Hydrogen Refuelling Stations
Safety, Regulations, Codes and Standards. Lessons Learned. Interim Report 4
H2ME2 Deliverable 5.22

Authors (main contact in bold):

**Dr. Peter Speers (Cenex),** peter.speers@cenex.co.uk

Denmark: Henrik Mortensen (Everfuel) & Lasse Dam (Nel Hydrogen Fueling)

Germany: Ben Becker, Mario Ludwig & Volker Schlabach (H2 MOBILITY Deutschland)

Netherlands: Jan Paul Kerkhof (Kerkhof), Nico van den Berg (Rijkswaterstaat, Dutch Ministry of Infrastructure and Water Management), Stefan Neis (Waterstofnet) & Gerard Schuiringa (Resato)

Honda R&D Europe: Thomas Brachmann

Toyota Motor Europe: Vincent Mattelaer

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Contents
Executive summary .............................................................................................................. 1
1 Introduction to H2ME ..................................................................................................... 3
2 Purpose of this document ............................................................................................... 3
3 Trends in hydrogen mobility and hydrogen refuelling .................................................. 4
  3.1 Trends in LDV deployment and refuelling within H2ME-2 ....................................... 4
  3.2 Trends in hydrogen mobility outside of H2ME-2 ..................................................... 6
  3.3 Implication of hydrogen mobility trends for H2ME-2 HRS ..................................... 6
4 Scope of this document .................................................................................................... 9
  4.1 Safety ......................................................................................................................... 9
5 Topics covered in the document ..................................................................................... 10
6 Country and organisational experience of HRS installation and RCS .................... 11
  6.1 Denmark – Nel Hydrogen Fueling & Everfuel ....................................................... 11
  6.2 Germany – H2 MOBILITY Deutschland ................................................................. 15
  6.3 Netherlands – Resato & Kerkhof ............................................................................. 21
7 Vehicle manufacturers’ perspective on hydrogen refuelling ...................................... 26
  7.1 Vehicle refuelling protocols: SAE J2601 ................................................................. 26
  7.2 Implementation of hydrogen refuelling station RCS in Europe ............................. 27
  7.3 HRS approvals process and the Site Acceptance Test (SAT) ................................. 28
  7.4 Implementation of the CEP HRS approvals process and the SAT ....................... 29
  7.5 Future streamlining of the SAT ............................................................................... 30
8 Summary and conclusions .............................................................................................. 32

Versions

<table>
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<th>Version</th>
<th>Comment</th>
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**Abbreviations**

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<th>Abbreviation</th>
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<tr>
<td>AFID</td>
<td>Alternative Fuels Infrastructure Directive</td>
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<td>AFIR</td>
<td>Alternative Fuels Infrastructure Regulations</td>
</tr>
<tr>
<td>AHJ</td>
<td>Authority having jurisdiction</td>
</tr>
<tr>
<td>ATEX</td>
<td>Explosive atmosphere</td>
</tr>
<tr>
<td>B2B</td>
<td>Back to back (refuelling)</td>
</tr>
<tr>
<td>CE</td>
<td>Conformité Européenne</td>
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<td>CEN</td>
<td>Comité Européen de Normalisation</td>
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<tr>
<td>CEP</td>
<td>Clean Energy Partnership</td>
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<td>CHP</td>
<td>Clean Hydrogen Partnership</td>
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<tr>
<td>CHSS</td>
<td>Compressed hydrogen storage system</td>
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<tr>
<td>DEMA</td>
<td>Danish Emergency Management Agency</td>
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<tr>
<td>FAT</td>
<td>Factory Acceptance Test</td>
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<tr>
<td>FC</td>
<td>Fuel Cell</td>
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<tr>
<td>FCEV</td>
<td>Fuel cell electric vehicle</td>
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<tr>
<td>FCHJU/FCH2JU</td>
<td>Fuel Cells and Hydrogen Joint Undertaking</td>
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<tr>
<td>FC REEV</td>
<td>Fuel cell range-extended electric vehicle</td>
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<tr>
<td>FSTM</td>
<td>Fuelling station test module</td>
</tr>
<tr>
<td>H35, H70</td>
<td>Hydrogen dispensing at 35Mpa, 70 Mpa (350 bar and 700 bar)</td>
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<tr>
<td>HDV</td>
<td>Heavy duty vehicle</td>
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<tr>
<td>H2M</td>
<td>H2 MOBILITY Deutschland</td>
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<td>H2ME</td>
<td>Hydrogen Mobility Europe</td>
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<td>HRS</td>
<td>Hydrogen refuelling station</td>
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<td>IED</td>
<td>Industrial Emissions Directive</td>
</tr>
<tr>
<td>IPCEI</td>
<td>Important Projects of Common European Interest</td>
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<td>LDV</td>
<td>Light duty vehicle</td>
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<tr>
<td>LH2</td>
<td>Cryogenic liquid hydrogen (storage)</td>
</tr>
<tr>
<td>NWP</td>
<td>Nominal working pressure</td>
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<tr>
<td>OEM</td>
<td>Original equipment manufacturer</td>
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<td>PED</td>
<td>Pressure Equipment Directive</td>
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<tr>
<td>RCS</td>
<td>Regulations, codes, and standards</td>
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<tr>
<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<tr>
<td>SAT</td>
<td>Site Acceptance Test</td>
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<tr>
<td>SOC</td>
<td>State of charge</td>
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<tr>
<td>TIR</td>
<td>Technical Information Release</td>
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Executive summary

Hydrogen Mobility Europe (H2ME, 2015-2023) is the largest passenger vehicle and hydrogen refuelling station demonstration initiative co-funded by the Fuel Cells and Hydrogen Joint Initiative (FCH JU). This report, the fourth in a series of five, provides three country case studies – Denmark, Germany, and the Netherlands – of hydrogen refuelling station (HRS) installations supported by H2ME-2 to understand how regulations, codes, and standards (RCS) are applied in each country to the station permitting and planning process, document lessons learned and record practical experience of the steps taken to ensure continued HRS safe operation. This version of the report also includes input from Honda R&D Europe and Toyota Motor Europe on the process of ensuring that HRS can refuel OEM vehicles safely and reproducibly according to accepted standards such as SAE J2601.

Denmark was cited in previous versions of this report as an exemplar of a country with a relatively centralised decision-making system which allowed established precedent and experience to apply to future installations, thereby speeding the HRS permitting process to as little as a week. However, from 2016 until the opening of the H2ME-2-supported Copenhagen Prags Boulevard HRS in 2021, few stations were installed in Denmark which meant that much of the experience and momentum built around hydrogen permitting and regulation had dissipated. The Prags Boulevard HRS took around two years to open from project inception. Station construction was slowed by equipment availability issues which were exacerbated by COVID-19. In contrast to the H2ME-2-supported Kolding HRS opened in 2016, the commissioning of the Prags Boulevard HRS also involved a Site Acceptance Test (SAT) using a fuel station test module (FSTM) with evaluation of the test results by vehicle OEMs. This is now a required part of the commissioning process for HRS under the AFID.

