in the deployment of fuel cell cars with a record number of 8,500 NEXOs shipped in 2021. In Japan, the Toyota Mirai continued to sell well, reaching almost 2,500 vehicles,

boosted by its use in the Olympic games held in Tokyo. Fuel cell vehicles, including the Mirai, will also be used during the 2022 Beijing Winter Olympics. In California there was growth in the number of FCEVs sold in 2020, with greater than 3,000 units.

Figure 4: Net number of FCEVs registered by country at end 2021
Source: EAFO[7]




In 2021, Germany deployed 33 new buses, bringing the total to 95, the largest fuel cell bus fleet in Europe. In the Netherlands, 17 fuel cell buses were registered, bringing their fleet total to 34. The UK saw the third largest increase in fuel cell bus fleet in Europe with the addition of 15 new buses. This brings the total fleet size in the UK to 68. A total of 72 new fuel cell buses were deployed in Europe in 2021, a 9% increase from 2020. Switzerland saw a large deployment of heavy-duty goods vehicles, with 60 vehicle registrations, giving it the largest fuel cell powered heavy duty goods fleet in Europe with 80.

The fleet of fuel cell buses grew slowly in California in 2021, with over 50 vehicles in mid-2021. This fleet is set to grow, with orders more than 40 new buses made. In the rest of the USA, the number of fuel cell buses increased at a greater rate, with 31 vehicles in operation in other states. By spring 2021, Japan saw its fuel cell bus fleet increase to 104 vehicles, with a similar number estimated to be operating in South Korea during that time. Cities in China continue to deploy larger number of fuel cell buses than almost anywhere else in the world

In 2021, Switzerland's growing fleet of fuel cell trucks saw the delivery of 41 Hyundai Xcient heavy duty trucks as part of the Swiss 1600 truck project which aims to deploy this many fuel cell trucks by 2025.

[7] Further information on the vehicle classifications can be found at https://alternative-fuels-observatory.ec.europa.eu/general-information/vehicle-types

8 fuel cell trucks were registered in the Netherlands. This acceleration in the deployment of fuel cell trucks fits with industry expectations, with further deployments planned for 2022.

Alstrom is still the world's leading supplier of fuel cell and hydrogen technology to trains with its Coradia Ilint unit. Following successful trials in 2020, there are plans to start a commercial service in 2022 in Lower Saxony, with 14 Coradia units ordered. Further trials of this unit started in Germany in Baden-Wurttemberg, along with trials in Sweden, France and Poland. In ships, the world's first hydrogen fuel cell powered ferry, MF Hydra, was delivered to the Norwegian ferry operator Norled. 2021 also saw progress in the development of fuel cell technology for aviation, with further testing of the H2FLY operated HY4, 4-seater aircraft in Germany, the allocation of funds for both the EnaBle project to develop a small aircraft with up to 19 seats and the Project Fresson Consortium to develop a 9-seater Isalnder light utility plane.

# 5. Electrolysers

The number of commissioned electrolysis units in Europe data as presented in the Technology and Market module of the Observatory is derived from E4tech's internal database of global electrolysis projects. This data presents a snapshot of the European electrolyser market in 2021. The data has been gathered from a range of sources spanning industry players to project announcements and has been attempted to be as up to date and correct as possible.

## 5.1. Electrolyser Units Commissioned

From 2000 to 2010, the number of electrolyser units deployed each year grew, tripling the initial number by the end of the decade. The size of the units deployed in this period remained small as the projects were generally small-scale demonstration projects. Over the following decade, the number of new units set up in Europe increased initially, before declining in number slightly in 2017. 2018 and 2019 showed significant growth in the number of units coming online. The impact of the COVID-19 pandemic resulted in a drop in the number of units commissioned in 2020, with 91% fewer units deployed compared to the preceding year. However, in 2021 the number of units rebounded strongly with 14 electrolysers commissioned.

