# Regulations, Codes, and Standards (RCS) for Large Scale Hydrogen Systems

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## Course Outline

- Topic 1.Introduction
- Topic 2. Renewable Hydrogen Generation
- Topic 3. RCS for Large-Scale Renewable Hydrogen Generation
- Topic 4. RCS Hydrogen Transport: Pipelines, Rail, and Highway
- Topic 5. Example Installation: performance based approach to large-scale production and storage installation
- Topic 6. Conclusion and questions



## Introduction

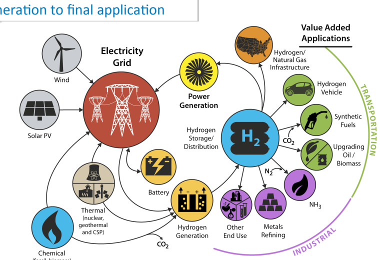
- Hydrogen has potential applications that require larger-scale storage, use, and handling systems than currently are employed in emerging-market fuel cell applications.
- There has been extensive work evaluating regulations, codes, and standards (RCS) for the emerging fuel cell market, such as the infrastructure required to support fuel cell electric vehicles. However, there has not been a similar RCS evaluation and development process for these larger systems.
- This paper presents an evaluation of the existing RCS in the United States for large-scale systems and identifies potential RCS gaps.
- The paper also identifies areas of potential safety research that would need to be conducted to fill the RCS gaps..

This analysis supports the H2@Scale project work



## Renewable Hydrogen Generation

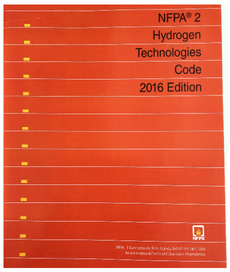
Multiple paths from renewable generation to final application




*H2@Scale Vision: widespread production and utilization of hydrogen as an energy carrier across power sources and end uses.*

## NFPA 2 National Hydrogen Code

194 Pages of Hydrogen safety




Adopted in Most US jurisdictions

- Referenced in the 2015 International Fire Code
- Referenced in NFPA 1 Uniform Fire Code
- These two Fire codes are used in almost every jurisdiction in the US
- Federal facilities often invoke compliance with NFPA requirements
- Covers almost all aspects of hydrogen safety

NFPA 2 provides the base for hydrogen technologies including large systems



## RCS for Large-Scale Renewable Hydrogen Generation

Chapter 13 of NFPA 2 has fairly limited requirements for production

Table 1. RCS for hydrogen generation

| RCS Document | Subject Matter |
|---|---|
| NFPA 2 Hydrogen Technologies Code | Chapter 13 hydrogen production |
| NFPA 2 13.2.2 Interconnection | Requirements for connecting system to the grid |
| NFPA 2 13.2.4 Siting | Structural requirements, exclusion from electrical classification zone, and safe venting per Chapter 6 |
| NFPA 2 13.3.1.2 Ventilation | Provisions for indoor venting |
| NFPA 2 13.3.1.5 Indoor installation | Setback distances for installations below and above the maximum allowable quantity |
| NFPA 70 National Electrical Code | Electrical requirements for classified areas |
| CGA H-5.5 | Vent stack design including vent termination geometry |
| ASME B31 (.3 and .12) | Piping design for hydrogen piping systems including dimensions and materials |
| CGA S-1. 1-1.3 | Pressure relief device design |



## RCS FOR LARGE-SCALE HYDROGEN STORAGE SYSTEMS

Current Requirements

- NFPA 2 addresses bulk gaseous storage in unlimited amounts and bulk liquid storage up to 283,906 L (75,000 gallons)
- Systems that are larger than current employed by industry may be considered to be outside of the scope of the prescriptive requirements in NFPA 2 Hydrogen Technologies Code
- NFPA 2 give performance-based option

Excerpt from NFPA 2 bulk liquid storage table

| 15,001 gal to 75,000 gal | 56,782 L to 283,906 L |
|---|---|
| ft | m |
| 75 | 23 |
| 75 | 23 |
| 75 | 23 |
| 50 | 15 |
| 75 | 23 |
| 25 | 7.6 |
| 5[a] | 1.5 |
| 75 | 23 |
| 5 | 1.5 |
| 50 | 15 |
| 100 | 30.5 |