H2 MOBILITY Deutschland (H2M) has installed over 90 HRS in Germany to create a national network linking seven German metropolitan areas (Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Nuremberg, Stuttgart and Munich) along the connecting arterial roads and motorways. Operational permitting for HRS in Germany is governed by clear centralised RCS such as the BetrSichV. However, building permitting is the responsibility of individual federal states, each one of which has its own building directive. In practical terms, the decentralised building permitting process in Germany requires repeated engagement to build know-how with the different authorities, which increases the permitting time and hinders standardised applications. H2M’s strategy is evolving towards building larger HRS located based on anchor demand from commercial vehicles and where a public filling station makes sense for a growing network of filling stations for cars. As such, it plans to upgrade 30 of its existing 700 bar HRS to add 350 bar fuelling to accommodate HDVs.

Opened in 2020 the H2ME-2-funded HRS in the Hague, the Netherlands operated by B. Kerkhof & Zn was the first public HRS constructed by Resato. permitting Anticipating the wider rollout of hydrogen fuelling, Netherlands national agencies such as the Ministry of Infrastructure and Water Management have been proactive in documenting the process for preparing, permitting, building, and commissioning at HRS. In common with the other country examples in this report, the key step is Environmental Permitting. This is controlled by the relevant municipality with is the authority having jurisdiction. In most cases the municipality delegates the permitting to the regional environmental
agency; the appropriate safety region (veiligheidsregio) is also consulted on safety-relevant aspects. On average the permitting process takes around 18 months.

Major progressions in hydrogen fuelling during H2ME have included the wider rollout of vehicles leading to increased station loads and the introduction of vehicles with larger hydrogen tanks (for example, comparing the Hyundai Nexo at 6.3 kg capacity versus the Daimler B-Class FCELL at 3.7 kg). The SAE J2601 Fueling Protocol for Light Duty Hydrogen Surface Vehicles is now the standard used by HRS (including all H2ME-2 HRS) to ensure that the vehicle hydrogen storage system stays within operating temperature and pressure limits, and an acceptable refuelling speed and final state of charge (SOC) is achieved. To ensure HRS comply with the EN 17127 refuelling standard which incorporates J2601, vehicle OEMs have worked with HRS suppliers in the CEP OEM Group to devise a process to approve HRS for refuelling of their vehicles involving a Factory Acceptance test (FAT, provided by the HRS supplier), a hydrogen quality report, and the SAT (discussed above in the Denmark case study). The testing process is currently overseen by the vehicle OEMs, which is a relatively time-consuming process. Work is underway to transfer responsibility for HRS testing, evaluation, and approval on behalf of all CEP vehicle OEMs to an independent third party. This is scheduled to be completed in Germany by the end of 2023, and in France and the Netherlands by the end of 2024.

Comparing the individual case studies shows that, while there is commonality in terms of the overall EU directives that are followed in each country, there are differences in the processes and involved in HRS permitting and installation, despite the continued evolution of hydrogen refuelling RCS such as EN 17124, EN 17127, SAE J2601 and ISO 19880-1. The optimal situation for speed through the HRS permitting and planning process in each country appears to be a relatively centralised decision-making system which allows established precedent and experience to apply to each future installation (i.e., the situation which existed in Denmark, at least until 2016). Involvement of decentralised/regional agencies in the process requires repeated engagement for each individual HRS construction project to build know-how with different authorities. This increases the permitting time and hinders standardised applications. It is also clear that the regulations for stations that use on-site electrolysis are generally more onerous than for HRS that use delivered hydrogen.

Looking forward, increased standardisation of fuelling station components, the wider availability of testing equipment and the growing momentum for HRS installation will be beneficial in terms of cost and in speeding up the station permitting and commissioning process.

All HRS covered in this report, and all stations so far installed by the H2ME project, are operating safely. As of April 2023, H2ME project refuelling stations have dispensed 484 000 kg of hydrogen in 196 000 refuelling events with no safety incidents that involved the release of hydrogen. If any safety incidents occur at H2ME stations in the future, they will be addressed in the final edition of this report.
1 Introduction to H2ME

Hydrogen Mobility Europe (H2ME, 2015-2023) is the largest light duty vehicle (LDV) and hydrogen refuelling station (HRS) demonstration initiative co-funded by the Fuel Cells and Hydrogen Joint Initiative (FCH JU). H2ME is formed of the two separate FCH JU-co-sponsored projects:

- H2ME-1 (2015-2020), which deployed 300 fuel cell electric vehicles (FCEVs) and fuel cell range-extended electric vehicles (FC REEVs) and 29 HRS.
- H2ME-2 (2016-2023), which aims to deploy over 1 000 FCEVs and FC REEVs and 20 HRS.

The aims and scope of H2ME are summarised below in Figure 1:

![H2ME Project Overview (2015-2023)](image)

**Figure 1. H2ME vehicle and HRS deployment summary**

2 Purpose of this document

The document is not intended to provide a comprehensive listing of regulations, codes and standards that are applicable to the installation of HRS in Europe, as that has been addressed by the HyLaw project (2017-18, [https://www.hylaw.eu/](https://www.hylaw.eu/)) which provides a comprehensive database ([https://www.hylaw.eu/database](https://www.hylaw.eu/database)) and summary of regulations, codes and standards (RCS) for applications of hydrogen. This report provides case studies of how RCS are applied in each country to the station permitting and planning process, documents lessons learned, and records practical

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experience of the steps taken by installers, operators, and vehicle manufacturers to ensure safe and efficient HRS operation.

3 Trends in hydrogen mobility and hydrogen refuelling

This report is the fourth in a series began in 2018. During that time, the H2ME project, and hydrogen mobility in general, has made substantial progress. This section discusses some of the trends that have emerged since the start of H2ME, both within the project - which is primarily focused on light duty vehicle (LDV) refuelling - and in hydrogen mobility in general, and their implications for HRS design and performance requirements.

3.1 Trends in LDV deployment and refuelling within H2ME-2

- The wider rollout of FCEVs and HRS: as of April 2023, 534 FCEVs, 246 FC REEVs and 43 HRS in nine countries reported data to H2ME; for comparison, the figures for May 2019 were 133 FCEVs, 178 FC REEVs and 23 HRS. As of April 2023, H2ME vehicles have reported almost 31 million km driven and the HRS (which fuel H2ME and non-H2ME vehicles) have dispensed 529 tonnes of hydrogen in 209,000 refuelling events.

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Urban deployments of FCEV taxis leading to increased HRS load: in 2017, STEP/Hype began the rollout of Hyundai ix35 FCEVs and Toyota Mirais as taxis in Paris. To the end of March 2023, the H2ME-2 STEP/Hype fleet in Paris has reported almost 6 million km driven (plus a further 4.2 m km for vehicles funded by the ZEFER project). The taxis in Paris drive an average of around 150 km per day with an average fuel consumption of \(~1.1-1.2\) kg H\(_2\)/100 km driven. As part of their operating patterns, they refuel at least once per day. Taxis therefore represent the highest intensity H2ME-2 vehicle and HRS use case.\(^6\)

Six HRS in locations where FCEV taxis are deployed have dispensed over 60% of the total hydrogen reported by the project. These HRS often have loads (measured by the daily amount dispensed as a proportion of the station’s maximum daily capacity) of over 20%; in contrast the average H2ME station load in locations where taxis are not deployed is around 5%. H2ME-2 continues to deploy taxis to build HRS usage in locations including Paris (France), The Hague (Netherlands) and, most recently, in Copenhagen (Denmark).