Figure 5: Annual number of electrolysers installed in Europe from 2000 – 2021
Source: E4tech Electrolysis database

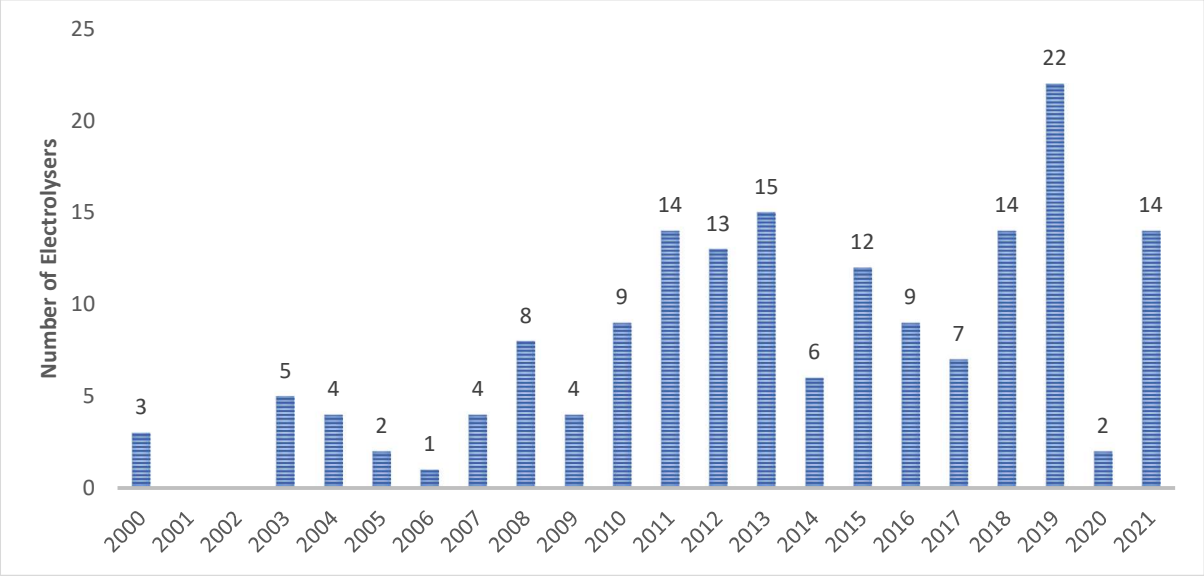
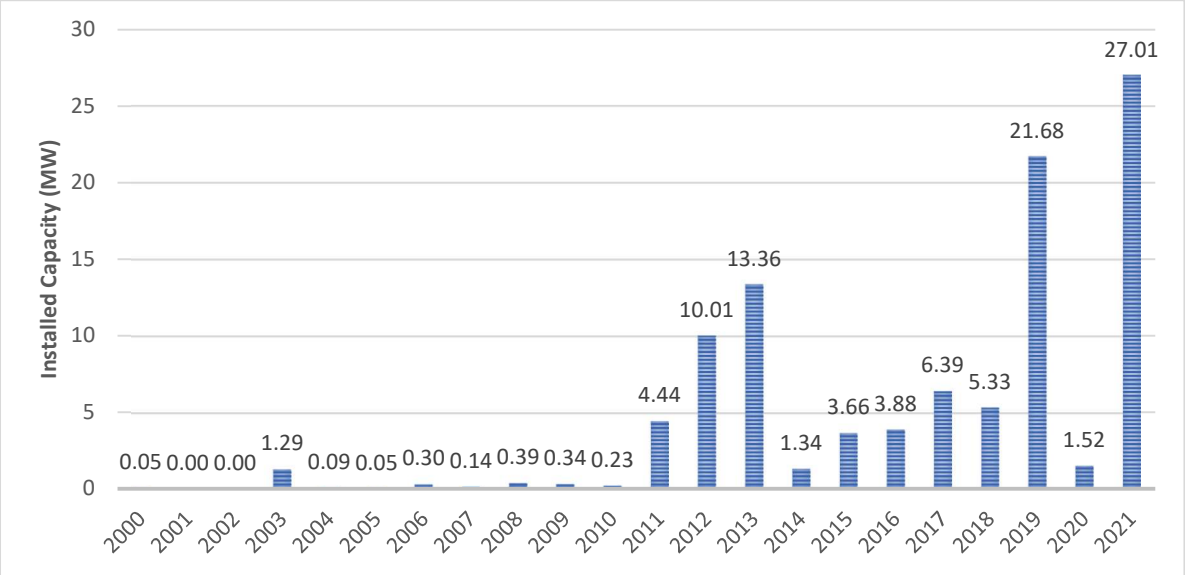



