A CHICKEN AND EGG SITUATION: ENHANCING EMERGENCY SERVICE WORKERS' KNOWLEDGE OF HYDROGEN

Ashworth, P.[1], Wade, B.[2] Witt, K.[3] and Elliot Clarke[4]
[1] School of Chemical Engineering, The University of Queensland, Brisbane, 4072, Australia, p.ashworth@uq.edu.au
[2] The Business School, The University of Queensland, Brisbane, 4072, Australia, b.wade@business.uq.edu.au
[3] The Centre for Natural Gas, The University of Queensland, Brisbane, 4072, Australia, k.witt@uq.edu.au
[4] School of Chemical Engineering, The University of Queensland, Brisbane, 4072, Australia, e.clarke@uq.net.au

ABSTRACT

This paper reports on the results of interviews conducted with 21 representatives from emergency services organisations within Australia and New Zealand. With a relative emergent industry such as future fuels, a chicken and egg situation does emerge with regards to how much training needs to be in place in advance of large-scale industry development or not. These respondents were employed in a variety of roles being directly involved in research and training of emerging technologies, frontline operational managers, and other senior roles across the emergency services sector. Participants' responses to a series of questions were able to provide insights into the state of knowledge and training requirements within their organisations in relation to hydrogen and other future fuels. The findings suggest that formal and informal processes currently exist to support the knowledge development and transferal around the adoption of hydrogen and other future fuels. From the interviews it became clear that there are a number of processes that have emerged from the experiences gained through the implementation of rooftop solar PV and battery storage that provide some background context for advancing future fuels information across the sector. Because safety is a critical component for securing a social licence to operate, engagement and knowledge sharing withg any representatives from across this sector will only help to build confidence in the industry. Similarly, because interviewees were very keen to access information, they expressed a clear willingness to learn more through more formalised relationships rather than an ad hoc information seeking that has been employed to date. The presentation will identify key recommendations and also highlight the importance of QR Codes across the emergency responder landscape. Implications for industry and policy makers are discussed.

Keywords: emergency services, safety, QR Codes, knowledge sharing, hydrogen

1.0 INTRODUCTION

A properly trained first responder community is critical to the successful introduction of hydrogen fuel cell applications and their transformation in how we use energy. Providing resources with accurate information and current knowledge is essential to the delivery of effective hydrogen and fuel cell-related first responder training (Barilo, Hamilton & Weiner 2016).

The origin of this study was motivated in a similar vein to the quote above. Emergency service workers of every kind, also referred to as first responders, will arguably be critical for the successful deployment of future fuels in Australia. However, the rapidly expanding interest in hydrogen at the government and industry level, means that a chicken and egg situation is emerging across the emergency services realm. Should the technology's deployment precede the necessary training of the emergency service sector, or is there a need for comprehensive training to be delivered in advance? Either way, the answer to these questions are not black and white - hydrogen is already being produced at industrial scale and Hazardous Materials (HAZMAT) emergency regulations and procedures are already in place for such production. As more and more pilot projects emerge across Australian states and territories, ensuring safety response procedures are in place has become paramount.

This is particularly important in Australia because a large portion of the emergency services sector is comprised of volunteers. The recent 2020 bushfires, floods and other severe weather events clearly demonstrate the significance of all volunteers' contributions to the safety of Australia. Arguably, such a contribution will also apply to the safe implementation of a future fuels industry. Therefore, it is important to understand the essential knowledge requirements for the first responder sector and whether they differ across different responder types. What knowledge they already have and what gaps in knowledge exist, and what is the best way for the sector to access and deliver information to fill those gaps.

To better understand the current state of play of the current knowledge and awareness of future fuels, we undertook ten interviews across various emergency response organisations in Australia and New Zealand. The organisations included Country Fire Services, Fire and Emergency Services, Ambulance, Police, State Emergency Services and representatives from the equivalent fire service in New Zealand. In total 21 individuals were interviewed. Either individually or through a group interview which ranged from 45 - 90 minutes in length. The maximum number of participants in any one interview was 5. Some participants also sent additional information via written emails and this has been incorporated as appropriate. All interviews were audio recorded and subsequently transcribed for analysis. NVivo was used to identify the major themes emerging from the data.

