# 17th ANNUAL MDEC CONFERENCE

*Hydrogen Mine Introduction Initiative –*
*Relevant Codes, Standards and Experience*
Toronto, October 6, 2011

**OUTLINE**

- **Introduction**
- **Relevant Experience**
- **Relevant Regulations and Standards:**
  - ✓ **Relevant Codes & Standards**
  - ✓ **Regulatory Review for Aboveground Mining Activities**
  - ✓ **Regulatory Review for Underground Mining Activities**
- **Summary / Conclusions / Recommendations**

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## Hydrogen: Changing Perspective

**"…This discovery begins a new era in the history of civilization. Never in history has society been confronted with power so full of potential danger and at the same so full of promise for the future of man and for peace of the world…"**

**"…The dangers are obvious. Stores of [this fuel]…would constitute a fire and explosive hazard of the first rank…"**

**"…Furthermore, the cost of producing it is beyond the financial capacity of private industry, yet the safety of the nation demands that an adequate supply should be produced…"**

**"…the discovery with which we are dealing involves forces of nature too dangerous to fit into our usual concepts…"**

**From the summary of the *Report of the Congressional Horseless Carriage Committee* "What's Gasoline", 1875.**

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## HMII Outline

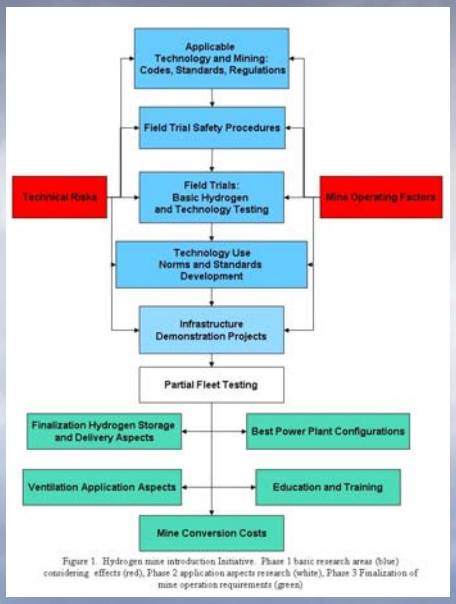
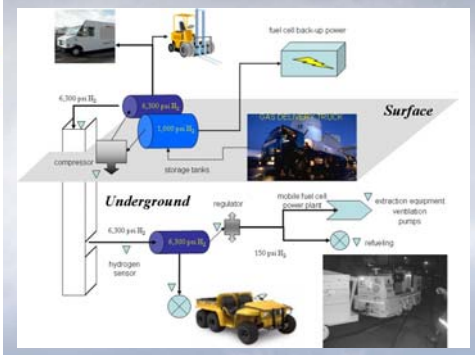



Figure 1. Hydrogen mine introduction Initiative. Phase 1 basic research areas (blue) considering effects (red), Phase 2 application aspects research (white), Phase 3 Finalization of mine operation requirements (green)






## General Approach to Task 1

- **Key objective is to:**
  - ✓ **Identify gaps in the mining regulations in relation to the use hydrogen**
  - ✓ **Identify the impediments in the mining regulations to the use of hydrogen**
- **Findings:**
  - ✓ **Currently the provincial mining regulations do not cover the use of hydrogen**
  - ✓ **Existing generic hydrogen C&S may be used to close this gap, while the relevant experience can be used to overcome impediments**
- **Approach:**
  - ✓ **Cross-reference major requirements of CHIC with provincial mining regulations (e.g. Nova Scotia, Ontario and Québec)**
  - ✓ **Identify specific requirements of mining regulations that would influence and shape any future application for use of hydrogen technologies**
  - ✓ **Review relevant experience**

## Safety and Risk

- **Definitions:**
  - ✓ **Safety is freedom from unacceptable risk (ISO/IEC Guide 51:1999)**
    - ➢ ***There is no zero risk or absolute safety***
  - ✓ **Risk *(acceptance)* criteria – terms of reference by which the significance of risk is assessed (ISO / IEC Guide 73: 2002)**
  - **Limbo Dancing (courtesy of Les Shirvill, Shell Global Solutions):**

