



European hydrogen train the trainer programme for responders: The impact of HyResponder on training across Europe

Síle Brennan^{a,*}, Christian Brauner^b, Dennis Davis^c, Natalie De Backer^d, Alexander Dyck^e, César García-Hernández^f, André Vagner Gaathaug^g, Petr Kupka^h, Laurence Grand-Clementⁱ, Etienne Havret^j, Deborah Houssin^k, Laurent Lecomte^l, Eric Maranne^m, Pippa Steeleⁿ, Paola Russo^o, Adolfo Pinilla^p, Gerhard Schoepf^q, Tom Van Esbroeck^d, Vladimir Molkov^a

^a HySAFER Centre, Ulster University, Belfast, United Kingdom

^b International Fire Academy, Balsthal, Switzerland

^c International Association of Fire and Rescue Services, Head office, Ljubljana, Slovenia

^d Service Public Fédéral Interieur, Brussels, Belgium

^e Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Networked Energy Systems, Germany

^f Design for Safety Research Group, University of Zaragoza, Spain

^g Department of Process, Energy and Environmental Technology University of South-Eastern Norway, Norway

^h Ministry of the Interior of the Czech Republic, Brno, Czech Republic

ⁱ Persee, Lyon, France

^j Univ. Grenoble Alpes, CEA, Liten, F-38000, Grenoble, France

^k Air Liquide, Innovation Campus Paris, Les Loges-en-Josas, 78354, France

^l Ecole Nationale Supérieure des Officiers de Sapeurs-Pompiers, Aix-en-Provence, France

^m Crisis Simulation Engineering, Aix-en-Provence, France

ⁿ Fire Service College, Moreton in Marsh, United Kingdom

^o Università degli Studi di Roma "La Sapienza", Rome, Italy

^p Servicio Contra Incendios, de Salvamento y Protección Civil del Excmo. Ayuntamiento de Zaragoza, Spain

^q Landes Feuerweherschule Tirol, Austria

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ABSTRACT

The impact of the HyResponder project on the training of responders in 10 European countries is described. An overview is presented of training activities undertaken within the project in Austria, Belgium, Czech Republic, France, Germany, Italy, Norway, Spain, Switzerland, and the United Kingdom. National leads with training expertise are given, and the longer-term plans in each region are mentioned. Responders from each region took part in a specially tailored “train the trainer” programme, and then delivered training within their regions. A flexible approach to training within the HyResponder network has enabled fit for purpose, region appropriate activities to be delivered, impacting over 1250 individuals during the project, and many more beyond. Teaching and learning materials in hydrogen safety for responders have been made available in 8 languages: English, Czech, Dutch, French, German, Italian, Norwegian, Spanish. They are being used to inform training within each of the partner countries. Dedicated national working groups, focused on hydrogen safety training for responders have been established in Belgium, the Czech Republic, Italy, and Switzerland.

1. Introduction

The importance of hydrogen in decarbonising Europe's energy sector is well recognised. Education and training are key to ensure the inherently safer deployment of hydrogen systems and infrastructure.

Emergency responders need training resources, and subject specific knowledge to be able to safely manage the potential incidents and associated risks involving hydrogen systems and infrastructure. Approaches to responder training vary across Europe, and indeed globally, and until recently, their training specific to hydrogen safety was limited

* Corresponding author.

E-mail address: sl.brennan@ulster.ac.uk (S. Brennan).

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due to lack of experience and specialised knowledge. Through the successful previous HyResponse project (2014–2016) led by L'École nationale supérieure des officiers de sapeurs-pompiers (ENSOSP) [1,2], a unique operational training platform and threefold approach to responders' training was developed. However, studies such as that by Li et al. [3] in the UK indicated that although emergency response tactics for hydrogen-related hazards existed these kinds of knowledge had not been passed to firefighters effectively. Many firefighters still had a knowledge gap when considering for example the hydrogen safety aspect of a fuel cell vehicle. While online training in hydrogen safety has existed for some time, e.g. Ref. [4] a clear need existed to address responder training more widely. As described by Brennan et al. [5] the HyResponder project "European Hydrogen Train the Trainer Programme for Responders" (January 2020–May 2023) was designed to build on the HyResponse project and to implement a pan-European approach to achieve synergy in the state-of-art response to hydrogen incidents. A properly trained responder community is recognised as critical to the successful acceptance of hydrogen technologies [6].