2.0 LITERATURE REVIEW

Understanding and demonstrating safety can be critical factors in the successful deployment of any new technology. Concerns around genetically modified foods, automated and battery electric vehicles are some recent examples where the public's response has impacted the deployment of a technology. Propositions for the more widespread use of hydrogen and other future fuels in common applications (such as for energy, transport and domestic appliances) have also raised questions about potential risks and safety.

While hydrogen is similar to other gases and fuels in that it does have hazardous properties [19], over the past two decades, much work has been dedicated to understanding the risks associated with the production, storage and use of hydrogen and other new fuels [1-2, 9, 13, 15-17, 21, 28-29]. In addition to developing appropriate regulations and safety standards [1, 6, 22, 28], there has been a database of Hydrogen-related Incidents and Accidents Database (HIAD) developed by the European Union (HIAD) which provides a useful reference point for anyone with an interest in the fuel.

San Marchi et al. [22] explain how standards and safety codes that develop with new technologies are often based on knowledge of, and experiences with, similar technologies. In addition, they argue how important it is to not only rely on engineering knowledge but to include the experiences and opinions of experts from related fields in the development of safety standards. It is also important to analyse incidents that have happened to understand what went wrong and what could have been done better and again the European Union has taken the lead on this through their Centre for Hydrogen Safety.

When incidents do happen, emergency services are usually the first on the scene. They need to be able to identify hazards as well as detect any other potential hazards quickly in order to manage them safely and effectively [24]. Therefore, a properly trained emergency response community is critical for the successful introduction of fuels in everyday applications [3].

Bottino [5] reports how emergency services' training has taken on increased importance since the enormity of the 9/11 terrorists attacks. He describes key lessons learned from that pivotal event. In particular, the need for emergency services divisions to work well together and to better communicate and collaborate with industries, governments and the communities in their jurisdictions. In an earlier study, Kapucu [11] also stressed the importance of information sharing and willingness to collaborate in effective emergency management.

Emergency management is generally thought of as consisting of five phases: prevention; preparedness; response; recovery; and evaluation [4]. The prevention and preparedness phases in particular, often involve public engagement activities. Emergency services are playing increasingly prominent roles in raising awareness and educating the public to prevent accidents occurring (e.g. road and fire safety) or how to be prepared should one arise (e.g. flood and bushfire safety). It is well known that risk information is more likely to be adopted and translated into action if it has come from a trusted source [12, 26] and several studies have shown that emergency services personnel, including local volunteers, are highly trusted, particularly during emergency situations (e.g. [4, 25, 27]). Extending the emergency management five phases of response, Perry and Lindell [18] identified three critical components for community emergency preparedness. These include planning, training and written plans, with emphasis on the role of the planning process and the collaborations required.

In relation to deployment of hydrogen and other future fuels at scale, there is a paucity of literature focussed on the information and training needs of emergency service workers despite their critical roles as first responders by facilitating emergency preparedness and public safety, and as trusted risk communicators. This study therefore seeks to understand the perspectives of emergency services personnel and organisations in relation to the more widespread use of future fuels such as hydrogen and identify what gaps in knowledge and information might exist and how best to fill those gaps.

3.0 ABOUT THE ORGANISATION

3.1 Structure

Understanding the way different emergency service organisations are structured is helpful to inform considerations around the information and training requirements of the emergency response sector in Australia in relation to future fuels. A number of key organisations were identified as important and one that was often mentioned was the Australia and New Zealand National Council for Fire and Emergency Services (AFAC) whose core membership consists of emergency services or fire management agencies of a state or territory government in Australia, or any other government agency with emergency management responsibilities. AFAC was seen as integral in coordinating a collaborative and consistent approach across agencies around Australia. Participants mentioned that AFAC concentrates on systematic, system-based improvements which often includes the development of national doctrines that can subsequently be called upon by all fire and emergency services. AFAC were also recognised as being the clearing house for risk protocols.

Within South Australia the fire and emergency service sector is coordinated through the South Australian Fire and Emergency Commission (SAFECOM) and includes the SA Country Fire Service, SA Metropolitan Fire Service and SA State Emergency Service. The SAFECOM Board was said to provide the necessary guidance for all agencies. Other relevant sections and departments that were mentioned and relevant to future fuels included the Built Environment sections, Training and Development departments (although these were not always regarded as the first information providers on new and emerging technologies) and Research and Scientific branches. More details on the roles and responsibilities of the organisations are documented below.