**Set the bar (acceptance criteria) first and then quantify the risks (QRA).**

**If the quantified risks don't get you below the bar, don't bend over backwards (fiddle the inputs to the QRA) to get beneath the bar! That's Limbo Dancing!**

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## Anticipated Outcome / Perceived Safety
*Realistic Perspective*


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Courtesy of Thomas Jordan, FZK

## Anticipated Outcome / Perceived Safety
*Overconfident Perspective*

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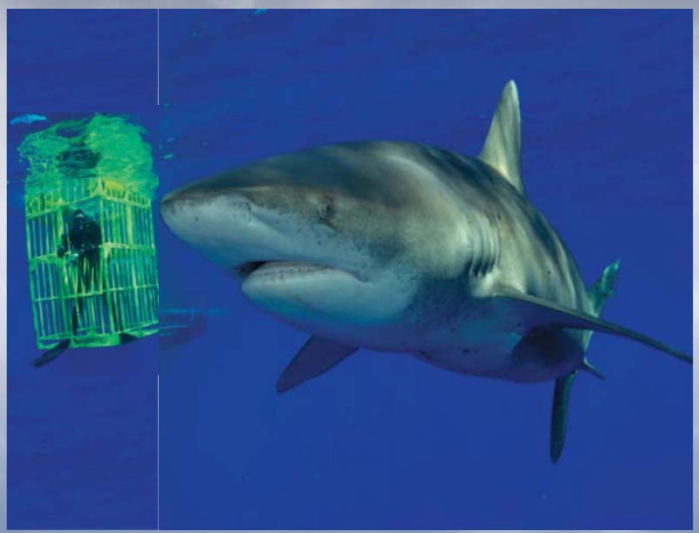
## Anticipated Outcome / Perceived Safety
*Overconservative Perspective*



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## Big Picture

- **Relevant Experience:**
  - ✓ There are about 210 hydrogen refueling stations in the world to date (including 90 stations in the USA and 10 in Canada) with about 70 in the works (including 31 stations in the USA and 4 in Canada). Source: http://www.fuelcells.org/info/charts/h2fuelingstations.pdf
  - ✓ Well developed codes & standards foundation for installation and approval of hydrogen and FC equipment exits in selected world jurisdictions:
    - Canada – Canadian Hydrogen Installation Code (CHIC);
    - USA – NFPA 52, NFPA 55, ICC IFC
    - Japan – High Pressure Gas Safety Law
    - Europe – ATEX, PED / TPED, etc.
    - International – ISO TC 197 (incl. with TC 22, TC 58, TC 220) documents, IEC TC 31 documents on hazardous areas, sensors

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## Relevant Experience

- Refueling infrastructure:
  - ✓ 90 stations in USA and 10 in Canada
- Transportation:
  - ✓ Bus fleets (20 buses in Whistler 2010)
  - ✓ Cars (300 + in North America)
  - ✓ Pickups
  - ✓ Baggage tractors
- Materials handling – forklifts (incl. Indoor operation and refueling)
- Backup power and UPS (incl. Indoor hydrogen generation and storage)
- FCP Locomotive project and demonstration at Val d'Or mine

**Bottom line:** THERE IS A LOT OF EXPERIENCE WITH PLACEMENT OF HYDROGEN AND FC APPLICATIONS AROUND THE WORLD

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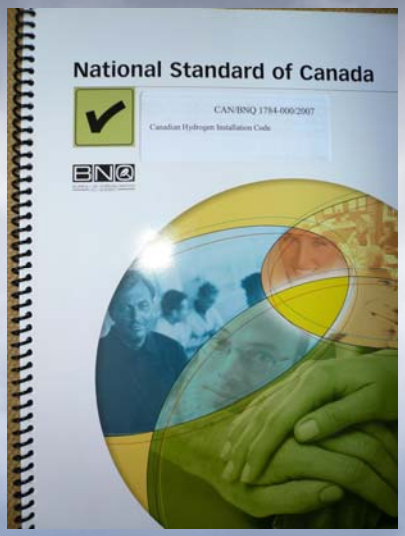
## CHIC vs Mining Regs