Through the HyResponse project, a comprehensive training programme for first responders was established [1]. The HyResponse programme consisted of a European Hydrogen Safety Training Platform (EHSTP). A threefold training programme comprising of educational training, operational training on real scale training hydrogen and fuel cell simulator installations at ENSOSP, and virtual reality training reproducing entire incident scenarios. Through HyResponse in-person pilot training sessions, delivered in English, was delivered at ENSOSP. The European Emergency Response Guide (EERG) was further developed and used to inform the training sessions. HyResponder sought to build upon these HyResponse activities by maximising the reach and impact of the training across Europe. The HyResponder consortium was composed of 16 partners from 10 countries and the main aim was to develop and implement a sustainable train the trainer programme in hydrogen safety for responders throughout Europe. All objectives of the HyResponder project were met, and an overview of the outcomes is given by Brennan et al. [5]. Outcomes included revision of the threefold training programme, to include lectures at different learning levels, an extended operational training platform, an online e-Platform and a revised EERG. However, the details presented in this paper are focused only upon the impact of the train the trainer programme in each of the 10 countries represented in the project. The approach to training in each region within HyResponder is summarised, the organisations leading national training are noted, and the longer-term impact of the activities is described. Before discussing the activities in each country, an overview is presented of both the training materials available, and activities undertaken to "train the trainers" from each country. This paper represents a summary of a HyResponder project deliverable, namely D4.3 "Report on the delivery of National Training Cluster Workshops" [7]. While workshop specifics can be found within the project deliverable [7], approved by the European Commission, an overview of the key impacts of HyResponder are documented here.

2. Training materials

The International Curriculum in Hydrogen Safety Training for First Responders, developed within the HyResponse project [1,2] was revised to incorporate advancements in the field, including liquid hydrogen, confined spaces and hydrogen refuelling stations [8]. A set of 12 revised lectures were developed covering the curriculum. Where appropriate the lectures were supported with online tools through the e-Laboratory in Hydrogen Safety (<https://elab.hysafer.ulster.ac.uk>) [9,10].

At the outset of the project, it was identified by partner CTIF (Comité Technique International de prevention et d'extinction de Feu) the International Association of Fire and Rescue Services that first responder training needs and backgrounds varied significantly across Europe. In some countries a large number of responders are volunteers. Efforts were made to identify different accepted learning requirements that

would be representative of the range of roles and competence used by firefighters across all regions. Four levels of need were identified and described as: 1. Firefighter, 2. Crew Commander 3. Incident Commander, and 4. Specialist Officer, with the specialist officer role being the most detailed content, equivalent to the level of training required by for example HAZMAT officers. The lectures were stratified with content made available, aligning to each of the four learning levels. To support delivery of the training in the national language core educational materials developed have been translated. The primary need for having suitable learning materials was identified as the firefighter because this would be represents the majority of first responders. Lectures at **firefighter level** were therefore prepared and made available in 8 languages: English, Czech, Dutch, French, German, Italian, Norwegian, Spanish. Firefighter level was agreed as key for translation and was used as the basis for the workshops delivered nationally. Training modules aligned to the European Qualification Framework was also designed around this level, and the translated materials can be used locally in support of this. Whilst there are some translations available at specialist level, it was agreed that English materials could be used in most regions at this level.

The operational training facilities in hydrogen safety at ENSOSP, designed and constructed within HyResponse [1,2] were extended within HyResponder to enable new training practices due to the risks of LH2 (Liquid Hydrogen) and LIN (Liquid Nitrogen). This extended the operating training platform to incorporate 10 operational exercises which can be combined in several scenarios. More details on the extended training platform can be found elsewhere [5].

Virtual reality exercises, led by partner CRISE, were developed to "train the trainers" in incident response. More details can be found on these elsewhere [5]. As with the operational training, it was not possible to replicate this element in each region, however key elements were used to inform local training arrangements. The virtual reality exercises developed within HyResponse were extended in HyResponder to include scenarios related to LH2.

The EERG for first responders developed within HyResponse [1,2] was revised and extended within HyResponder. Revisions have included scenarios related to LH2 and confined spaces.

As described elsewhere [5], the stratified, and translated, teaching materials, the e-Laboratory of Hydrogen Safety, training sequences, details on the operational and virtual reality activities and the revised EERG can all be accessed on the HyResponder e-Platform for responders (<https://hyresponder.eu/e-platform/>) which was developed and implemented online by partner Persee. The e-Platform incorporates a body of training resources in hydrogen safety. It is expected that responders utilising these to provide training have undertaken operational training in this area. Furthermore, A framework has also been developed by CTIF whereby the firefighter training can be delivered and assessed [5].

The educational, operational, and virtual reality training resources, underpinned with the EERG were used to provide training to trainers in the first instance.

3. Train the trainer approach

"National Training Clusters" were established in each of the 10 partner countries within the project (Austria, Brussels, Czech Republic, France, Germany, Italy, Norway, Spain, Switzerland, and the United Kingdom). The clusters incorporated responder training organisations, experts in hydrogen safety, and additional stakeholders where appropriate. Each training cluster considered the regional training provision and needs and nominated trainers to take part in the HyResponder training.

The nominated trainers from each region undertook comprehensive training through a two-step approach. In the first instance a 5-day virtual training course was delivered, and this was followed by hands-on training at ENSOSP. The online educational training course included

12 lectures at specialist level and “virtual operational training” utilising digital training sequences supported by video content. In person training at ENSOSP incorporated the operational training platform and virtual reality exercises underpinned by the EERG.