The addition of FCEVs with larger onboard hydrogen storage capacities: As new FCEV models are released, in general the amount of hydrogen stored onboard has increased. Figure 3 below shows that the Daimler B-Class FCEVs deployed by H2ME in 2015 had a tank capacity of 3.7 kg. The next generation of FCEVs deployed by the project in 2017, such as the Generation 1 Mirai and the Honda Clarity, had tank capacities of around 5 kg of hydrogen. Since 2019, H2ME-2 has deployed Hyundai Nexos with a tank capacity of 6.3 kg, and is continuing the roll out the Generation 2 Toyota Mirai with an increased hydrogen tank capacity of 5.6 kg compared to the 5 kg stored in the first generation vehicle.

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• Development and adoption of the SAE J2601 vehicle refuelling standard: introduced in 2010, SAE J2601 establishes the fuelling protocol and process limits for hydrogen fuelling of vehicles with total volume capacities greater than or equal to 49.7 l.

3.2 Trends in hydrogen mobility outside of H2ME-2

• The anticipated wider rollout of hydrogen heavy duty vehicles (HDVs): the main development in hydrogen mobility since the start of H2ME has been the growth in interest and associated investment in hydrogen HDVs. This interest has been promoted by need to achieve Net Zero in this hard to decarbonise vehicle segment and the continued evolution of fuel cell technology. Limited deployments of fuel cell HDVs are underway; for example, Hyundai XCIENTs driven by 20 operators in Switzerland accumulated more than 5 million km driven since 2019.8 The vehicles store 31 kg of hydrogen in seven tanks and refuel at 350 bar in 8-20 minutes.9 Demonstrations such as these are seen as crucial in developing the fuel cell HDV market and the business case for HRS as deployment ramps up from 2025 onwards across Europe.10

3.3 Implication of hydrogen mobility trends for H2ME-2 HRS

Amongst the implication of the developments in hydrogen mobility highlighted in Sections 3.1 and 3.2 are:

• Future HRS at likely to dispense at 350 and 700 bar: Many stations supported by H2ME-1, such as the stations in Kolding (Denmark) opened in 2016 and Potsdam (Germany) opened in 2018 discussed in the last version of this report, were single 700 bar dispenser HRS aimed at refuelling relatively small fleets of LDVs. Many current FC HDVs, such as the Hyundai XCIENTs discussed above, refuel at 350 bar. Therefore, stations that wish to fuel HDVs need to dispense at both pressures.11

• HRS need higher daily dispensing capacities: the rollout of increasing numbers of FCEVs and FC HDVs means that HRS will need higher capacities. The figure below shows that the capacities of HRS deployed by H2ME reflect this, with newer stations installed under H2ME-2 generally being capable of dispensing much more than the ~200 kg/day norm of H2ME-1 HRS.12

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HRS face the increasing probability of back-to-back (B2B) refuellings: There are two principal limitations on HRS performance:

- The first, as discussed above, is the daily capacity (how much hydrogen can the station dispense in a day?). In terms of station hardware, this is essentially dictated by the amount of low pressure onsite storage, and/or onsite generation.
- The second is back-to-back (B2B) refuelling capacity (how many consecutive refuels within 10 minutes of a previous event can the station handle?). This is determined largely by the amount of high pressure storage and/or the HRS compressor capacity. If B2B refuelling capability is exceeded regularly, it is likely that issues such a lack of sufficient hydrogen availability at the HRS for immediate refuelling, and therefore increased waiting time for vehicles to refuel, will emerge.13

HRS need to demonstrate that they support relevant refuelling protocols: SAE J2601 has a performance target of a fuelling time of 3 minutes and SOC of 95% to 100% with communications, which can be achieved under reference temperature conditions with a 700 bar (H70) T40-rated dispenser.14

Incomplete compliance with J2601 in FCEV refuelling has three potential consequences:

- Low state of charge: The state of charge (SOC) of a FCEV measures the hydrogen in the tanks after a refuel as a percentage of their capacity. From a vehicle user’s perspective, the most common manifestation of a non-J2601-compliant fill is an incomplete tank. The figure below shows H2ME data on post-fill SOC for Toyota Mirai Generation 1s operating in seven countries accumulated in 2017-2019. Only one

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country achieved an average fill of 95% or above; the average post-fill SOC for all H2ME Mirais in the period was 91.5%.\textsuperscript{15}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{average_soc.png}
\caption{Average post-fill SOC (%) for H2ME Mirais}
\end{figure}

\textbf{Figure 5. Post-fill SOC of H2ME Mirai Generation 1s from 2017-2019}

- \textit{Possible damage to vehicle tanks}: The operating temperature of Type IV composite on vehicle storage tanks must stay between -40°C and 85°C to prevent degradation of the tank liner. As hydrogen exhibits a negative Joule-Thomson coefficient, and therefore the hydrogen inside the tank warms up as the fill proceeds, precooling (to -40°C in the case of T40 fuelling), and vehicle to dispenser communication where available, prevents the temperature in the tank from exceeding these safe limits.

- \textit{Increased station wear}: In case of very low flow fuelling, neither the SOC nor the tank temperature is an issue. However, continuous chattering of the check valves can cause unintended wear over time with the risk of having leaking check valves. This is especially the case with non-SAE J2601 compliant stations such as ambient temperature fuelling that has fuelling ramp rates of below 1 MPa/min.

Efforts by HRS and vehicle OEMs to ensure safe refuelling and compliance with appropriate standards are discussed in more detail later in this report.

4 Scope of this document

This report covers the installation of selected H2ME-2 HRS that have been begun reporting data to the project since the last edition to this report in 2020 as summarised below in Table 1. Although H2MOBILITY Deutschland does not have any stations supported by H2ME-2, it continues to upgrade its existing HRS network to support the developments in mobility, particularly the need for 350 bar refuelling of medium duty vehicles such as buses, discussed in Section 3. As such it has also provided input to this edition of the report.

<table>
<thead>
<tr>
<th>Country</th>
<th>Location(s)</th>
<th>Station description</th>
<th>Opened</th>
<th>Installer/Operator</th>
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<td>March 2016</td>
<td>Nel Hydrogen Fueling</td>
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<tr>
<td>Denmark</td>
<td>Copenhagen</td>
<td>Dual 350/700 bar HRS integrated into a conventional refuelling station</td>
<td>November 2021</td>
<td>Nel Hydrogen Fueling/Everfuel</td>
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<td>Germany</td>
<td>Potsdam</td>
<td>700 bar HRS integrated into conventional refuelling station</td>
<td>September 2018, upgraded 2021 to handle larger vehicles</td>
<td>Linde/H2MOBILITY Deutschland</td>
</tr>
<tr>
<td>Germany</td>
<td>Erfurt</td>
<td>700 bar HRS integrated into conventional refuelling station incorporating cryogenic liquid H₂ storage</td>
<td>September 2020</td>
<td>Linde/H2MOBILITY Deutschland</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Den Haag</td>
<td>Dual 350/700 bar HRS integrated into a conventional refuelling station</td>
<td>April 2020</td>
<td>Resato/J P Kerkhof</td>
</tr>
</tbody>
</table>

4.1 Safety

All stations covered in this report (and all stations so far installed by the H2ME project) are operating safely. As of March 2023, H2ME project refuelling stations have dispensed 529 000 kg of hydrogen in 209 000 refuelling events with no safety incidents that involved the release of hydrogen.
5 Topics covered in the document

To ensure that answers could be compared across countries and regions, installers of HRS were asked to respond to a standard set of topics as presented below:

- A high-level overview of the process of station permitting and installation.
- The key RCS for installing stations in each country.
- How the process for installing stations in each country has evolved from the installation of early, pre-H2ME, HRS to the latest stations in H2ME (if applicable).
- Whether the presence of onsite hydrogen generation using electrolysers influences the applicable RCS, and therefore the planning and installation process (if applicable).
- Whether the RCS and planning processes for station installations differ between countries.
- How installers have worked to establish a pool of contractors for stations.
- How station installers have ensured that HRS that are integrated with conventional refuelling stations are safe and customer friendly.
- How the move in H2ME-2 to larger stations with increased amounts of HRS onsite storage and the possibility to refuel HDVs impacts RCS, planning and installation.
- Other significant issues that have arisen since the start of the H2ME project in 2015.