**Underground Mining Regulations**
**made under Section 82 of the**
***Occupational Health and Safety Act***
**S.N.S. 1996, c. 7**
**O.I.C. 2008-306 (June 3, 2008, effective August 1, 2008), N.S. Reg. 296/2008**

**Table of Contents**

- **Note: CHIC is formally adopted into provincial legislation in Ontario, Saskatchewan, Newfoundland and Labrador and New Brunswick**
- **Other Canadian provinces are at various stages of adoption process**

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## CHIC vs Mining Regs: Main Titles

**Canadian Hydrogen Installation Code (CHIC), 2007**

- Purpose & Scope
- Normative References
- Definitions
- General Requirements
- Equipment
- Electrical Requirements
- Gaseous Hydrogen Installations
- Liquid Hydrogen Installations
- Residential Installations
- Portable Equipment

**Nova Scotia Underground Mining Regulations, electronic version 2009**

- Interpretation & Application
- General Safety Requirements and Work Procedures. Job Training.
- Electrical and Mechanical Work
- Ventilation. Monitoring Flammable Gas.
- Mechanical Equipment and Travelways
- Fire Prevention and Dust Explosion Prevention
- Emergency Preparedness and Mine Rescue

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## CHIC vs Mining Regs: Criticality Analysis

| Canadian Hydrogen Installation Code (CHIC), 2007 | Nova Scotia U/G Mining Regulations, electronic version 2009 |
|---|---|
| Purpose & Scope | Interpretation & Application |
| Normative References | General Safety Requirements and Work Procedures. Job Training. |
| Definitions | Electrical and Mechanical Work |
| General Requirements | Ventilation. Monitoring Flammable Gas. |
| Equipment | Mechanical Equipment and Travelways |
| Electrical Requirements | Fire Prevention and Dust Explosion Prevention |
| Gaseous Hydrogen Installations | Emergency Preparedness and Mine Rescue |
| Liquid Hydrogen Installations | |
| Residential Installations | |
| Portable Equipment | |

Colour coding:

| | |
|---|---|
| red | critical |
| orange | important |
| yellow | relevant |
| white | not relevant |

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## CHIC Review (example)

**General Note: CHIC requirements are fully applicable to mining operations, both above and underground.**

**Example: Electrical Requirements – Chapter 6:**

- **Area classification – General (6.2.1)**
  - ✓ **Area classification shall be determined using the requirements of IEC 60079-10.**
    - ➢ **Note: not applicable to mines susceptible to firedamp (gassy mines) but fully applicable to hard-rock mines**
- **Use of uncertified nonsparking electrical equipment (6.2.3)**
  - ✓ **Uncertified nonsparking electrical equipment may be used in a Class 1, Zone 2 area provided it is interlocked with a hydrogen detector such that the uncertified equipment along with the associated hydrogen process is de-energized upon a hydrogen concentration reaching 25% of LFL. This system shall be subject to approval by the authority having jurisdiction.**

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## CHIC Review (example)

**Example: Gaseous Hydrogen Installations (Chapter 7):**

- **Hydrogen detection systems (7.12.3):**
  - ✓ **A hydrogen detection system must be provided for single storage systems with a capacity of 1 kg or more of gaseous hydrogen, or for multiple storage systems, each having a total hydrogen content of less than 1 kg but located less than 1.5 m from each other (7.12.3.1).**
    - ➢ **Note 1: In case of on-site hydrogen production, if two electrolyser containers are installed inside a bigger room (each with its own ventilation outdoors), no hydrogen detection in this room is required PROVIDED the containers are more than 1.5 m apart.**
    - ➢ **Note 2: No hydrogen detection system is required if the amount of gaseous hydrogen at any given time inside the container is kept to below 1 kg.**

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## IEC 60079-10 Review (example)

**General Note: IEC 60079-10 requirements are fully applicable to all above ground mining operations and to hard-rock underground mining.**