Having undertaken training, the trainers, supported by the HyResponder consortium, were then instrumental in delivering training in each of their regions.

4. Need for variance in training requirements and approaches

Identified by CTIF the tasks, structures, working methods and training of the fire departments across the individual European countries are individual and diverse. Prior experience and training vary amongst responders, and organisational structure of the fire services ranges from nationwide in some countries (e.g., Belgium and Italy) to region specific in others (e.g., Norway and Switzerland). For these reasons it was agreed that a “one size fits all” approach to training would be neither appropriate nor sustainable. Instead, the HyResponder training was adapted to meet the needs of each specific region. Where appropriate, the training was delivered as an independent topic, or in some cases embedded within the existing training provision. The subjects of most relevance are in some cases also region specific, for example tunnel fires in Switzerland. The German speaking area has also some conformities in organisation structures and content demand that was adapted in the national relationships. Despite the variance in training needs, there was unanimous agreement amongst all regions that the sharing of best practice in operational response and experience in training between

countries is essential.

5. Overview of initial training approaches

A key objective of HyResponder was to “support newly trained trainers to deliver workshops for responders in at least 10 countries, maximising the reach and impact of the training programme”. Trainers from each of the 10 countries represented in the project (Austria, Belgium, Czech Republic, France, Germany, Italy, Norway, Spain, Switzerland, United Kingdom) underwent training. Observed by CTIF this training was then modified into modules of training that were adaptable to every region, which could then be utilised in the development and delivery of local training activities for responders. In each of the countries, partnerships or “National clusters” were established between responders, academia, and wider stakeholders in order to support the effective and sustainable delivery of training for responders. The locations of the training are shown in Fig. 1.

Over the course of the project, HyResponder training was delivered in 11 regions in 10 countries. There were two activities in France, one at ENSOSP utilising their unique operational facilities, and a second theoretical workshop at Commissariat à l'énergie atomique et aux énergies alternatives (CEA) Grenoble, building on links with the local fire brigades. In all cases the national training was delivered in the **local language** and supported by the translated HyResponder materials. To account for local preferences approaches ranged from fully online to in-person. This was deemed to be the most effective and sustainable approach, ensuring the training in hydrogen safety could be delivered

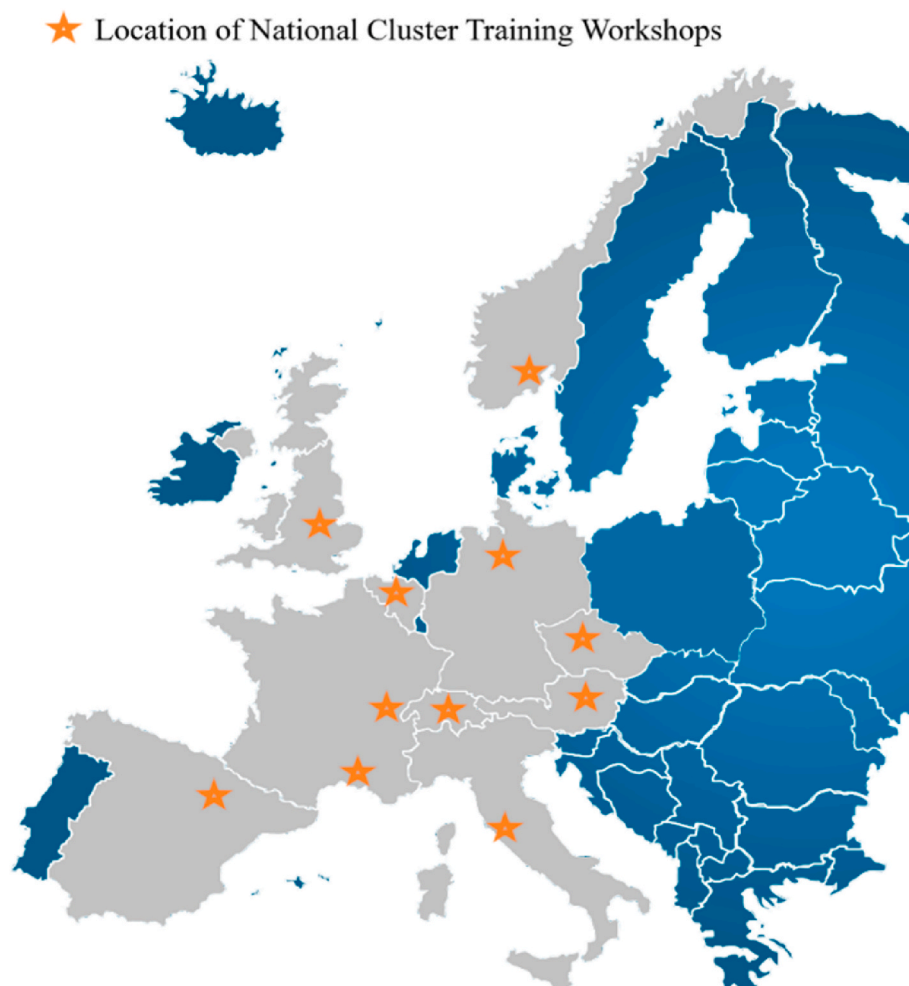


Fig. 1. National training clusters.