Honda and Toyota, vehicle OEMs participating in H2ME, also provided input on the evolution of RCS and best practice in ensuring safe and effective hydrogen vehicle refuelling.
6 Country and organisational experience of HRS installation and RCS

6.1 Denmark – Nel Hydrogen Fueling & Everfuel

Nel Hydrogen Fueling has extensive experience of installing hydrogen refuelling stations – with or without integrated electrolysers. The company has installed six HRS in Europe since the Copenhagen station.

Everfuel operates eight HRS, plus 12 hydrogen distribution trailers, with a further 11 HRS in development.\(^{16}\)

The H2ME-2-supported HRS at Prags Boulevard, Copenhagen Denmark opened in November 2021 was built by Nel Hydrogen Fueling and is operated by Everfuel. The HRS has two, essentially independent, 700 bar dispensers which primarily support the DRIVR FCEV taxi fleet, plus a 350 bar dispenser designed for hydrogen bus refuelling.

![Figure 6: Prags Boulevard HRS (source: Nel Hydrogen Fueling)\(^{17}\)](image)

The author would like to thank Henrik Mortensen (Everfuel) and Lasse Dam (Nel Hydrogen Fueling) for providing much of the content in this section.

6.1.1 Key RCS for station installation in Denmark

- The first H2ME HRS was opened by Nel in Kolding in 2016.
- Key documents/procedures for the installation of the Kolding HRS were:


\(^{17}\) [Copenhagen gets a new Nel fueling station. Nel Hydrogen Fueling. Available from](https://nelhydrogen.com/articles/hydrogen-fueling/copenhagen-gets-a-new-nel-fueling-station/) (accessed 3\(^{rd}\) April 2023)
6.1.2 The process for installing a HRS in Denmark

- Two processes are involved – building permitting and operation permitting.
- HRS building and permitting are controlled by centralised regulation, but are implemented by municipalities, as illustrated below:

![Figure 7. HRS permitting process in Denmark](image)

- Building permitting:
  - Nel has used its extensive experience in HRS installation to become skilled in preparing and submitting applications.
  - Early in the project Nel meets with all relevant municipality stakeholders (e.g., fire marshals, planning officers) to ensure that any concerns that they may have (e.g., interpretation of safety distances) are addressed.
  - Any concerns that stakeholders have (such as safety distances) can be mitigated in different ways – e.g., firewalls. The key point is that Nel tries to operate in a standard fashion in each installation which establishes precedent that can be followed and passed on to each municipality.

- Operational permitting:
  - The key sign-off point is the local fire marshal.
  - As part of an effort to facilitate the process of operational permitting, Nel was instrumental in getting the fire marshals together at a national level to share best practice and knowledge of H₂. In addition, it helped author national regulations which were not well developed when Nel began installing stations.

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19 Guidance: emergency service operations at hydrogen tank facilities. Danish Emergency Management Agency
As part of the process of obtaining buy-in and establishing a relationship with fire marshals, Nel offers ongoing training and support once the stations are operational.

- The Danish Safety Technology Authority ([https://www.sik.dk/](https://www.sik.dk/)) is the national agency controlling work and installations involving gas.
- The Copenhagen HRS has less than 5t of onsite storage (i.e., under the SEVESO limit), so that main steps in ensuring HRS compliance are:
  - That all equipment is CE marked
  - That the installation is signed off by a notified body (in the case of the Copenhagen station this was TUV).

### 6.1.3 The evolution of HRS installation in Denmark 1. Pre-2016

- In previous versions of this report, Denmark was cited as an exemplar of a country with a relatively centralised decision-making system which allowed established precedent and experience to apply to future installations, thereby speeding the HRS permitting and building process.
- The permitting process for the Copenhagen South station (opened in 2013 with FCH JU support during the HyTEC project) took around six months. Two examples illustrate how this evolved in subsequent stations in 2015-16:
  - The HRS deployed in Korsør under HyFive in 2015 took only 48 hours from submission of the application and appendixes to the granting of the permit.
  - In 2016 permitting for the Esbjerg HRS took four days: the application was sent in May 27th, 2016 and the permit was granted on May 31st, 2016.

### 6.1.4 The evolution of HRS installation in Denmark 2. The Prags Boulevard HRS

- From 2016-2020 few stations were installed in Denmark. This meant that much of the experience and momentum built around hydrogen permitting and regulation discussed in the previous section has dispersed by the time the project to install the Copenhagen HRS was initiated in 2019. Therefore, effectively, the process had to start from scratch.
- A key further difference from previous HRS installs in Denmark was the introduction of Site Acceptance Tests (SATs) by the AFID (discussed in detail in Section 7) which are now mandatory and inevitably increase the HRS commissioning timeline.
- The COVID-19 pandemic in 2020 and 2021 also meant that key components for the HRS has long lead times and were delivered much later than anticipated.
- As a consequence of the points noted above, the permitting and construction time of the HRS was around two years.

### 6.1.5 Comments on and lessons learned from the Prags Boulevard HRS permitting, installation and commissioning

- **Deployment at scale is needed to make the HRS permitting and installation cheaper for all in the long term.** As noted above, developing the Prags Boulevard HRS after a relative lull in HRS deployment was a relatively inefficient process, with Everfuel and Nel Hydrogen Fueling suffering from first mover disadvantage in restarting this market. It is hoped that recent announcements for large-scale HRS deployment across the EU in the AFID and activities related to REPowerEU will mean that permitting times will again fall in Denmark and other countries.
- **The SAT process needs to be optimised.** Crucial steps in the SAT are the:
  - Testing of the HRS by a Fuel Station Test Module (FSTM) certified for CEP usage
  - Approval of the SAT results a vehicle OEM.
As detailed in Section 7, steps are being taken by the CEP to increase the number of FSTMs, and SAT result approval is being transition to a third party. It is anticipated that these steps will speed SAT for new HRS.

- **Standardisation is required for hydrogen supply to the HRS as well as from the HRS to the vehicle.** Much like the standardisation that has been developed between the hydrogen dispenser and the vehicle that fuels at the dispenser, a standard must be developed for the interface between a hydrogen supply truck/trailer and the station. The lack of standardisation in this interface currently means that each station/trailer combination must undergo a risk assessment, and potentially engineering changes, to ensure safe operation. This increases the cost of ownership. A standardization of this interface would mean the following:
  - **Higher level of safety due to standardisation by removing the potential hazards of a case-by-case approach.** A standardised approach would be beneficial for all HRS and for safety.
  - **Lower TCO.** Lower CapEX due to off the shelf product being compatible with the H₂ supply trailer. During operation the operator would also see an increased flexibility in their supply chain as multiple suppliers would be able to provide/connect to their station, ensuring competition among suppliers, but also strengthening the supply of hydrogen to the sites. This would remove costs originating from having to perform interface risk assessment on new hydrogen suppliers/trailers.
6.2 Germany – H2 MOBILITY Deutschland

Founded in 2015, H2 MOBILITY Deutschland (H2M) – a partnership of Air Liquide, Daimler, Linde, OMV, Shell and TOTAL – has installed over 90 HRS in Germany. The organisation’s initial aim was to install 100 700 bar HRS in seven German metropolitan areas (Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Nuremberg, Stuttgart, and Munich), and along the connecting arterial roads and motorways, to create a true national network. Opened in September 2018, the station in Potsdam was the first of 20 H2M-built stations in Germany supported by H2ME.

