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SITING CONSIDERATIONS FOR ELECTROLYZER SYSTEMS

Size, footprint, and setback requirements

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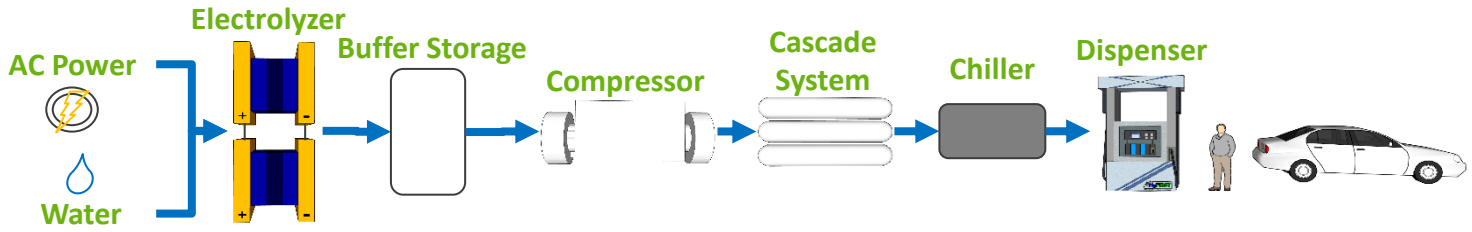
SAND2023-09107PE

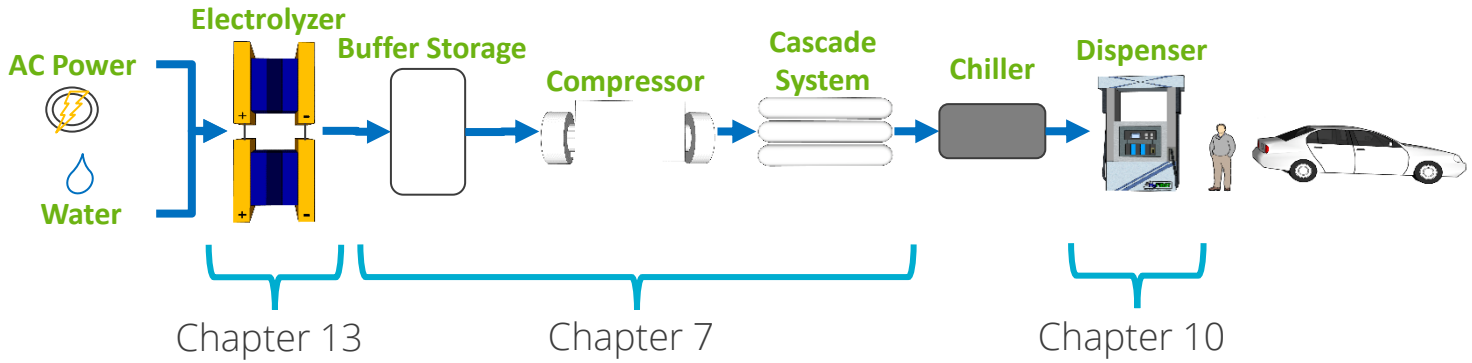
OVERVIEW OF ELECTROLYZERS AS PART OF A LARGER SYSTEM



- Example hydrogen refueling station illustrates that many different components make up a system
  - Depending on the system and application specifics
  - Production, storage, refueling, fuel cell, etc.
- Even a straightforward electrolyzer production facility is likely to have:
  - Storage
  - Transfer point

Graphic adapted from: Ehrhart et al. "Hydrogen Refueling Reference Station Lot Size Analysis for Urban Sites" SAND2020-0754 PE, January 2020

EXAMPLE NFPA 2 CHAPTER APPLICABILITY



- Different regulations, codes, and standards can apply to different parts of a system
  - Even within a single code (e.g., NFPA 2) different requirements can apply to different sub-systems
- Some requirements can be similar or the same; others can be very different; e.g.:
  - Electrolyzers and gas storage have similar setback distances and vent pipe requirements
  - Dispenser has independent setback distances

Graphic adapted from: Ehrhart et al. SAND2020-0754 PE, January 2020

ELECTROLYZER SITING PER NFPA 2

- Only applies to systems rated for 36 g/hr to 100 kg/hr
  - Otherwise points to nationally recognized standards (see next talk)

- General requirements for all hydrogen generation systems
  - System capacity determines acceptable locations indoors/outdoors
    - Also determines setback distances to different exposures
  - Area around hydrogen generation system will be classified per the national electric code
  - Additional requirements for systems installed on a rooftop
- Additional requirements specific to electrolyzers
  - Support and anchoring requirements
  - Vent termination requirements