Figure 2 highlights how there was very little electrolyser capacity installed across Europe between 2000 and 2011, again reflecting the implementation of the units in small-scale demonstrations. From 2011 to 2013 there was a very large increase in the total size of the electrolysers commissioned in Europe, growing from 4.44 MW to 13.36 MW. In the period from 2014 to 2018, the total capacity of electrolysis units going into operation dropped, averaging 4.12 MW, but this was followed by a large increase in capacity, reaching 21.64 MW in 2019. This was set to be followed by further growth, but the global pandemic severely inhibited the annual installed capacity in 2020. But, as reflected in Figure 1, the number of new units installed in 2021 bounced back to pre-pandemic level with a capacity 27.01 MW.

This rebound is expected to continue through 2022, with industry sources indicating that greater than 40 MW of capacity will be deployed in 2022. Beyond 2022 we expect further growth in both the number and size of electrolyser coming online, with >100 MW of capacity announced.

Figure 6: Annual installed electrolyser capacity in Europe from 2000 – 2021
Source: E4tech Electrolysis database



## 5.2. Electrolysers commissioned by technology type

With relatively few electrolysis projects coming online from 2000 to 2010, the main focus was on alkaline electrolysers which accounted for 56% of the total units from that decade. PEM electrolysers accounted for 37% of the projects, with an uptick in the number of projects using these systems in 2008 and 2010. There were no solid oxide electrolysis systems online in this time period as the technology was still.

Table 7: Electrolyser technology types commissioned in Europe from 2000 – 2010

| Units | 2000 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|
| PEM | 1 | 1 | 1 | 1 | 1 | 1 | 5 | 1 | 3 |
| ALK | 2 | 4 | 3 | 1 | 1 | 2 | 2 | 3 | 5 |
| SOEC | | | | | | | | | |
| Unknown | | | | | | 1 | 1 | | 1 |

From 2011 – 2021 the number of electrolysers brought online increased significantly, with growth in the number of both alkaline and PEM electrolysers commissioned. PEM technology projects accounted for 56% of all the units commissioned in this period, with more alkaline units also commissioned annually, but accounting for a lower total percentage of projects compared to the previous decade at 28%. As solid oxide electrolyser technology developed, the number of units being trialed also increased in number, accounting for 11% to the units in this period and showing a small increase in the number of projects in 2018 and 2019.

Table 8: Electrolyser technology types commissioned in Europe from 2011 – 2021

| Units | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PEM | 4 | 2 | 7 | 2 | 6 | 6 | 3 | 7 | 14 | 1 | 5 |
| ALK | 7 | 6 | 6 | 2 | 3 | 2 | 3 | 4 | 3 | | |
| SOEC | 1 | 2 | | 1 | 2 | 1 | 1 | 2 | 4 | | |
| Unknown | 2 | 3 | 2 | 1 | 1 | | | 1 | 1 | 1 | 9 |

In 2019, PEM electrolysers accounted for 64% of the units commissioned in Europe. Fewer electrolyser units of any technology type were installed over 2020 and 2021 due to the COVID-19 pandemic it is difficult to reconcile any trends as there may also be less data report in these years. However, the outlook for 2022 and beyond will likely show increased numbers, but similar ratios of alkaline and PEM systems commissioned, with electrolyser customers making choices based on specific requirements (e.g. use case, CAPEX and OPEX cost, system size, maintenance costs, required hydrogen purity and pressure, vendor location and servicing capability, power source) rather than technology type alone. Solid oxide electrolyser systems deployed to industrial processes will likely increase in number as the technology progresses from a pre-commercial state and reduces in system cost.