From 2021, H2M’s strategy evolved towards building larger HRS located based on anchor demand from commercial vehicles and where a public filling station makes sense for a growing network of filling stations for cars. Under plans being developed for the SENECA project, H2M is looking to:

- **By 2024:** upgrade 30 existing HRS along Germany’s core TEN-T corridors by adding 350/700 bar refuelling for heavy duty vehicles (HDVs) to supplement their existing passenger car/light duty vehicle 700 bar facilities.
- **By 2026:** install up to 30 new dual 350/700 bar HRS at key logistics centres and transport hubs. These HRS will be capable of dispensing between 1 tonne and 2 tonnes of hydrogen per day depending on the requirements of the location.

Upgrading existing locations to handle larger vehicles, and installing new, bigger HRS, raises challenges for HRS installers. These are discussed in Sections 6.2.7 and 6.2.8 below.

The author would like to thank Ben Becker, Mario Ludwig, and Volker Schlabach of H2M for providing much of the content in this section.

6.2.1 Key RCS for station installation in Germany

- In Germany it is necessary to apply for an operation permit and for a building permit.
- Operational permitting is governed by clear centralised RCS:
  - The most important are the BetrSichV, the German Operation Safety Directive, with its corresponding TRBS 3151 (Technical Rule for Operation Safety) regarding the building and operation of refuelling stations.
  - The ATEX zones classifications set in the TRBS and oriented on other gases used at refuelling stations allows a safe integration of HRS into existing refuelling infrastructure while keeping the footprint of the HRS to a minimum.
- Each federal state has its own building directive, which defines the application for the building permit.
- Compliance with Alternative Fuels Infrastructure Directive (AFID) 2014/94/EU is checked and proven by the Clean Energy Partnership (CEP) by the CEP-test (DIN EN 17127). The successful completion of the CEP Site Acceptance Test (SAT) is a precondition for the public release of a HRS in Germany; see Section 7 for a detailed discussion.

6.2.2 The effect of incorporating on-site electrolysis into an HRS in Germany

- H2M does not build stations with on-site electrolysis. However, it is working on several projects that use electrolysis as hydrogen source.
- The main difference is that the basis for the operation permit is no longer the BetrSichV, but the BImSchV, the Immission Protection Directive. The BImSchV has much stricter and more extensive regulations and this results in longer application duration.
• The BImSchV is also more demanding, e.g. operation of a hydrogen refuelling station with on-site electrolysis would necessitate the constant attendance of operators.
• The BImSchV is intended to regulate large industrial plants. However, the rules include even the smallest electrolyser. It would make sense to discuss a power limit for electrolysis that can be operated without considering full BImSchV requirements. A reasonable power can be in the range of a few MW that would allow small and medium hydrogen refuelling stations to be supplied on-site.

6.2.3 How the process for installing HRS in Germany is evolving
• Together with its HRS suppliers, architects, safety assessors and the notified body H2M has improved its processes to generate the documents needed for the building and operation permits. The established standards and learnings by suppliers and authorities mean that H2M has reduced average project duration significantly from 18-24 months down to 12-16 months.
• However, evidence suggests that permitting and construction times will not decrease significantly in the near future, particularly for HRS co-located with conventional fuelling stations which is H2M’s preferred option. The main reason for this is that the initial sites chosen in Germany for HRS installation were generally the most favourable, in terms of the key issues such amount of space available for integration of the HRS to avoid permitting problems. Future stations, particularly the further 300 planned for full network expansion, will inevitably involve building HRS in less favourable locations, which will mean that the permitting and building process will still require much stakeholder liaison and planning.
• The Erfurt HRS discussed below provides an example of why HRS permitting and construction times may not necessary fall in all locations in the future.

Erfurt HRS
• The station in Erfurt, capital of Thuringa, is a strategically important HRS location for H2MDE as it is close to the A4, a main east-west connection.
• This was H2MDE’s first HRS in Thuringa. Permitting and construction of the Erfurt HRS has been relatively complex and involved considerable liaison with the local authorities, leading to delays from the initial proposed timetable. Reasons include:

• Permitting:
  o The site comprised seven parcels of land with different owners, of which four were relevant for building the HRS. Obtaining consents and their registration in the real estate registry led to a delay of eight months during the permitting process.
  o The site involves cryogenic liquid hydrogen storage (LH2) to support anticipated future high demand, a different design to that employed on previous H2M HRS (discussed further below).
  o Pressure vessels were moved to the roof of the HRS container following safety workshops after the Kjørbo incident. This required a new housing design, which in turn increased planning and construction time.

• Construction:

A vacuum pipeline is required to move LH2 from container to the dispenser. Limited production capacities for pre-constructing the pipeline delayed the project several months.

- HRS construction was postponed due to the limited availability of highly trained manpower for welding the pre-constructed pipeline onsite.
- A vacuum leakage was found in the underground piping between container and dispenser, which involved much remedial work.
- Lessons learned involve further inspection of the piping and its vacuum insulation before closing pipe trenches, as well as additional tests at factory level.

- Construction of Erfurt was initially scheduled to take about three months, but in fact including all additional work/constraints it took 14 months. The Erfurt HRS opened in September 2020.

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**Figure 8. Erfurt HRS enclosure (including LH2 storage) and dispenser pictured during commissioning (source: H2M)**

### 6.2.4 How HRS RCS and planning processes differ between Germany and other countries

- H2M’s projects are exclusively carried out in Germany.
- The decentralised permitting process in Germany requires a repeated know-how build-up by the different authorities. This increases the permitting time and hinders standardised applications.
- However, from its experience the way the station itself is planned (e.g. whether standalone or on existing infrastructure) and how much experience the authorities, HRS manufacturer, contractors, notified body and HRS builder have are far more important for the project duration than the country location of the HRS. As stated above, not every location is suitable for every HRS, and any legal requirement can lead to delays if options in design and technology are not known.
6.2.5 Practical measures adopted with contractors to speed HRS installation

- The awarding strategy includes the build-up of know-how by several suppliers to reduce future resource bottlenecks. H2M has established framework contracts with architects, electricians, civil constructors, HRS suppliers and notified bodies.
- H2M and its suppliers spend a lot of effort into creating a standardised set of documentation. These include documents for the application for permits, technical specifications, requirements for the layouts and civil work, plans of electrical cabinets and wiring and functional testing of its stations.