3.2 Roles and Responsibilities

Participants reported being in a variety of roles across the emergency services landscape and detailed a range of responsibilities that fall within their remit that are relevant to future fuels. The majority of the roles fell under various permutations of the following: Senior Scientific and Environmental officers; Research and scientific branches; Fire investigators; Built Environment sections; Executive Managers; Technical Operations Managers; Doctrine officers; Risk Managers; Preparedness Operations; Emergency Management Coordinators; Commander, and Training and Development departments.

In addition to the key roles and associated responsibilities outlined above, there were a number of other responsibilities that arose from the interviews. These may have not been attached to a specific role but

were deemed important and provide greater context around the overall operations of emergency services across Australia (and New Zealand) and their relevance to planning for future fuels integration.

Some mentioned how the Act under which they operate, requires them as the lead agency for hazardous materials and fires to be prepared from a safety point of view. Other regulatory requirements included a role in the built environment and representation on standards committees as part of AFAC.

> *It requires to pre-plan, respond to, recover from, understand current hazards, future hazards and what that actually means to us, to ensure we meet the needs of our community from that point of view INT10*

A large portion of the participants additionally mentioned their responsibility in relation to risk management and providing the necessary information that would help their associated agencies to manage risks. This included how to manage hazardous materials and emergencies. Most acknowledged that future fuels would be part of this.

Importantly, research was an integral part of the fact finding to ensure all of the hazard profiles were well understood. This included mention of a number of systems and processes in place, including a number of modelling programs that helped them to ensure they could respond with the required information. There was also acknowledgement that across many of the agencies exist thousands of volunteers who undertake many roles including preparedness and prevention work across their communities.

> *Obviously, as a fire service, we're interested in where the rubber hits the road and how that's going to affect communities and the risks that any new emerging technology places on us as a fire service and how we respond to that, should there be an incident. INT05 a-e*

Prevention and education were also seen to be critical. This included public education and communication and engagement programs which target those most at risk of fire. According to participants, home fires are known to be where most fire fatalities occur. Similarly, it was reported that a commercial training arm exists that delivers emergency response training into the commercial market.

4.0 THE SECTOR AND FUTURE FUELS

4.1 Knowledge and Awareness of Future Fuels

> *One of the main issues with the initial planning of the hydrogen facilities was that the developers and regulators had no idea what emergency services needed, i.e. access-wise, fire safety-wise. INT01*

Across the interviews, participants had varying degrees of knowledge about future fuels. However, consistently, hydrogen was more likely to be referred to and discussed than biogas. It was clear that knowledge of the topic was influenced by a number of factors which included whether the participants were aware of, or had been involved in, the establishment of a hydrogen demonstration project in their area; their background degrees and experience; their length of time in the sector and therefore had already worked with hydrogen as a HAZMAT gas and their current position in the organisation. It was also suggested that most responders that were situated outside urban areas would be more likely to have limited knowledge on the topic.

> *I think often, my experience with the fire services in SA and Victoria, and I guess this extends across the board, we are often the last people to find out about some of these things that are happening. And so, we've become very reactive in developing training and capabilities and doctrines to meet something that already exists. INT 04a-d*

Regardless of their knowledge and awareness of future fuels, all participants were extremely grateful to have been contacted by the research team on this topic. They expressed hope that the interaction with

the FFCRC and potential links to early research findings would continue past this initial project. For all participants, having access to accurate and timely information on this topic was seen to be essential for maintaining the safe working environment of their workers.

> *Well, first of all, I mean, finding out whether – like this, we found out because you've contacted us with this sort of research, and as I said, that was the first I became aware you've got hydrogen-powered vehicles out there. So now you're stuck – like where do you get that information from now? INT03a-b*

Exacerbating this need for knowledge were the challenges surrounding the rapidly changing pace of the industry. One participant suggested that what seemed like 'pie in the sky' discussions only a year ago, to now seeing vehicles on the ground and potential projects being deployed. This was felt to be further complicated by a lack of understanding of emergency service organisations' needs.