**Calculations to determine the degree of ventilation:**

- **Example: State-of-the-art electrolyser operating at 10 bara**
  - ✓ **Option 1 leak (from 0.1 mm orifice): 4.70E-06 kg/s**
  - ✓ **Option 2 leak (from 0.2 mm orifice): 1.88E-05 kg/s**
- **The calculations as per IEC 60079-10 show that the minimum air flow required to maintain 25% LFL concentration within the container at Option 1 flow rate is 0.006 $m^3$/s and for Option 2 – 0.024 $m^3$/s.**
  - ✓ **Based on these calculations a proper exhaust fan may be selected.**
- **For secondary releases, i.e. 50% LFL, the minimum air flows will be reduced by the factor of 2.**

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## Recommended C&S for $H_2$ Powered Vehicles

**Vehicles that might be used in mining environment:**

- **Forklift (RC and ICE):**
  - ✓ CSA B335 Safety Standard for Lift Trucks
  - ✓ UL2267 Standard for Fuel Cell Power Systems for Installation in Industrial Electric Trucks
- **Pick-up or Delivery Truck (FC and ICE):**
  - ✓ CSA B109 Natural Gas for Vehicles Installation Code
  - ✓ NFPA52, Chapter 7 Service and Maintenance of GH2 Fuel Systems
  - ✓ SAE J2578, Recommended Practice for Fuel Cell Vehicle Safety
  - ✓ SAE J2579, Technical Information Report for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles
- **Electric Vehicles:**
  - ✓ SAE J1718 Measurement of Hydrogen Gas Emission from Battery-Powered Passenger Cars and Light Trucks during Battery Charging

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## Reviewed Legislation for Aboveground Mining

**The following documents were reviewed:**

- **Ontario:**
  - ✓ Occupational Health and Safety Act R.R.O. 1990
  - ✓ Regulation 854 Mines and Mining Plants
  - ✓ Regulation 213/07 Fire Code
  - ✓ Regulation 264/99 Electrical Safety Code
- **Québec:**
  - ✓ An Act Respecting Occupational Health and Safety
  - ✓ Regulation Respecting Health and Safety, 2001 G.O.Q. 2, 3888
  - ✓ Regulation Respecting Occupational Health and Safety in Mines, O/C 213-93, 1993 G.O. 2, 1757, 2603, and 2769

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## Findings for Aboveground Mining

**None of the above documents contains specific requirements that would prevent the use of hydrogen as a fuel source in aboveground mining operation.**

- **Worth noting that Ontario Regulation 213/07 Fire Code in section regulating storage and handling of gas cylinders accepts NFPA 55, Standard for the Storage, Use and Handling of Compressed and Liquefied Gases in Portable Cylinders as alternate compliance strategies for compressed gas manufacture and cylinder filling, storage and handling:**
  - ✓ **NFPA 55 now contains chapters on both gaseous and liquid hydrogen but those will be replaced by NFPA 2 Hydrogen Technologies**
  - ✓ **CHIC references NFPA 55 in bibliography (non-mandatory)**
  - ✓ **Plan is to harmonize CHIC and NFPA 2 requirements**

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## Reviewed Legislation for Underground Mining

**The following documents were reviewed:**

- **Nova Scotia:**
  - ✓ **NS Occupational Health and Safety Act 1996**
  - ✓ **NS Underground Mining Regulations (N.S. Reg. 296/2008)**
  - ✓ **NS Occupational Safety General Regulations (amended to N.S. Reg. 4/2004)**
- **Ontario:**
  - ✓ **OHS Act R.S.O 1990**
  - ✓ **R.R.O 1990 Regulation 854**
- **Québec:**
  - ✓ **An Act respecting Occupational health and safety, R.S.Q. c.S-2.1**
  - ✓ **Regulation respecting health and safety committees, R.Q. c. S-2.1, r.6.1.**
  - ✓ **Mining Act, R.S.Q. c. M-13.1 and Regulation respecting occupational health and safety in mines, O.C. 213-93**

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# CHIC vs Mining Regs: Critical Elements

**Electrical Requirements**

- Electrical equipment: CEC CAN/CSA C22.1 Safety Standard for Electrical Installations
- Area classification: IEC 60079-10 Classification of Hazardous Areas
- Emergency shut down (ESD) system
- Grounding and bonding

**Electrical and Mechanical Work**

- Designation of zones for use of electrical installations

- Standards for electrical installations

- Portable electrical equipment

- Electrical installations in explosion and non-explosion risk zones

Part 6 - Electrical and Mechanical Work Section 194ff outlines standards, approved procedures, competent persons, certification, equipment, installation, operation and maintenance requirements, etc. Electrical incorporates a restrictive zoning approach in coal mines and uses flameproof and intrinsic safe requirements in high risk zones; CSA standard CAN/CSA-M421-00 (R2005), Use of Electricity in Mines.]