alongside existing training, and aligned to local needs. It should be emphasised that the focus was on educational training and use of the training sequences, it was not possible, nor planned, to deliver “hands-on” training and virtual reality training at a local level. However, this was utilised in the “train the trainer” activities held prior to the national training, ensuring that trainers from each region have access to support and an effective “blueprint” for training facilities, when they are in a position to develop them.

An overview of the training leads and supporting organisations, and format of initial training is given in Table 1, (also listed in Ref. [5]). It is important to emphasise that this HyResponder training represented the first steps, rather than the conclusion of training with activities extending beyond the project. Furthermore, whilst the activities were delivered by National Clusters, there was ongoing collaboration across the regions examples include.

- Support from ENSOSP to the teams of National Clusters in Italy and Spain initially, and more widely beyond the project in the development of operational training facilities.
- Collaboration in the translation of materials and delivery of training where a language is shared, e.g. German and French.

Country level activities and longer-term impact is discussed on a country-by-country basis in the following sections. The approaches to training, stakeholders, and barriers and supports to longer term impact vary significantly from region to region. This is reflected in the variance in information reported for each region. It is important to emphasise that the authors include a training lead from each of the regions described in Section 6. The authors have been directly involved in the development and implementation of the training plans within their regions. **6. Country level activities and longer-term impact.**

5.1. Austria

Austrian training lead, Landes-Feuerwehrschnule Tirol (LFT), were the first partner to initiate training in an e-learning format, which they have built upon since 2021. The learning platforms “Moodle” and “Articulate Rise” were used in support of this. Thus, at the time of HyResponder completion in May 2023 this activity had already impacted significantly across Austrian fire-schools, and it has been continuously built upon since. LFT initially developed a pilot course. Based on these two further e-learning modules were developed. Specifically, “Basic hydrogen knowledge” and “Procedures for operations”.

Through the initial training the following number of trainees were

provided with hydrogen knowledge.

- Pilot course (Austria-wide) 70 people partially viewed the content and 48 completed the course. This pilot course was targeted at group commanders or operations managers and was limited to instructors from other provincial fire brigade schools in Austria, officers from the professional fire brigades in Austria and members of various working groups on the topic of hydrogen. This raised awareness of the HyResponder project throughout Austria and ensured that that appropriately qualified feedback was given. The training was split into 12 lessons, utilising the translated material, the EERG, and the sequence videos.
- Basic Knowledge - "Basic Hydrogen Knowledge" 217 people initially completed this in the state of Tirol.
- The operations tactics course for leaders, "Procedures for Operations," was completed by 71 people in the first instance.

By the end of 2023, 800 people had completed the basic knowledge course and 350 leaders had completed the tactical course. Activities have been disseminated to key Austrian stakeholders including the Austria National Panel on Hazmat of the Austrian Federal Fire Brigade Association. The intention from the outset was to have a sustainable course for Austrian firefighters. This is in place at two levels and the delivery is ongoing.

5.2. Belgium

Partner Service Public Federal Interieur (SPFI) were the Belgian lead within HyResponder. They utilised both Dutch and French materials at **firefighter level**. SPFI have been instrumental in ensuring the HyResponder training impacts long term in Belgium and they have continued to deliver train the trainer events beyond the project closure in 2023, these have taken the form of in-person workshops and webinars. An example webinar, targeted at fire fighters, delivered in March 2023 in Dutch, remains available online 450 participants joined this event live and as of May 2024 there had been 2.5k views of the recorded video. The webinar remains a digital resource in Dutch available on YouTube (https://www.youtube.com/watch?v=-3m_cUHdB3o). French digital resources, developed by SPFI include a podcast created with the Fire School of Hainaut.

Significantly, SPFI have been pursuing recognition of the training course through official bodies – the Ministry of Home Affairs (Centre of Expertise). This will result in an officially recognised course with a certificate through the High Council for Education. A 5-year plan is in

Table 1
Overview of initial HyResponder training nationally [5].