Increasing concerns around this topic were based on some of the challenges that had been experienced, and were continuing to be experienced, around the early and rapid introduction of batteries and battery electric vehicles. Several participants highlighted how the lack of early and consistent standards with the implementation of home battery storage across Australia had caused real safety concerns for some working in the emergency services sector. A "learning from experience" approach had been adopted whereby the different organisations, both within and across states and territories, had established knowledge dissemination networks to increase visibility of accidents and the learnings that arose from each of them.

One innovation that has emerged with electric vehicles was the use of QR-Codes that manufacturers had developed. A participant reported that QR-Code stickers are placed in five different positions around the vehicles. Scanning these codes links responders to all of the necessary safety information required for responding at the scene of an accident. It was hoped that a similar approach would be adopted for hydrogen vehicles. There is also a licence plate regimen where electric vehicles and hydrogen vehicles require a sticker on the number plate to also help with identification to differentiate them from an internal combustion engine.

> *I mean, from my perspective – as far as fire and rescue, what make, and model vehicles are out there that are on hydrogen power? I wouldn't have a clue. Whether that's common knowledge or it's – it's all new to me. What with this – now meeting you and then receiving this email about it, yeah. INT03ab*

There was mention of the new Tonsley production plant that was being established in South Australia. Some participants had been involved in assisting with the emergency response plans, ensuring it was compliant with existing regulations. The mere fact that the project came on the radar had prompted some to learn more about what is happening in this space. It was also mentioned they were given an opportunity to tour to site which helped them better understand what was planned. Generally, a positive working relationship had emerged as a result.

4.2 Challenges and Concerns Around Future Fuels

> *We don't see things at their best. We unfortunately – we come across things when they're at their absolute worst and where the blueprints and the paper and the tolerances designed into things and the failure points. We kind of see them when these are actual real risks that we're emerging with. INT04*

Participants expressed concerns around obtaining the information necessary to develop a clear understanding of the fuel parameters. This included direct safety aspects of the different fuels. For example, physical impacts on skin, eyes and breathing, and around the way different fuels and associated technologies react in different situations. The time critical nature of responses to different fuels and technology types, with risk levels dependent on the response times, were discussed in terms of the implications for respondent safety at different locations. This was particularly exacerbated if it

was in regional or remote areas of Australia compared to metropolitan where response times could be much greater over longer distances.

Several participants highlighted the necessity of considering emergency service requirements in the development and introduction of hydrogen. This requirement was seen to extend beyond the production of new standards to the development of new hydrogen facilities, starting from the trial phase. One emergency service respondent observed that consultation in the development of future ISO standards would assist with avoiding inconsistencies with existing legislation and obligations. Challenges were also perceived to exist with standards keeping pace with the current rapid pace of technological change and community adoption of new energy.

> *...one of the main issues with the initial planning of the hydrogen facilities was that the developers and regulators had no idea what emergency services needed, i.e. access-wise, fire safety-wise. INT01*

System challenges were highlighted to exist within and between emergency services. Although not necessarily directly related to future fuels these system challenges have the potential to impact the ability of emergency services to respond. One that was raised by respondents is the lack of integration between systems of different states which extend to both rules and equipment.

5.0 TRAINING EMERGENCY SERVICES WORKERS

5.1 General Requirements for Training

Across the interviews there was a uniform acceptance of the need for training to be developed associated with the increasing use of future fuels. It was stressed however, that any training needs to be developed, based on the knowledge and clarity of the technical parameters of any future fuel. This included the identification of potential issues and interactions that may result within different structures (e.g. pipes and steel), events and the systems in which they are used. It was felt that training content will also require consistency between the different emergency service providers, such as police, ambulance and fire services. However, it was noted that each organisation may require different levels of knowledge about the related topics. The nature of emergency service work means that training sessions need to differentiate between the need for routine knowledge and developing the art of dealing with issues on occasions where they are not controlled, particularly in relation to safety for both responders and community.