## RCS HYDROGEN TRANSPORT: PIPELINES, RAIL, AND HIGHWAY

Pipeline network is very limited in the US to certain geographic areas

Table 2. RCS for hydrogen transport

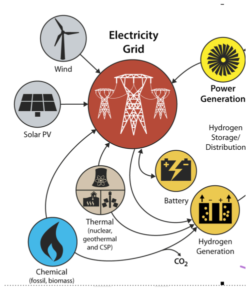
| Transport Method | RCS Document |
|---|---|
| Hydrogen pipelines – hydrogen is covered under the scope of this part of the U.S. Department of Transportation (DOT) regulations as a flammable gas | DOT 49 CFR Part 192 Subparts A–P cover:<br>Materials<br>Pipe design<br>Welding, joining, and corrosion control<br>Test requirements<br>Operations, maintenance, and qualification of personnel<br>Integrity management |
| Tanker truck | DOT 49 CFR Part 172 (provisions T75 and TP5) |
| Rail transport | DOT 49 CFR Part 174 |

## Example Installation: performance based approach to large-scale production and storage installation

The basic parameters:

- Wind turbines capable of generating megawatts of power
- Electrolyzers capable of producing (combined with liquefaction plant) 5,360 kg/day (20,000 gallons/day)
- Storage system capable of holding 26,800 kg (100,000 gallons) of liquid hydrogen
- Transport capable of moving 5,360 kg/day (20,000 gallons/day)
- Based on fuelling > 1000 vehicles or supplying a small network of stations

Generation Portion of Schematic






## Key Elements of Performance Based Approach

Excerpt from summary of performance based requirements in NFPA 2 Hydrogen Technologies Code

Table 3. Performance-based code design

| ...ment | Application to Large-Scale Liquid Hydrogen Storage System |
|---|---|
| ...bjectives. The performance- ...l meet the goals and objectives ...cordance with Section 4.3. | A large-scale system would exceed the 75,000-gallon liquid storage limit for NFPA 2 and would lie beyond the basic storage applicability. |
| ...ttal Documentation. When a performance-based design is submitted to the authority having jurisdiction (AHJ) for review and approval, the owner shall document, in an approved format, each performance objective and applicable scenario, including any calculation methods or models used in establishing the proposed design's fire and life safety performance. | The focus of the performance objectives would be on establishing that a large-scale system could be safely designed, built, and operated and present a comparable level of risk to a system within the prescribed code boundaries. |
| 5.1.6 Sources of Data. Data sources shall be identified and documented for each input data requirement that is required to be met using a source other than a required design scenario, an assumption, or a facility design specification. | Data should be from large-scale bulk liquefied hydrogen storage systems. The applicant will likely need data on both intended and unintended releases of hydrogen as well as data on the fate of these releases. |
| 5.1.8 Operations and Maintenance Manual. An approved Operations and Maintenance (O&M) Manual shall be provided by the owner to the AHJ and the fire department [for review] and shall be maintained at the facility in an approved location. | The manual should address preventive maintenance to reduce the frequency of release as well as the impacts of planned releases. |
| 5.1.11 Annual Certification. Where a performance-based design is approved and used, the property owner shall annually certify that the design features and systems have been maintained in accordance with the approved original performance base design and assumptions and any subsequent approved changes or modifications to the original performance-based design. | Annual certification can potentially be met through existing testing requirements in the prescriptive code text. |



## Key Elements of Performance Based Approach

- Very broad open-ended approach with qualitative compliance targets
- Will require data collection to evaluate hazards
- Will require a significant effort to demonstrate compliance
- Will require working closely with enforcing authority
- May be the only way to get large unique systems approved



## Research Required to Deploy Large Systems

- Component performance in large scale storage systems is yet to be demonstrated for some components
- Electrolyzer oxygen/hydrogen mixtures may present a flammability hazard and require more detailed requirements in NFPA 2
- Performance based compliance for systems outside of current boundaries is an area that will require further work
- Communications for system to perform in an integrated fashion may require further work
- Hydrogen Wide Area Monitoring (HyWAM) to detect releases in large storage systems is a technology that needs to be developed and demonstrated

## CONCLUSION

- Large scale systems not defined in RCS
- Portions of large scale systems may fall outside of the boundaries of current RCS
- Approval process for these systems may require a performance based approach similar to that applied to large LNG storage systems
- No US national system of hydrogen pipelines- filling this gap will require additional safety analyses
- Research may be required in characterizing risk and safety measures for large scale systems



## Thank You and Questions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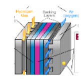

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