Region	Lead	Supporting organisations	Format of initial training*	Language
1 Austria	Landes-Feuerwehrschnule Tirol		Online, e-learning modules	German
2 Belgium	Service public Federal Interieur	Centre of expertise, KCCE, Brussels	Online and F2F workshop	Dutch French
3 Czech Republic	Fire and rescue service of the Czech Republic		F2F workshop	Czech
4 France (I)	ENSOSP French national fire officers Academy	CRISE	F2F, hands-on	French
5 France (II)	Commissariat à l'énergie atomique et aux énergies alternatives	Local fire brigades, hydrogen energy stakeholders	F2F workshop	French
6 Germany	German Aerospace Center (DLR)	Fire service of Oldenburg	F2F workshop	German
7 Italy	Sapienza University of Rome	Italian national fire Corps	F2F workshop	Italian
8 Norway	University of South Eastern Norway		F2F workshop	Norwegian
9 Spain	Zaragoza Ayuntamiento	University of Zaragoza, Foundation for the development of new hydrogen technologies in Aragon	F2F workshop	Spanish
10 Switzerland	International fire Academy		F2F workshop	German
11 United Kingdom	Fire service College	Ulster University, CTIF	F2F workshop	English

Note: F2F – face to face.

place, ultimately targeting up to 16k firefighters across 4 learning levels, with the training integrated in national basic education. The prospect of developing postgraduate level training for HAZMAT advisors is also being investigated.

5.3. Czech Republic

Lectures at all levels from fire fighter to specialist and the EERG were translated into Czech in order to support longer term training needs. Activities in this direction have been led by the Fire and Rescue Service of the Czech Republic within the Ministry of the Interior. Thus, the activities undertaken, and planned beyond the project have impact across all fire departments in the country.

Within the scope of HyResponder a workshop was undertaken with key persons responsible for training from across the country. The attendees were those firefighters who are responsible to set procedures for intervention tactics and education. It is planned that that the attendees will implement HyResponder project outputs into the education system in the Fire Rescue Service of the Czech Republic for all professional and volunteer firefighters, from beginners to incident commanders. A national working group is now in place to support this activity, focused on ensuring the hydrogen training can be embedded and built upon going forward. Longer term the prospect of an operational facility is being considered.

5.4. France

Both ENSOSP and CEA delivered training activities in France. HyResponder training lectures are available in French at both firefighter and specialist level and the EERG is also available in French.

ENSOSP are the French National training lead, and indeed the lead for operational training in hydrogen safety globally. The unique training facility at ENSOSP has been extended within HyResponder and represents a key resource for responders. All trainers from across the countries represented in HyResponder, undertook training at ENSOSP prior to delivery of national training. Whilst that activity is not described in detail here, it was key to the subsequent delivery of national training events. ENSOSP have also provided support within and beyond HyResponder to regions in the development of their own operational facilities. CEA led the delivery of a face-to-face workshop to disseminate the project results and to introduce the training to the local fire service. Three of the operational training modules at ENSOSP are depicted in Fig. 2, specifically a LH₂ like release, and ignited H₂ release and an accidental H₂ release from storage.

The unique facility at ENSOSP represents the state of the art for responder training and is being utilised not just by French groups, but by responders and industry representatives from across Europe. Beyond the HyResponder activities, ENSOSP have continued to utilise the operational platform, through the delivery of longer (5-day training) sessions

and shorter (1-day workshops) in hydrogen safety. For example, in 2023, four hydrogen risk training sessions for French fire services were delivered, with each 5-day course training 15 trainers. From June to December 2023, 46 trainers have been trained and thus, the educational kit has been provided to 26 fire and rescue services. In the same period, 200 technicians and engineers (industrials partnerships) were trained through 1-day training events. It is intended that this activity will be further built upon going forward.

5.5. Germany

Partner Deutsches Zentrum für Luft-und Raumfahrt (DLR) led HyResponder activities in Germany. As noted previously, and utilised in Austria and Switzerland, the HyResponder lectures are available at all levels in the German language. Within HyResponder, an in-person training workshop was delivered in Oldenburg. The workshop was delivered in collaboration between DLR and the professional fire brigade of Oldenburg fire station. The purpose was to communicate proposed reactions to "hydrogen in the case of an emergency" to the German firefighting experts. The workshop incorporated elements of the HyResponder lectures and practical examples of the challenges for rescue workers in dealing with hydrogen. Practical samples like hydrogen refuelling station, a hydrogen bus and car (Fig. 3) and hydrogen labs including CHP unit were demonstrated. Trainings were continued in 2024 It is intended that the training will be built on locally in the Oldenburg region through further train the trainer hydrogen workshops focused on hydrogen safety for firefighters. Furthermore, collaboration between the German speaking HyResponder partners with common support for related training activities across Austria, Germany, and Switzerland.