> *There's a difference between routine knowledge. It's an art for many people to deal with their stuff when it's no longer under control. Which is what our specialty is. INT10*

Participants expressed different training needs depending on the operations of a centre, the individuals who are involved, as well as the various levels of capabilities in different jurisdictions. Some programs may be more advanced than others. It was identified that as the uptake of future fuels increases, there will be a need for more routine training on hydrogen. Training was reported to take place using a range of mediums including face to face, video and other multimedia or a combination of delivery options using a blended learning approach. In line with other education components, the impacts of COVID-19 had forced organisations to a much more online delivery mode. Participants stressed that consideration needs to be given to how any new knowledge can be integrated into existing programs. It was also discussed that purpose built training will always be developed on a needs' basis which is consistent with past introductions of new fuel or technology types.

Additionally, emergency service workers reported the need to adapt to new technologies and fuel types in the past and saw the growing adoption of future fuels as an extension of this work. Many interviewees spoke about the way they met the challenges of electric vehicles batteries and LNG in vehicles as examples of past adoptions. With future fuel use posing a new challenge to emergency service

personnel, training requirements will need to adapt in line with changes in market proliferation and practice knowledge.

5.2 Knowledge Required

The types of information and examples of specific knowledge required by emergency service personnel to safely deal with a situation featured prominently in the responses of many interviewees. An insightful view was provided by one respondent who felt it was important to achieve the correct overarching principles before building the training as training on incorrect principles or "doctrine" and without the correct capabilities is "training people to fail".

Interviewees also identified that the development of the training was an iterative process to make sure all points needed are covered through a model of continuous improvement. In developing training on future fuels, respondents felt that knowledge of the systems where the future fuels will be used, was critical to ensuring emergency service staff have the knowledge to enable them to step in in the case of an emergency.

> *From an emergency point of view, what sort of system are you actually using? How do we know it's maintained? Fit-for-purpose, and I don't mean from your point of view, because that's not my risk to my own, but from our perspective, when it goes wrong, we need to know what sort of system you have, how it's managed, how can we – so how's it de-energised? Int10*

Industry trials of new technology were seen to offer an opportunity to develop information for emergency service responses. There is the understanding that just because something is new it does not necessarily mean a significant deviation in system management. Existing responses may be sufficient even with new fuel types however trials and research are required to establish where change is or is not required.

Finally, national and international knowledge was found to be gathered and contextualised to make sense and stay relevant to Australian conditions. Key topic areas include de-energising issues, products/biproducts generated through use of hydrogen and their impact and management, management issues in critical incidents such as road crashes and associated technical issues.

5.3 Sources of Information

> *At the moment, we're getting our heads around PV arrays, energy battery storage systems, residential storage systems, commercial storage systems and wind farms which is hitting us pretty hard. And now with hydrogen coming on board, that's another world for us. We are limited, to be honest with you, are limited in that information. INT06*

The emergency service personnel interviewed through this research not only highlighted their need for information but also demonstrated their ability to seek this information through both formal and informal networks - internal and external to their organisation. As well as to draw on past experiences to resolve new challenges. Interviewee's mentioned emergency information sought through various Australian supporting emergency organisations such as AFAC and other local state and territory organisations.

Participants also reported that technical information was often sourced from overseas studies and research literature. For example, participants remarked that hydrogen was more established in the United States of America, Europe and the United Kingdom and studies from these countries provided quality sources of information. The Netherlands was also mentioned as a useful example for advancement in transport technologies, although this was mainly linked to electric vehicle use.

> *So you know, as this sort of alternate energy and I was just reading with great interest that California rolled out hydrogen refuelling sites, around 43 different existing petrol stations, you know, just in California alone. INT4a-d*

There was a notable absence of general information about future fuels and that much of the information seeking initially was motivated by the interests of individuals within organisations rather than direct engagement from regulatory and policy bodies.

5.3.1 Internal information networks and resources

Elucidating the process by which first responders develop and utilise information networks, interviewees described their formal and informal sources of information. Internally the emergency services have established repositories of information relevant to their operations, procedures, and technology systems to facilitate information access.

There was a recognition that the information on theory and practice examples were critical but the importance of an applied overlay of knowledge was also stressed that could be understood as "meeting in the middle". This meeting in the "middle" produces formal procedures or doctrines that clarify processes in certain types of events, while technological dashboards make information available from vehicles.