Table 9: Capacity of electrolyser technology types commissioned in Europe from 2000 – 2010

| MW | 2000 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|
| PEM | 0.001 | 0.003 | 0.002 | 0.030 | 0.000 | 0.075 | 0.044 | 0.004 | 0.005 |
| ALK | 0.536 | 1.290 | 0.085 | 0.015 | 0.300 | 0.062 | 0.346 | 0.336 | 0.206 |
| SOEC | | | | | | | | | |
| Unknown | | | | | | | 0.000 | | 0.022 |

Table 10: Capacity of electrolyser technology types commissioned in Europe from 2011 – 2021

| MW | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PEM | 0.266 | | 1.945 | 1.009 | 1.902 | 1.719 | 5.042 | 2.571 | 18.726 | 1.500 | 25.006 |
| ALK | 4.124 | 9.767 | 11.394 | 0.330 | 1.750 | 2.150 | 1.201 | 2.596 | 2.680 | | |
| SOEC | 0.006 | 0.038 | | | 0.010 | 0.015 | 0.150 | 0.158 | 0.196 | | |
| Unknown | 0.040 | 0.208 | 0.022 | | | | | 0.001 | 0.081 | 0.020 | 2.000 |

## 5.3. Electrolysers commissioned by application

From 2000 to 2010, the main focus of electrolysis projects was power generation, which accounted for 47% of all the electrolysers installed in Europe in this period. Projects on the generation of transport fuel were the next most frequent European electrolysis application in this period, accounting for 19% of projects. Sector coupling and industrial heat projects also emerged throughout this period, each accounting for 12% of the total number of projects. Projects for both of these areas peaked in number 2010. Few electrolyser units for industry feedstock and grid injection were commissioned in this period.

Table 11: Applications associated with electrolysers commissioned in Europe from 2000 – 2010

| Year commissioned | 2000 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|
| Transport Fuel | | 4 | 1 | 1 | 1 | 1 | 1 | | 2 |
| Industry Feedstock | | | | | | | | 2 | |
| Steel Making | | | | | | | | | |
| Industrial Heat | | | 2 | 1 | | 1 | | | 3 |
| Power Generation | 3 | 1 | 4 | 2 | 1 | 4 | 4 | 2 | 6 |
| Grid Injection | | | | | | 1 | 2 | | |
| Sector Coupling | | | | 1 | | 2 | 1 | | 3 |

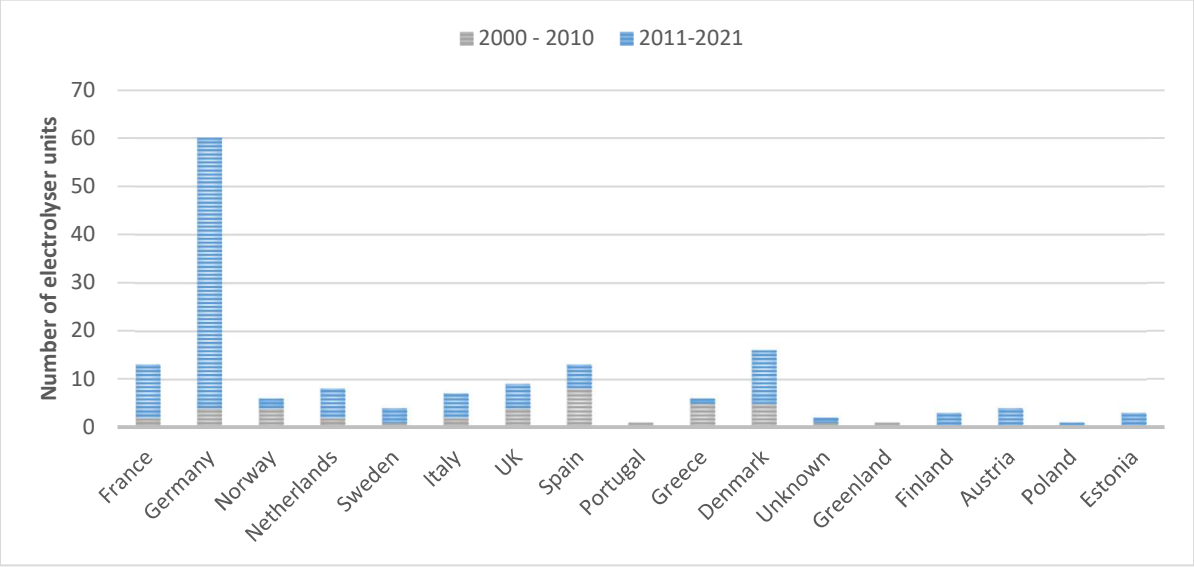
The period from 2011 to 2021 was a far more active time for electrolyser installations, with a >300% increase in the number of electrolysers installed compared to the previous decade. Along with the greater number of electrolysis projects, there was greater variation in their applications. The main application in this period was focused on industry feedstocks, accounting for 27% of projects, a large shift when compared to the period from 2000 to 2010 which saw only 4% of projects focused on this area. 21% of projects were focus on power generation, followed by 18% on transport fuel. Sector coupling electrolyser applications accounted for 14% of the units installed, while grid injection and industrial heat applications each accounted for 9% of projects. The vast majority of industrial heat projects occurred after 2015. Very few electrolysers were commissioned relating to steel making projects, but this is a growing area and many steel manufacturers have announced projects that incorporate electrolytic hydrogen into their processes. The recent surge in natural gas prices coupled with supply uncertainty as a result of the Russian invasion of Ukraine makes electrolytic hydrogen even more appealing.