5.6. Italy

Sapienza University of Rome, supported by the Italian National Fire

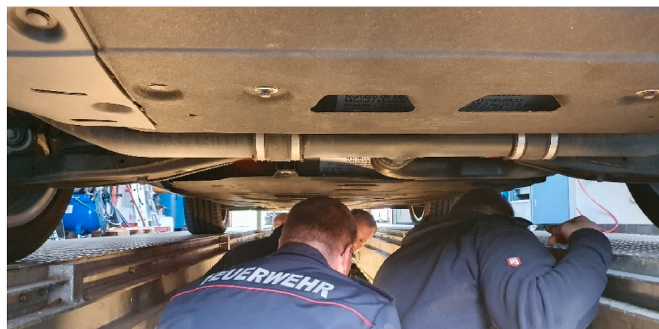


Fig. 3. Training on a hydrogen car in Oldenburg.

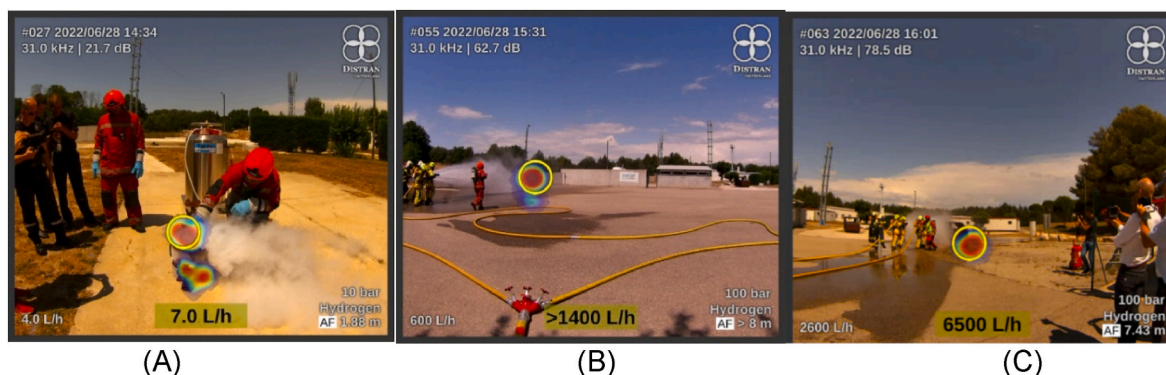


Fig. 2. Three operational training modules: (A) LH₂-like release disposal, (B) ignited H₂ release, (C) release on accidented H₂ storage.

Corps are the training lead in Italy. All levels of HyResponder lectures are available in Italian along with the EERG. In addition to successful delivery of a HyResponder training workshop, a working group is in place along.

Within the scope of HyResponder an in-person training workshop was hosted by the Operational Training School of Montelibretti. This was organized by the National Fire Corps in Italy in collaboration with Sapienza University of Rome as part of a wider event on energy transition and fire safety. There were 85 participants including 60 officers of the National Fire Corps from regions across Italy. In addition to theoretical lectures, utilising the translated HyResponder materials, a small-scale operational facility was used for demonstration.

Since the completion of HyResponder, a further follow up workshop has been organised for 60 officers. A summer school has been organised in collaboration with the National Fire Corps, incorporating HyResponder outputs. And significantly, it is planned that a course on hydrogen safety will be prepared as one of the standard courses offered to the officers by the National Fire Academy in Italy (ISA). To support this a manual is under preparation utilising a selection of the HyResponder lectures and a National Italian working group is in place to ensure delivery of these plans.

5.7. Norway

The University of South Eastern Norway (USN) have been the HyResponder lead in Norway. They successfully delivered a training workshop within HyResponder, and secured National funding to deliver and grow the training in Norway. Lecture materials at firefighter level are available in Norwegian and have been utilised in the delivery of training. From a training delivery perspective, a challenge existed due to the lack of overarching authority to contact all fire departments in Norway. This was also the situation in other partners countries. An initial in-person training workshop was held in in Porsgrunn with 47 attendees. The attendees were mainly from the largest fire departments in Norway, but also from relevant industrial fire brigades. The HyResponder lecture materials and the EERG were introduced, alongside a practical demonstration, and discussion on relevant hydrogen accidents and the lessons learned from them. Beyond HyResponder, the training for responders has been developed further, with longer term plans for 5 online workshops, 13 physical workshops around Norway and a goal to start a training program. The trainers who attended training at ENSOSP within HyResponder are working with USN to develop an operational training facility.

5.8. Spain

The Spanish training was led by the Escuela de Bomberos in Zaragoza, supported by the University of Zaragoza and The Foundation for the Development of New Hydrogen Technologies in Aragon. Lectures at Fire Fighter level are available in Spanish, and a demonstration facility was developed in Zaragoza to support the HyResponder training workshop. An in-person training workshop took place in Zaragoza within HyResponder. Firefighters from across Spain attended, specifically those with training responsibilities. The workshop was over-subscribed with interest exceeding venue capacity. The workshop incorporated a combination of technical presentations and practical demonstrations. A thermal image taken during the Spanish national training is given in Fig. 4.