Informal processes for sourcing and sharing information were also a recurring theme within the data collected. Sharing of information, training guides and resources through informal internal networks were reported to generate assurance for interviewees. Informal networks were observed to exist due to the collaborative nature within the services and the varied backgrounds of their volunteer team.

> *...having a good black book. So, if I need to know something about a particular industrial process to a degree that's much deeper than normal, there's a fair chance that one of our volunteers actually works for one of those processes, so we can have that conversation. And it's a quid pro quo. INT10*

An array of backgrounds and skill sets were reported to exist within the emergency services from engineers to lawyers to management consultants to industrial designers. This diversity of backgrounds provides the services with the ability to source and interpret information in a way to synthesise and plan for new complex situations. Again, this knowledge set can also come from volunteers who make themselves available to provide advice in specific situations.

5.2.2 External information networks and resources

Participants highlighted a range of external sources of information and resources that some of them had sought out. This included conferences, government liaison points as well as a plethora of online webinars that had emerged as a formal communication tool as a result of COVID-19: "Smart Energy webinars that were based around the focus of hydrogen" - INT05.

The manufacturers of new technologies were also mentioned by interviewees as sources of information, as outlined earlier in this report, with government bodies playing a role in the proliferation of this knowledge. Respondents outlined that formalised in addition to less formal relationships have been established between their services and many government agencies. These relationships facilitated the sharing of information that was discussed over the course of many of the interviews.

> *... they sort of take on board what we're doing and if it's relevant to their operation, then they certainly are involved. But I have made the key point with XXX (department) and we've had the opportunity to speak to one of the XXX organisations in New Zealand and they're just waiting for our EV training module to be complete, and then they're quite interested in it. Because we want to – we obviously work with them on the ground, hand in hand, at quite a number of jobs. And so we want to ensure that they are both protected when we are not around, but also understand what we're doing when we do arrive, and what we need to do. INT09*

Further, one interviewee described how the services alternative energy doctrine group worked hard to get the Australian Energy Market Operator onboard to collaborate with them. As a result, they are now

negotiating access to a database of information from every state and territory's regulator about installation of PV panels and storage batteries. There were a number of legal processes to progress through, however this type of information was seen to be critical for ensuring safe responses could be conducted when responding to household events.

Lastly, delays in information sharing and emergency service departments sometimes "being the last to hear about what is happening" with solar installations, battery storage and battery electric vehicles was a common theme that emerged through the interviews. These delays were something participants hoped could be avoided in relation to future fuels. Particularly, based on this early contact with the FFCRC through this interview process.

6.0 SYSTEMS PROCESSES FOR TRAINING AND INFORMATION SHARING

Providing adaptive training systems which capture experiences from individuals and plants as they come online will be important. Training in an emerging fuel type used with new technology has the potential to lead to unforeseeable situations. It is therefore important that there is an avenue to capture these challenges and adapt training systems to address knowledge deficits quickly. Participants reported a range of technology available for training at some sites that is quite progressive, with the potential to create videos via a recording booth and green screen as well as develop online situations and training modules. Technology to deliver technical information to emergency service crews is also rapidly progressing with the planned introduction of electronic manuals being available in trucks to provide guidance on specific situations. There is also a hydrogen training vehicle available for training purposes which one respondent was seeking access to.

The need for information on the fuel type and associated technology as well as the sites of installation were specifically recognised by many of the interviewees. Different methods of collecting and providing information are currently accessed and utilised by the emergency services. Operational sites need to produce an emergency plan reviewed by emergency services to ensure emergency services have all the information they require should they need to attend an emergency. Electric vehicle manufacturers are utilising stickers or web registries to flag their vehicles to emergency service personnel. There are also overlays on the mobile data terminals of emergency services for solar arrays where first responding fire trucks can identify if and where an array is on the premises in question. An electric motorbike manufacturer is also putting QR codes on their items which can provide information to frontline workers facilitating the knowledge of how to make a situation safe.

> *"QR codes are ideal for that because it's instant information and it's up to date, and we can get it, bingo, two pages, that's what we want to see, how to isolate that, how to make it safe. It's that simple … It can be applied all across the industry. INT05*

Equipment such as gas detectors, visual imaging cameras and sensors are all in existence, and interviewees identified the need to extend their use to hydrogen rather than add new sets of equipment to the emergency rescue caches. However, there are known issues of cross-sensitivity between hydrogen and carbon monoxide (CO) detectors. For example, existing CO detectors could alarm in the presence of hydrogen and give a misleading impression to emergency responders that they are dealing with a toxic CO release instead of a flammable hydrogen release.