193. Designation of zones for use of electrical installations underground at coal mine demonstrates use of zoning – again a principle which could apply for use of hydrogen.

Part 10 - Mine Hoisting Plants for Shafts Section 376 ff. – *does not seem to include transportation of diesel fuel in shafts (see Part 4*).

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# CHIC vs Mining Regs: Critical Elements

**Gaseous Hydrogen Installations**

-Hydrogen generating equipment (ISO 22734-1; ISO 16111-1)
- Hydrogen utilization equipment (i.e. FC)
- Maximum allowable working pressure (MAWP)
- Hydrogen piping, tubing and fittings (ASME B31.12, CSA B51-1)

- Flow control mechanisms
- Pressure control mechanisms and vent systems
- Compressors and compressor packages
- Storage containers
- Dispensing equipment
- Placement
- Outdoor installations (incl. clearance distances)
- Indoor installations (incl. clearance distances):
  - Ventilation system
  - Hydrogen detection systems
- Inspection and testing
- Commissioning
- Operation
- Maintenance

**Ventilation. Monitoring Flammable Gas.**

- Insllation and maintenance of ventilation system

- Flammable gas monitoring

- Flammable gas levels

Part 7 – Ventilation Section 210 ff - outlines requirements for mine ventilation including quantities, qualities , routing, monitoring, gases, dusts, diesel engine use and exhaust fumes, etc(over and above the parallel General regulations which cover ventilation of facilities, buildings, etc.), etc.

211. Air quality monitoring program" (1) The threshold limit values for all of the following set out in the publication "TLVs and BEIs" do not apply to any coal mines: methane, butane, ethane, propane.

218. Prohibiting entry into unventilated area of non-coal mine: *should any part of hydrogen plant involve unventilated areas – access is obviously restricted.*

Part 8 - Monitoring Flammable Gas Section 238 ff - includes requirement for a mine-wide environmental monitoring system with a surface control room.

241. Flammable-gas monitors on equipment in coal mine

**Mechanical Equipment and Travelways**

173-175. Design of underground enclosures and shelters *could apply to use of hydrogen underground* – 173. all service garages, fuelling stations, fuel storage areas must be appropriately designed, separate entry and exit, ventilated and prevent uncontrolled vehicle access.- 174. and be located to minimize impact on the underground mine; have spill containment have no pits and use non-combustible materials; 175 – fuel station separate, totally enclosed with self closing non-combustible door, etc; all designated by manager and approved by engineer. **A mobile fuelling station must conform with NFPA standard** [ref. NFPA 385: Standard for Tank Vehicles for Flammable and Combustible Liquids, 2000 edition].

176. Diesel fuel transfer system *could apply to use of hydrogen underground* – pre-set quantity of <90% of receiving tank; flow control devices; shaft/slope pipeline can only be used for fuel when no hoisting, approved procedures and competent persons.

177. Diesel fuel pipelines *could apply to use of hydrogen underground*: properly constructed maintained and routed (avoid service garage, switch room, magazine, refuge station or first aid station), approved by engineer, be leakproof, pressure tested to **345kPa**, drained empty after each use, clearly marked

178. Storage Tanks *could apply to use of hydrogen underground:* similar with vent pipes, fuel gauge and spill containment [ref. ULC standard ULC-S601-00, Standard for Shop Fabricated Steel Aboveground Horizontal Tanks for Flammable and Combustible Liquids, 3rd edition; (b) ULC standard ULC-S630-00, Standard for Shop Fabricated Steel Aboveground Vertical Tanks For Flammable and Combustible Liquids.]