Table 12: Applications associated with electrolysers commissioned in Europe from 2011 – 2021.

| Year commissioned | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Transport Fuel | 4 | 2 | 2 | 2 | 1 | 4 | 2 | 5 | 9 | | 2 |
| Industry Feedstock | 6 | 5 | 9 | 4 | 7 | 2 | 1 | 6 | 8 | | 1 |
| Steel Making | | | 1 | | | | | | 1 | | 1 |
| Industrial Heat | 2 | | | | 2 | 2 | 2 | 4 | 3 | | 2 |
| Power Generation | 5 | 5 | 3 | 2 | 6 | 4 | 4 | 3 | 5 | 1 | 1 |
| Grid Injection | 1 | 2 | 1 | 2 | 2 | 3 | | 1 | 3 | | 2 |
| Sector Coupling | 3 | 2 | 1 | 2 | 3 | 3 | 2 | 3 | 5 | | 2 |

## 5.4. Electrolysers commissioned by country

Figure 7: Number of electrolyser units commissioned by county in Europe from 2000 – 2010 and 2011 - 2021
Source: E4tech Electrolysis database




From 2000 – 2010, very few electrolyser units were commissioned in Europe. In this period, Spain had the highest number of units installed compared to other countries in Europe, with 8. Greece, Denmark followed Spain with 5 units installed each and Norway, Germany and the UK each had 4 installations. As can be seen in figure 3, there was far more activity in period from 2011 – 2021, with the number of

installations growing significantly. Germany has installed far more units than any other European country, with 56 units brought online. France and Denmark follow with 11 units each, the Netherlands with 6 and the UK, Italy and Spain with 5. With many more projects announced and under construction, including the expansion of electrolyser manufacturing facilities across Europe and globally, the landscape of electrolysers online in Europe is set to change significantly over the coming decade.

# 6. Conclusion

This report gives an overview of fuel cell, FCEV and HRS deployment over 2021, along with a summary of electrolyser deployments in Europe since 2000.

In the period from the first FCHO Technology and Market report in 2019 to the end of 2021, there has been substantial growth in the hydrogen space. The annual number of fuel cells deployed globally has grown by 91% 2.3 GW since 2019, with a 75% increase to 197.8 MW in Europe. The number of HRS in Europe has seen slow growth, but this is set to further increase with future developments to accommodate the growing number of fuel cell vehicles, particularly trucks and buses. New FCEV registrations have seen substantial growth from 608 registrations in 2019 to 1,176 registrations in 2021. There was also an increase in the number and capacity of electrolyser units across Europe, with a 25% increase in capacity from 2019 to 2021. This growth across the hydrogen sector is set to continue and accelerate in order to meet national targets over the rest of the decade.