6.2.6 Measures taken to work with operators of conventional fuelling stations to ensure that forecourt-integrated HRS are safe and customer-friendly

- The safety and satisfaction of customers is H2M’s top priority. Therefore, it is constantly striving to improve the hydrogen mobility experience, as evidenced by its growing network of HRS, and the ever-increasing availability and improved performance of its stations.
- H2M’s H2.live app and 24-hour hotline enable close communication with its customers. All feedback is recorded and evaluated by its customer relation manager to identify customer needs or recurring problems.
- H2M HRS are mainly integrated into existing conventional refuelling stations of its shareholders. Selection of locations, layout, suppliers, and contractors are chosen in close communication and cooperation with its shareholders and H2M has adopted the tested and proven safety standards established by its shareholders who have many years of experience of operating refuelling stations, specifically Shell, TOTAL and OMV.
- Systematic recording of potential hazards and near misses and their discussion with the station operators to implement sufficient countermeasures.
- H2M performs joint safety training with the station operators to test and improve emergency response procedures.

Figure 9. Potsdam HRS. The left image shows the fire protection wall with the HRS. The right image shows the integration of the H₂ dispenser with the conventional refuelling points (source: H2M)

6.2.7 Upgrading existing HRS to provide HDV fuelling

- H2M plans to upgrade 30 of its existing 700 bar HRS to accommodate HDVs.21

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As well as the presence of hydrogen HDVs in a given location, additional factors that must be considered in the upgrade include:
- Space for vehicles, in terms of turning radii, access, and canopy height
- Space for additional dispensers, H₂ storage and balance of plant.

At present, there are two types of HDVs using H₂M’s network:
- FAUN/ZÖLLER refuse collection vehicles with a tank capacity of 8.4 kg @ 700 bar per tank system. Some vehicles have two tank systems.
- Trucks and buses with a tank capacity of up to 40 kg @ 350 bar.

The differing refuelling requirements of these vehicles put different upgrade requirements on each HRS:

### 700 bar HDV refuelling

- One existing HRS is already capable of refuelling the FAUN/ZÖLLER vehicle.
- Others require retrofit to meet the needs to dispense the required volumes @ 700 bar.
- H₂M is adopting two approaches to satisfy these vehicles
  - **FAUN-compatible** (HRS software modification required only):
    - Capable of refuelling up to three vehicles per day.
    - Deliver 80%+ state of charge (SOC) with an extended refuelling time (> five minutes)
    - Upgrade targeted at up to 30 HRS.
  - **FAUN-ready** (HRS software and hardware modification required)
    - Capable of refuelling more than three vehicles per day with a similar experience to LDV fuelling.
    - Deliver 95%+ state of charge (SOC) with a refuelling time of four-five minutes.
    - Upgrade targeted at up to ten HRS.

![Figure 10: 700 bar refuelling test at Potsdam HRS (source: H₂M)](image)

### 350 bar HDV refuelling

- The upgrade will add a 350 bar or dual 350/700 bar dispenser for buses and trucks.
- The upgrade will also provide onsite storage of at least 400 kg of hydrogen.
- The HRS will dispense hydrogen using SAE J2701 T10 fuelling.
- Nine HRS have been upgraded to this capability, including the H₂ME HRS at Aachen and Herten.
- Further locations are being investigated.
6.2.8 Installation of new HRS capable of dispensing at least 2t/day to provide HDV fuelling

Plans are still being developed, and locations sought, for additional HRS to support the wider rollout of hydrogen HDVs. The following factors are being considered in this rollout:

- Space requirements (for vehicle access and expanded storage and equipment).
- Securing sufficient anchor demand to support these larger stations.
- The potential to support 700 bar refuelling with up to 80 kg per refuelling
- New hydrogen delivery and storage concepts.
6.3 Netherlands – Resato & Kerkhof

B. Kerkhof & Zn (http://www.kerkhof.com) operates a refuelling station which, since 1966 has been sited at Binckhorstlaan in The Hague. The site offers:

- Hydrogen 350 & 700 bar (opened in March 2020)
- Petrol and diesel for passenger cars (10 pumps, four hoses each)
- Four high-speed diesel HGV pumps
- Two AdBlue and two GTL hoses
- Two BioCNG pumps
- Four LPG pumps
- Electric charging plus a 350 panel solar array capable of generating 100kW
  - 2x22kW AC
  - 4x150kW and 10x300 kW DC

![Image of The Hague HRS](https://resato-hydrogen.com/)

Figure 12. The Hague HRS (source: J P Kerkhof)

Resato (https://resato-hydrogen.com/) is a Dutch company with more than 25 years' experience in high pressure systems and testing equipment. The Hague station was its first public fast-fill HRS installation providing considerable learning and experience as a first step to become one of the market leaders in HRS development and manufacture. The company now has installed over 25 HRS in different European countries.
Dissemination Level: Public
HRS Safety and RCS: Lessons Learned H2ME-2 DS.22

The author would like to thank Jan Paul Kerkhof (Kerkhof), Nico van den Berg (Rijkswaterstaat, Dutch Ministry of Infrastructure and Water Management), Stefan Neis (WaterstofNet) & Gerard Schuiringa (Resato) for providing much of the content in this section.

6.3.1  Key RCS for HRS installation in the Netherlands
Given the ongoing rapid development of hydrogen mobility and anticipated increase in HRS numbers, Netherlands agencies such as the Ministrie van Infrastructuur en Waterstaat (Ministry of Infrastructure and Water Management) and the Dutch H2 Platform (https://opwegmetwaterstof.nl/) have been proactive in documenting information on HRS permitting and - installation. The content of this and the following sections is primarily taken from the 2020 document Permitting process on Hydrogen Refuelling Stations, which should be consulted for further detail and links. Key points include:

- **Environmental permitting** HRS are classified as Type C establishments under the Activities Decree (https://rwsenvironment.eu/subjects/environmental-0/activities-decree/) which means they require an environmental permit from the relevant municipality, which is the competent authority. In most cases the municipality delegates the permitting to the regional environmental agency (Omgevingsdienst or Regionale UitvoeringsDienst (RUD)); the appropriate safety region (veiligheidsregio) is also consulted on safety-relevant aspects. On average, the environmental permitting process could take up to 18 months, when starting from scratch. The regular process duration is legally set at 26 weeks.

- **Storage** HRS with onsite storage below 5 tonnes are under the SEVESO III threshold and so are not covered by the Major Accident Risks Decree (https://brzoplus.nl/aanpak/brzo-2015/inleiding-brzo-2015/).


- **HRS** (whether new, or as part of an existing fuelling station) generally require a building permit.

6.3.2  The process for installing a HRS in the Netherlands

- Figure 13 below summarises the HRS installation and licensing process in the Netherlands.

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Figure 13. HRS planning, installation, and licensing process in the Netherlands

- Exploration and preparation
  - Spatial planning does not currently account for the use of hydrogen as a fuel. Therefore, it is important to allow as much time as possible for consultation with all stakeholders – including the municipality, environmental agency, safety region and local residents – in the Exploratory and Preparatory stage and to allow for amendment where needed of the appropriate development plan.
  - **PGS 35** *Hydrogen: Installations for Delivery of Hydrogen to Road Vehicles* (PGS Publicatiereeks Gevaarlijke Stoffen, Publication Series Dangerous Substances)\(^{25}\) is considered the best available reference on hydrogen refuelling station design, construction, operation, testing and safety. It therefore forms the basis for the Environmental Permit.
  - Risk as assessed in line with the Decree on External Safety of Establishments\(^{26}\) which means a Quantitative Risk Assessment (QRA) will be needed, even though HRS are not currently covered by the decree.