It was planned during HyResponder that the training would be utilised further going forward with Zaragoza leading this activity in Spain. The fire service at Zaragoza is now well placed as a centre of expertise in hydrogen safety training in Spain. They have will build on this, in collaboration with the University of Zaragoza in terms of training delivery, and support for other fire services. Some examples of the activities already developed are.

- Training of further Spanish fire services and companies in hydrogen safety utilising the installations of the Zaragoza Fire Service.
- Collaborative development of the hydrogen safety module within the course about sustainable energies for vocational training teachers from different Spanish centres (CFIFP Piramide, Huesca, Spain).
- HyResponder outcomes were presented in the *Workshop about New Technologies for Firefighting*, implemented for experts in Health and Safety at Work, organized by ISSLA – Gobierno de Aragón (Zaragoza, Spain).
- Zaragoza Fire Service and University of Zaragoza have collaborated in sessions about hydrogen safety, as part of the Master's Degree on Hydrogen Technologies (<https://www.mondragon.edu/cursos/e/s/master-interuniversitario-tecnologias-hidrogeno>), it is planned to continue this activity going forward.

5.9. Switzerland

The International Fire Academy (IFA) led HyResponder activities in Switzerland. As noted, all lecture materials are available in German at levels from firefighter to specialist. A focus at IFA was in raising awareness of HyResponder throughout Switzerland. A training workshop was delivered within the project as a part of the overall

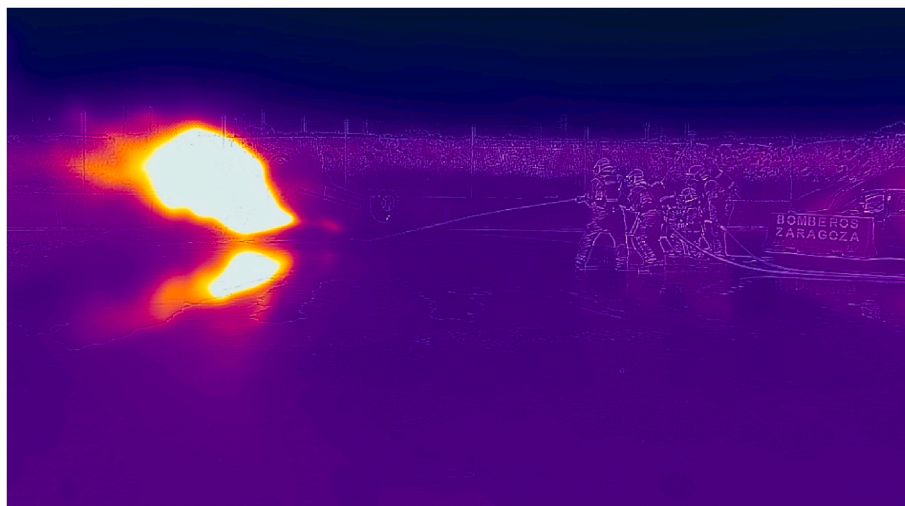


Fig. 4. Thermal image during the Spanish national training.

dissemination activities. Switzerland consists of 26 cantons, each with its own fire service laws. In order to achieve the same level of training throughout the country, the activities of the 26 cantons must be coordinated. This is the mission of the Swiss Fire Service Coordination FSCS. Therefore, the International Fire Academy's primary objective was to inform those responsible for training in the cantons about what the HyResponder project has to offer and initiate a national working group. Interest in the topic of hydrogen was initially low. Therefore, IFA initially focused on raising the risk awareness of those responsible and showing that the risks can be managed. To this end, presentations were given at meetings and congresses of the relevant organisations and bodies, and German language articles [11] were published. As a result of activities, interest in the topic of hydrogen vehicles was raised with experts in expert circles. A national cluster "Hydrogen Working Group" has been formed.

In parallel with the communication work, the hydrogen train-the-trainer course was developed and delivered to 12 participants. The participants were senior instructors from the International Fire Academy. The issues raised during the train the trainer activity have benefited into the National working group. It is intended that a nationally uniform operational doctrine on hydrogen is developed for responders in Switzerland. It has been agreed that training on hydrogen will be integrated into the regular training of the respective command levels. There will be no special courses on hydrogen. This means that all future trained firefighters will be trained on the topic of hydrogen in the course of the regular training. For already trained firefighters, follow-up training, e.g. in the form of webinars, will be offered during a transitional period. It is planned that a hydrogen flame simulator or demonstrator is to be built for the training. It should be noted that a number of open questions remain particularly around tunnel fires and detection methods. An impact of HyResponder in Switzerland is that the topic of hydrogen is dealt with systematically on a national level. Furthermore, it was achieved that the training contents are exactly tailored to the tasks and needs of the fire departments. Furthermore, the responsible authorities now deal intensively with the topic of hydrogen. In the medium term, this will enable fire departments and other emergency services to contribute to the safe use of hydrogen technologies by mitigating hazardous situations and limiting any damage. It is ensured that the topic of hydrogen is dealt with in a sustainable manner and that tactics and techniques are systematically developed further.