Part 9 - Mechanical Equipment and Travelways Section 263 ff. – *includes use of internal combustion engines, diesel powered vehicles, etc, including construction, brakes, maintenance, no release of sparks.*

263. File information on use of any internal combustion engine underground, on specifications, certifications (flameproof), areas of use, procedures *could apply to hydrogen vehicles.*

268. Maintaining diesel-powered and battery-powered equipment is required *could apply to hydrogen vehicles.*

290. Procedures for safely operating mobile equipment and mine cars *could apply to hydrogen powered equipment underground*

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## Findings for Underground Mining

**There was at least one clause found which represents a potential impediment to the introduction of hydrogen equipment underground:**

- **Nova Scotia:**
  - ✓ **Underground Mining Regulations ban underground use of generating acetylene gas, (Section 156) and gasoline (Section 172) and propane or other similar fuel underground (Section 182)**
- **Ontario:**
  - ✓ **Regulation 854 bans use of internal combustion engines that uses gasoline, propane or other volatile substance (Section 30 (4))**
  - ✓ **Some fuels are not allowed to be stored in gaseous state (Section 30 (5))**
- **Québec:**
  - ✓ **Regulation Respecting Occupational Health and Safety in Mines, O.C. 213-93, bans use of an internal combustion engine (except diesel engines) near surface access points to underground mine (Section145) and also bans the use or storage of propane underground (Section 153 )**

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## Findings for Underground Mining

**Overall Summary:**

- **Gaps:**
  - ✓ **There is no provision for use of hydrogen fuelled equipment underground (-)**
  - ✓ **At the same time there are no provisions explicitly excluding hydrogen (vs other fuels) from mining operations (+)**
- **Impediments:**
  - ✓ **Essentially, hydrogen fuelled internal combustion engines are banned under current legislation (-)**
  - ✓ **However, current legislation does permit generation of hydrogen underground in limited quantities in battery charging stations (+)**

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## Legislative Routes for Underground Mining

**Existing legislation contains clauses that may permit one of the three following routes to be used to facilitate regulatory approval to use hydrogen fuelled equipment underground:**

- **Justification of introducing a new technology into an underground mine**
  - ✓ **Outline the technology and introduction**
  - ✓ **Note impact on OHS, including ventilation, ground control and equipment underground at the mine**
- **Justification of alteration, varying, validating existing systems or procedures**
  - ✓ **Outline systems, procedures, equipment and installations at a mine that may affect OHS**
  - ✓ **Ensure they operate in conformity with the design intent**
- **Preparation of a specific Code of Practice**
  - ✓ **Demonstrate equal or better than current requirements of OHS**
  - ✓ **This may require specific direction from the Director responsible**

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## Legislative Routes for Underground Mining

**Whichever of the three approaches was adopted the key compliance items to address are covered in the supporting spreadsheet but would include:**

- **Comply with prevailing generic standards and codes elsewhere**
- **Identify all potential hazards associated with the technology and demonstrate how they will be mitigated to be "as safe or safer than" existing regulations (flammable, explosive, pressurized, power-packs, fuelling, storage, transport, charging, etc.)**
- **Address mine-specific aspects: planning, ventilation, emergency response, firefighting, fire suppression, zoning, accessible, competent persons, management**
- **Include special provisions for transport of hydrogen underground through shaft. Slope or ramp access.**

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## Conclusions / Recommendations

- From the generic C&S perspective review, there are no codes and standards barriers to introduction and implementation of hydrogen and fuel cells technologies in the mining environment, above or underground.
- No regulations were identified that would prevent the use of hydrogen at aboveground mining operations, however a few requirements were identified that will need to be explicitly addressed as part of the HMII project plan. If addressed at the planning stage, there is minimal project risk.
- There is no provision in any of the jurisdictions reviewed for use of hydrogen fuelled equipment underground. At the same time there are no provisions explicitly excluding hydrogen (vs other fuels) from mining operations:
  - ✓ The US regulations are the most prescriptive reviewed, stressing mandatory requirements and Queensland the least prescriptive with New South Wales being closer to the latter than to the USA and Nova Scotia, Ontario, Quebec and lying somewhere in between
  - ✓ Comparison of international requirements shows some apparent common themes for all jurisdictions, which indicates that common approach could likely be applied

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## Q & A

# THANK YOU FOR YOUR ATTENTION!

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