- Permitting
  - The permitting procedure for HRS is the same as for other establishments (as described in the *Administrative Guide to Licensing Hydrogen Filling Stations*\(^{27}\)), encompassing:


1. Preliminary phase and ‘quick scan’ outlining the possibilities and potential sticking points
2. Determining whether the application is admissible and licensable
3. Justification of the group risk
4. Formulation of rules
5. Data input in the risk register/risk map
6. Risk communication
7. Enforcement
8. Preparation of incident control.

Information required is decided by the AHJ, but includes:
- Environment and ecological surveys
- Justification of land use change in development plan
- Traffic study
- QRA
- Waste and energy management plans.

It is also likely that the following information will be required once operation has begun:
- Explosion protection document and emergency plan
- HAZOP study
- Hydrogen transport routes

Interested parties have three options for issuing a formal response during the permitting process:
- An opinion on the draft decision during an official six-week window.
- An objection to the definitive decision during a further six-week window.
- An appeal to the courts is also possible.

**6.3.3 Timeline for installation of The Hague HRS**

- Initial discussion and planning for the HRS began in March 2017 between Kerkhof and Resato to be the launch customer for this new product line.
- The draft decision on the HRS was received in July 2019
- HRS construction began on October 2019
- CEP acceptance tests were carried out in June 2021
- The HRS was opened in December 2019.
- The Den Haag HRS was the first HRS built by Resato and operated by Kerkhof. As such, many lesson were learned in the process such as:
  - A new market approach: moving from business to business to a more complex situation involving multiple stakeholders
Customer experience is important to maintain success of HRS. H2ME-2 has been invaluable for obtaining feedback on fuelling experience and system availability, and to allow Resato to make design and performance improvements.

Using the lessons learned from The Hague, Resato is productising HRS to ensure long term performance and reliability.

The product line is being built and developed in a modular fashion to allow rapid response to the continually-changing market and to allow for individual module improvements.

- With this knowledge, it is possible that building and permitting a new HRS will take 9-12 months. In practice we see a period of ~12-14 months due to the stakeholder complexity.

6.3.4 How the process for installing a HRS in the Netherlands is evolving

- Due to come into force in 1st July 2023, The Environment and Planning Act (Omgevingswet) embodies several acts. It is set up to make it easier to test building projects on all necessary aspects. The new Act consists of 26 existing acts around built environment, housing, infrastructure, environment, nature and water (formerly Environmental Permitting Act or Omgevingsrecht). The advantages are: [https://business.gov.nl/amendment/introduction-environmental-and-planning-act-omgevingswet](https://business.gov.nl/amendment/introduction-environmental-and-planning-act-omgevingswet).

- From the moment the Environment and Planning Act enters into force, all municipalities should be connected to the digital system for this act (Digitaal Stelsel Omgevingswet, DSO). DSO will be a one-stop shop to apply for permits, consult the applicable rules for a specific location and at a later stage access information on the quality of the physical environment. Once the Act has come into force, in many cases it should be possible to issue a permit within 8 weeks of application.

- For activities involving risk however, such as HRS installation and operation, the need to ensure that regulations are observed will remain paramount. For example, for the first time fixed safety distances of 35 metres will be mandated from the refueller where hydrogen is delivered by tube trailer, and 55 metres from the buffer tank.

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7 Vehicle manufacturers' perspective on hydrogen refuelling

Honda R&D Europe (H2ME-2) and Toyota Motor Europe (directly in H2ME-1, and through National Marketing and Sales Organisations in Denmark and Norway in H2ME-2) have deployed vehicles across Europe as part of H2ME. Both manufacturers have been active in work coordinated by the CEP aimed at establishing processes and documentation to ensure the safe and reproducible refuelling of hydrogen vehicles to accepted performance expectations.

The author would like to thank Thomas Brachmann of Honda R&D Europe and Vincent Mattelaer of Toyota Motor Europe for providing much of the content in this section, including presentation material for the graphics.

7.1 Vehicle refuelling protocols: SAE J2601

A refuelling protocol is a set of procedures that dictate the process that a HRS follows to safely fuel a vehicle’s compressed hydrogen storage system (CHSS). Refuelling protocols ensure:

- The CHSS stays within its operating temperature and pressure limits
- An acceptable refuelling speed and final SOC.

As introduced in Section 3, for H2ME, the relevant refuelling protocol is SAE J2601, which is the worldwide protocol standard for light duty fuelling. The objectives and implementation of J2601 are summarised below.

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**Figure 14. SAE J2601**

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J2601 has evolved since its first introduction, and during H2ME, as shown below.

**Figure 15. Evolution of SAE J2601 (TIR = Technical Information Release)**

### 7.2 Implementation of hydrogen refuelling station RCS in Europe

The implementation of the 2014 Alternative Fuels Infrastructure Directive (AFID) and its proposed 2021 revision, are summarised below in Figure 16. The current proposal is for publicly accessible hydrogen refuelling stations to be deployed with a maximum distance of 150 km in between them along the TEN-T core and the TEN-T comprehensive network, and that at least one should be available in every urban node. The figure also summarises the ramifications of the implementation of AFID for HRS, and in particular the importance of compliance with J2601 and EN 17127 to ensure safe and reproducible refuelling.

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7.3 HRS approvals process and the Site Acceptance Test (SAT)

Given the issues observed with low vehicle SOC (discussed in Section 3.3), and the potential issues of maintaining tank integrity in non-compliant refuelling, vehicle OEMs have worked with HRS suppliers in the CEP OEM Group to devise a process to approve HRS for refuelling of their vehicles based on EN 17127.\(^{31}\) As part of the standards noted in Figure 16, the HRS operator must also supply for OEM inspection:\(^{32}\)

- Factory Acceptance Test (FAT) report (in general provided by the HRS supplier to the HRS operator)
- Hydrogen quality sampling and analysis report
- Site Acceptance Test (SAT) report

The SAT is summarised in Table 2.

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Table 2. HRS SAT (NWP = Nominal Working Pressure)\(^\text{33}\)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Prep to be performed</th>
<th>Test info</th>
<th>Acceptable Test</th>
<th>CEP/ISO test #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient, fuelling pressure and temperature sensor accuracy table</td>
<td>-</td>
<td>Verification of ambient and fuelling temperature sensor and fuelling readings, review of calibration</td>
<td>Sensors show value reasonable to state of the refuelling point; calibration certificates OK</td>
<td>3 (ISO 19880-1)</td>
</tr>
<tr>
<td>Fault: CHSS starting pressure</td>
<td>CHSS with starting pressure greater than the appropriate vehicle NWP to be refuelled (attempted)</td>
<td>Connect the CHSS to the HRS and initiate the refuelling. HRS shall recognize full CHSS and not start main part of refuelling</td>
<td>Main refuelling is not allowed to start.</td>
<td>8 (ISO 19880-1)</td>
</tr>
<tr>
<td>Communication break</td>
<td>Simulated communications and then a break in communication signal</td>
<td>Confirm that the refuelling switches to non-communication fuelling</td>
<td>Dispensing system switches to non-com refuelling or stops refuelling.</td>
<td>16 (ISO 19880-1)</td>
</tr>
<tr>
<td>Fault: Communication Abort Signal</td>
<td>Simulated communications Abort Signal, e.g. by manipulation of the signal loop</td>
<td>To be monitored even with non-communications refuelling (if applicable)</td>
<td>Refuelling Stop within 5 seconds of Abort Signal being sent</td>
<td>18 (ISO 19880-1)</td>
</tr>
<tr>
<td>Non-comm refuelling validation for each pressure level (H70 and H35)</td>
<td>2 different starting conditions</td>
<td>Two tests per hydrogen service level applicable</td>
<td>( P_{\text{target}} ) ±2 MPa without exceeding the fuelling protocol process limits</td>
<td>36 (ISO 19880-1)</td>
</tr>
<tr>
<td>Communication refuelling validation</td>
<td>2 different starting conditions, one of which is below 2 MPa starting pressure</td>
<td>Two tests per hydrogen service level applicable</td>
<td>SOC or ( P_{\text{target}} ) without exceeding the fuelling protocol process limits and with no abort signal received.</td>
<td>37 (ISO 19880-1)</td>
</tr>
</tbody>
</table>