5.10. United Kingdom

The United Kingdom was represented in a number of ways within HyResponder. The project was coordinated by Ulster University (UU), plans are now in place to build on the materials developed in HyResponder longer term, specifically through the delivery of modules in a higher education setting. The Fire Service College (FSC) were UK lead in delivering a training workshop, this took the form of an online webinar, which the FSC recorded in order to utilise materials as a digital resource. The webinar focused on the HyResponder training package, the training framework developed by The International Association of Fire and Rescue Services (CTIF), and hydrogen specific considerations. The webinar was supported by UU, CTIF and the National Chemical Emergency Centre in the UK. It is intended that elements of the HyResponder training will be embedded into alternative fuel training activities at the FSC. Additionally in UK the training has been viewed by specialist groups involved in aviation and preliminary activities are commencing to consider the implications of hydrogen in this industry.

5.11. Global

5.11.1. Framework for recognition of firefighter level training

A goal of HyResponder was that the training impacts in each partner country beyond the lifetime of the project and it informs the recognised standard of training for responders in Europe and potentially beyond

[5]. To this end, CTIF led the development of recommendations for a route to ensure the HyResponder training materials can be used to support a recognised training standard.

A HyResponder framework for the recognition of firefighter level training can be freely accessed through CTIF and HyResponder (<https://ctif.org/commissions-and-groups/hyresponder-european-hydrogen-train-trainer-programme-responders>).

The framework is sufficiently flexible to accommodate the range of training arrangements, levels and existing provisions that exist across Europe. This flexibility provides a pathway for widespread adoption. The training programme aligns to the qualification requirements for the European Qualification Framework at Level 2. "Recommendations on the Pan-European Recognition and Continuation of Hydrogen Safety Training for Responders are available through CTIF (<https://ctif.org/commissions-and-groups/hyresponder-european-hydrogen-train-trainer-programme-responders>).

5.11.2. Impact beyond HyResponder regions: Australia

The National Australian Hydrogen Project is in the process of developing a trial training module and the development of the training module has commenced. HyResponder material including lectures and videos is being used to inform this activity.

6. Conclusions

Overall, the reach and impact of the HyResponder training has been significant. Through the HyResponder project, trainers from 10 countries, namely Austria, Belgium, Czech Republic, France, Germany, Italy, Norway, Spain, Switzerland, and the United Kingdom have been trained in hydrogen safety. National contact points with training expertise have been established in each partner region and are amongst the authors of this paper.

Initially 20 trainers undertook the train the trainer programme but they then in turn delivered training within their regions. A flexible approach to training within the HyResponder network has enabled fit for purpose, region appropriate activities to be delivered. Over the course of the project training has been delivered in different formats to over 1250 individuals, with concrete plans in place to extend the reach of the activity to a minimum of over 22,000 responders across Europe by 2028. Awareness of the activities extends beyond this with, e.g. views of the HyResponder webinar in Dutch, which targets responders, exceeding 2500 people.

Training materials in hydrogen safety are freely available in 8 languages English, Czech, Dutch, French, German, Italian, Norwegian, Spanish and these are being used to inform training within each of the partner countries.

Plans are in place in each of the 10 countries to build upon the HyResponder training. Dedicated National Clusters (national working groups), focused on hydrogen safety training for responders have been established in Belgium, the Czech Republic, Italy and Switzerland. Whilst these training plans are not publicly available, they have been developed by the national contact points, and authors of this paper.

Regional and National funding in Spain and Norway respectively enabled the activities in these regions to be extended and small-scale operational training platforms to be developed.

An original training framework for recognition of firefighter level training in hydrogen safety has been established and is supported internationally by CTIF. Plans are in place to develop higher education modules in Belgium and the United Kingdom, and the training resources are being used to support activities outside of Europe in a nationwide programme for responders in Australia.

Further work is needed to ensure the training materials are revised and updated, and differences remain in the application and adaptation of the EERG. There is a clear pathway and need amongst responders for hydrogen safety training going forward.

CRedit authorship contribution statement

Síle Brennan: Writing – review & editing, Writing – original draft, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Christian Brauner:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Dennis Davis:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Natalie De Backer:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Alexander Dyck:** Writing – review & editing, Methodology, Investigation, Formal analysis. **César García-Hernández:** Writing – review & editing, Methodology, Investigation, Formal analysis. **André Vagner Gaathaug:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Petr Kupka:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Laurence Grand-Clement:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Etienne Havret:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Deborah Houssin:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Laurent Lecomte:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Eric Maranne:** Methodology, Investigation, Formal analysis. **Pippa Steele:** Writing – review & editing, Investigation, Formal analysis. **Paola Russo:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Adolfo Pinilla:** Writing – review & editing, Methodology, Investigation. **Gerhard Schoepf:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Tom Van Esbroeck:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Vladimir Molkov:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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