> *So all our – throughout the state - our stations have a risk plan and try to identify hazards within that – whether it's a hospital or a chemical plant or that sort of thing. I'm sure hydrogen would probably fall under that, because then also like part of this role in this office with XX is looking at our fleet profile. INT3a-b*

While there was positivity expressed in relation to the informal sharing of information across the different services, when it came to formal processes, it was clear that sometimes information may get stuck at higher levels of organisations. Particularly when it was a new and emergent technology. This

was also exacerbated by having a large volunteer workforce that meant there was a need to balance the formal training and information process flows. However, it was recognised that an important component of information sharing was to collate and circulate widely to the different areas and regions.

7.0 CONCLUSIONS

It is clear this engagement with representatives from across the emergency services sector was timely. All participants welcomed engagement through the interview process and expressed a willingness to continue to engage with the FFCRC. Participants expressed hope at being able to gain access to the latest research and technical information in a timely manner, as well as to explore opportunities for potential joint research and ongoing collaboration. Their involvement in the process will also be important to ensure adequate safety precautions are in place as the industry evolves to provide confidence to potential host communities.

While many who had responsibility for new technologies within their organisation had already begun undertaking research on this topic, they expressed definite information needs and raised specific questions in relation to hydrogen. Answers to these types of questions about the specific fuel types, their properties and the associated technologies will help to put in place the appropriate risk management processes to avert the chance of potential emergency situations. To enable this, it was acknowledged that emergency service workers need to be included in the discussions around the development and regulation of a future fuels/hydrogen industry. This included the development of standards and procedures to be used at trial sites, including the development of emergency site response plans.

What is also clear is that through the goodwill of the organisations and their workers (both paid and volunteer), there is a strong collaborative network that exists. This not only transcends across the different types of response organisations within a state and territory, but also across jurisdictions in Australia and even internationally. Given that there is a growing international hydrogen industry, there is merit in ensuring a coordinated approach to knowledge sharing across the emergency services sector. The HyResponse Project from Europe, provides a good starting place for sharing of training materials.

From the interviews it was clear that emergency service workers are used to dealing with new technologies and fuel types, and they take a proactive approach in seeking out required information based on their roles and responsibilities within their organisation and the sector. This was clearly evidenced through the introduction of electric vehicles and home battery storage units. These examples provide useful experiences for contextualising the potential challenges and disruption that may emerge through the introduction of future fuels.

ACKNOWLEDGEMENTS

This work was funded by the Future Fuels CRC, supported through the Australian Government's Cooperative Research Centres Program. We gratefully acknowledge the case and in-kind support from all our research, government and industry participants.

REFERENCES

1. Aprea J.L. 2008. New standard on safety for hydrogen systems: keys for understanding and use. International Journal of Hydrogen Energy, 33:3526-3530.

2. Ball M. and Wietschel M. 2009. The future of hydrogen – opportunities and challenges. International Journal of Hydrogen Energy, 349:615-627.

3. Barilo N.F., Hamilton, J.J. & Weiner, S.C. 2016. First responder training: Supporting commercialization of hydrogen and fuel cell technologies. International Journal of Hydrogen Energy, 1-6.

4. Boin A. & McConnell A. 2007. Preparing for critical infrastructure breakdowns: The limits of crisis management and the need for resilience. Journal of Contingencies and Crisis Management, 15(1):50–59.

5. Bottino B. 2019. Large-scale incident safety for first responders, Emergency management and response have changed since 9/11, Safety and Health Magazine, August 25. https://www.safetyandhealthmagazine.com/articles/18761-large-scale-incident-safety-for-first-responders

6. Buttner W.J., Post M.B., Burgess R., Rivkin C. 2011. An overview of hydrogen safety sensors and requirements. International Journal of Hydrogen Energy, 36:2462-2470.