### 7.4 Implementation of the CEP HRS approvals process and the SAT

When HRS station testing began in Germany in 2011, each new HRS was tested separately by each vehicle OEM, which was an inefficient and lengthy process. In moving to a more efficient, repeatable process for new HRS, questions to be addressed included:

- How tests are to be performed and evaluated?
- How should the tests be documented?
- Who should do the testing and evaluation?
- How frequently (if at all) do tests need to be repeated?

\(^{\text{33}}\) Table derived from EN 17127
The status of the CEP process and SAT in Germany and other countries in the EU such as Denmark is summarised in Table 3. A key aspect of the implementation of the SAT is the use of a mobile testing rig capable of carrying out and recording tests that are representative of the range of OEM vehicles using the station (as discussed in Section 3 this covers vehicles with tank capacities ranging from 4.6 kg to 6.3 kg H₂ at 700 bar), such as the mobile Fueling Station Test Module (FSTM) developed by ZSW. FSTM testing is also carried out by ZSW, and the results documented in an acceptance report.

However, as shown in Table 3, the evaluation of the results of the SAT is still carried out individually by each vehicle OEM in a long, manual process before the station can be approved. If any issues are found in the evaluation, the testing and evaluation process must generally be repeated, further delaying the HRS approval.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>declaration</td>
<td>The HRS supplier declares the SAE conformity of the system.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>testing</td>
<td>The HRS supplier tests the HRS, or a qualified independent 3rd party test the HRS on behalf of the operator/supplier in accordance with the CEP acceptance programme. The results are documented in detail in an acceptance report.</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>evaluation</td>
<td>The acceptance report and declaration of conformity are submitted to the OEMs, who check the conformity of the test results. Deviations from standards are discussed with the HRS supplier bilaterally.</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>approval</td>
<td>Explicit approval of the acceptance reports by OEMs.</td>
</tr>
</tbody>
</table>

Table 3. Current CEP HRS approval process

### 7.5 Future streamlining of the SAT

Discussions during the compilations of this report have indicated that, at times, the limited number of, and availability of, FSTMs that are certified for CEP usage have delayed the SAT. This should be addressed by the provision of additional FSTMs as currently there are two in use in CEP approvals.

Table 4 shows that work is underway to transfer responsibility for HRS testing, evaluation, and approval on behalf of all CEP vehicle OEMs to an independent third party. This is scheduled to be completed in Germany by the end of 2023, and in France and the Netherlands by the end of 2024. By bringing an external body to carry out this work, it is expected that a smoother process for HRS testing and approval will result and that typical station testing, evaluation and acceptance times will reduce to around one month.

---

Table 4. Future HRS approval process (key changes from current marked in red)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Description</th>
<th>Responsibility</th>
</tr>
</thead>
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<tr>
<td>1 declaration</td>
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<td>HRS-Supplier</td>
</tr>
<tr>
<td>2 testing</td>
<td>The HRS is tested by a qualified independent 3rd party on behalf of the HRS operator/supplier in accordance with the CEP acceptance programme/EN 17127. The results are documented in detail in an acceptance report.</td>
<td>3rd Party</td>
</tr>
<tr>
<td>3 evaluation</td>
<td>The acceptance report and declaration of conformity are checked and confirmed by a qualified independent 3rd party on behalf of the HRS operator/supplier. Deviations to the standard will be discussed between the independent 3rd party and the HRS acceptance report creator.</td>
<td>3rd Party</td>
</tr>
<tr>
<td>4 approval</td>
<td>Explicit approval of the acceptance reports by the independent 3rd party.</td>
<td>3rd Party</td>
</tr>
</tbody>
</table>
8 Summary and conclusions

Three country/installer HRS case studies are presented in this report:

- **Denmark** was cited in previous versions of this report as an exemplar of a country with a relatively centralised decision-making system which allowed established precedent and experience to apply to future installations, thereby speeding the HRS permitting process to as little as a week. However, from 2016 until the opening of the H2ME-2-supported Copenhagen Prags Boulevard HRS in 2021, few stations were installed in Denmark which meant that much of the experience and momentum built around hydrogen permitting and regulation had dissipated. The Copenhagen HRS took around two years to open from project inception, with construction slowed by equipment availability issues which were exacerbated by COVID-19. In contrast to the H2ME-2-supported Kolding HRS opened in 2016, the commissioning of the Prags Boulevard HRS also involved a CEP SAT with evaluation of the test results by vehicle OEMs. This inevitably added to the commissioning time.

- H2 MOBILITY Deutschland (H2M) has installed over 90 HRS in **Germany** to create a national network. Operational permitting for HRS in Germany is governed by clear centralised RCS such as the BetrSichV. However, building permitting is the responsibility of individual federal states, each one of which has its own building directive. In practical terms, the decentralised building permitting process in Germany requires repeated engagement to build know-how with the different authorities, which increases the permitting time and hinders standardised applications. H2M’s strategy is evolving towards building larger HRS located based on anchor demand from commercial vehicles and where a public filling station makes sense for a growing network of filling stations for cars. As such, it plans to upgrade 30 of its existing 700 bar HRS to add 350 bar fuelling to accommodate HDVs.

- Opened in 2020 the H2ME-2-funded HRS in the Hague, the **Netherlands** operated by B. Kerkhof & Zn was the first public HRS constructed by Resato. permitting Anticipating the wider rollout of hydrogen fuelling, Netherlands national agencies such as the Ministry of Infrastructure and Water Management have been proactive in documenting the process for preparing, permitting, building, and commissioning at HRS. In common with the other country examples in this report, the key step is Environmental Permitting. This is controlled by the relevant municipality with is the authority having jurisdiction. In most cases the municipality delegates the permitting to the regional environmental agency; the appropriate safety region (veiligheidsregio) is also consulted on safety-relevant aspects. On average the permitting process takes around 18 months.

Comparing the country case studies shows that, while there is commonality in terms of the overall EU directives that are followed in each country, there are differences in the processes and involved in HRS permitting and installation, despite the continued evolution of hydrogen refuelling RCS such as EN 17127. The optimal situation for speed through the HRS permitting and planning process appears to be a relatively centralised decision-making system which allows established precedent and experience gained through HRS installation to be applied to each future proposed installation (i.e., that of Denmark, at least up to 2016). Involvement of decentralised/regional agencies in the process requires repeated engagement for each individual HRS construction project to build know-how with different authorities. This increases the permitting time and hinders standardised applications. It is hoped that recent announcements for large-scale HRS deployment across the EU in the AFID and activities related to REPowerEU will mean that permitting times will again fall in Denmark and other countries.
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