7. Cairns J. 2010. North American and international hydrogen/fuel cell standards. Int J Hydrogen Energy, 35:2767-2771.

8. DeLuchi M.A. 1989. Hydrogen vehicles: an evaluation of fuel storage, performance, safety, environmental impacts, and cost. International Journal of Hydrogen Energy, 14:81-130.

9. Duijm N.J. and Markert F. 2009. Safety-barrier diagrams as a tool for modeling safety of hydrogen applications. Int J Hydrogen Energy, 34:5862-5868.

10. Gupta R.B. 2008. Hydrogen fuel-production, transport, and storage (1st ed.), Boca Raton-Taylor and Francis Group, New York.

11. Kapucu N. 2006. Interagency communication networks during emergencies. The American Review of Public Administration, 36(2):207–225.

12. Kasperson R.E., Renn O., Slovic P., Brown H.S., Emel J., Goble R., Kasperson J.X. & Ratick S. 1988. The social amplification of risk: a conceptual framework. Risk Analysis, 8(2):177–187.

13. Kim J. and Moon I. 2008. Strategic design of hydrogen infrastructure considering cost and safety using multi-objective optimization. International Journal of Hydrogen Energy, 33:5887-5896.

14. Kim J., Lee Y. and Moon I. 2011. An index-based risk assessment model for hydrogen infrastructure. International Journal of Hydrogen Energy, 36: 6387-6398.

15. Mirza N.R., Degenkolbe S., Witt W. 2011. Analysis of hydrogen incidents to support risk assessment. International Journal of Hydrogen Energy, 36:2068-2077.

16. Najjar, Y.S.H. 2013. Hydrogen safety: The road toward green technology. International Journal of Hydrogen Energy 38(25):10716-10728.

17. Noguchi H., Omachi T., Seya H. and M. Fuse. 2020. A GIS-based risk assessment of hydrogen transport: Case study in Yokohama City. International Journal of Hydrogen Energy, 46(23):12420-12428.

18. Pasman H.J. 2011. Challenges to improve confidence level of risk assessment of hydrogen technologies. International Journal of Hydrogen Energy, 36:2407-2413.

19. Perry W.R and Lindell M.K. 2003. Preparedness for Emergency Response: Guidelines for the Emergency Planning Process. Disasters, 27(4):336–350.

20. Reider R., and Edeskuty F. J. 1979. Hydrogen safety problems. International Journal of Hydrogen Energy, 4(1):41-45.

21. Rigas F. Sklavounos S. 2005. Evaluation of hazards associated with hydrogen storage facilities. International Journal of Hydrogen Energy, 30:1501-1508

22. San Marchi C., Hecht E.S., Ekoto I.W., Groth K.M., LaFleur C., Somerday B., Mukundan R., Rockward T., Keller J. and C. W. James. 2017. Overview of the DOE hydrogen safety, codes and standards program, part 3: Advances in research and development to enhance the scientific basis for hydrogen regulations, codes and standards. International Journal of Hydrogen Energy 42(11):7263-7274.

23. Schroll, C. 2006. First responder safety, Industrial Safety and Hygiene News, November 1. https://www.ishn.com/articles/86571-first-responder-safety

24. Seebauer S. and Babcicky P. 2018. Trust and the communication of flood risks: comparing the roles of local governments, volunteers in emergency services, and neighbours. J Flood Risk Management, 11:305-316.

25. Slovic P. 1993. Perceived risk, trust, and democracy. Risk Analysis, 13(6):675–682.

26. Taylor M., W. Joung, B. Griffin, D. Hill, R. Chisari, B. Hesketh, and B. Raphael 2011. The public and a radiological or nuclear emergency event: threat perception, preparedness, and anticipated response. The Australian Journal of Emergency Management, 26(1): 31-39.

27. Weiner S.C., Fassbender L.L. and Quick K.A. 2011. Using hydrogen safety best practices and learning from safety events. Int J Hydrogen Energy, 36: 2729-2735

28. Winter C.J. 2006. Energy policy is technology politics—the hydrogen energy case (with an eye particularly on safety comparison of hydrogen energy to current fuels.) International Journal of Hydrogen Energy, 31: 1623-1631

29. Zarei E., Khan F. and Yazdi M. 2020. A dynamic risk model to analyze hydrogen infrastructure. International Journal of Hydrogen Energy, 46: 4626, 4643.