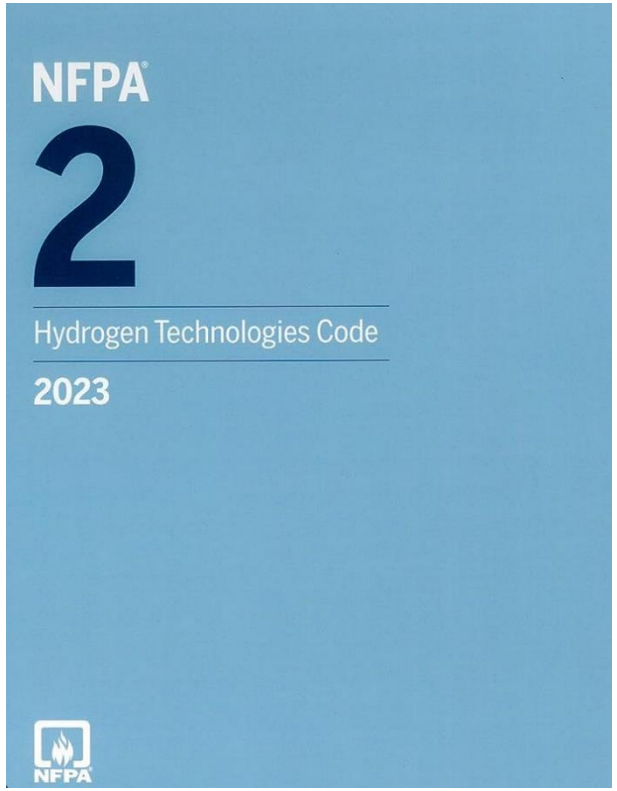


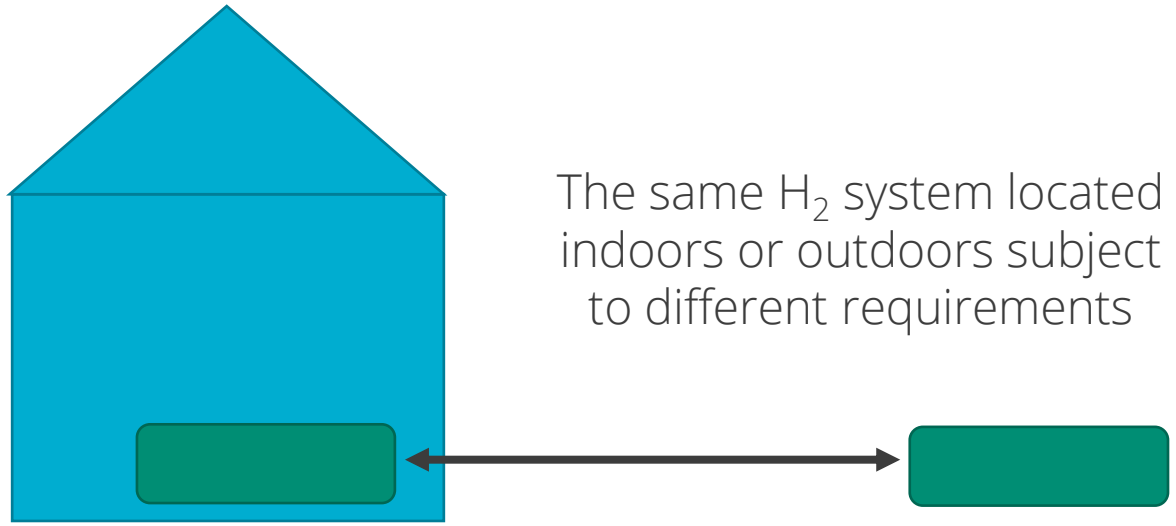
Image: https://www.fire-police-ems.com/NFPA2-2023.shtml

NON-BULK VS. BULK HYDROGEN STORAGE IN NFPA 2

- Bulk gaseous hydrogen system: 5,000 scf (141.6 Nm^3) ≈ 12 kg H_2
  - Can be in a single container, or multiple connected containers
- Setback distances differ for bulk vs. non-bulk
  - Written for storage systems
  - But 'Hydrogen Generation Systems' section points to same requirements as for storage
- Non-Bulk setback distances
  - Distance determined based on amount stored
  - Different distances to lot lines, public ways, and buildings on same property
- Bulk setback distances
  - Distance determined based on storage pressure and inner diameter of interconnecting piping
  - Different distances to lot lines, air intakes, exposed persons, combustibles, and many others

INDOOR VS. OUTDOOR ELECTROLYZERS IN NFPA 2

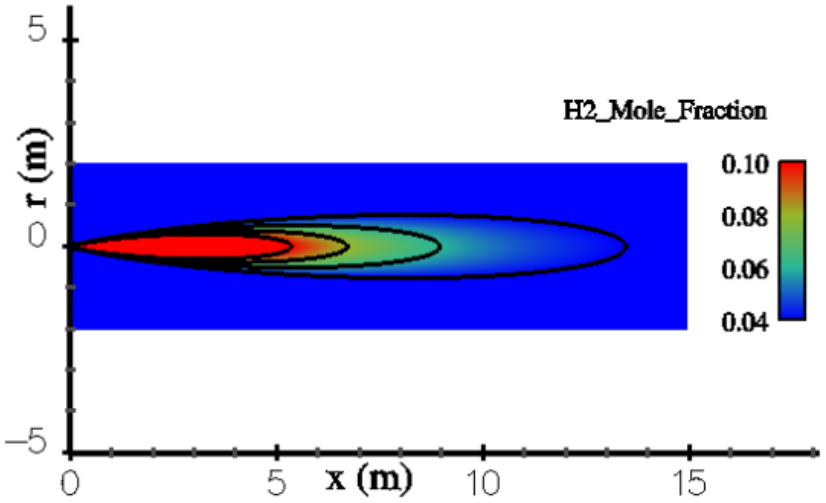
- Indoor installations
  - Whether or not H_2 system allowable indoors depends on
    - Quantity stored (or interior quantity)
    - Occupancy type of building
    - Prescence of sprinklers, gas cabinet
  - Small quantities less than “maximum allowable quantity” (MAQ) generally allowed
- Outdoor installations
  - Generally allowed, subject to requirements and separation distances



The same H_2 system located indoors or outdoors subject to different requirements

SETBACK DISTANCES INTENTION AND BASIS

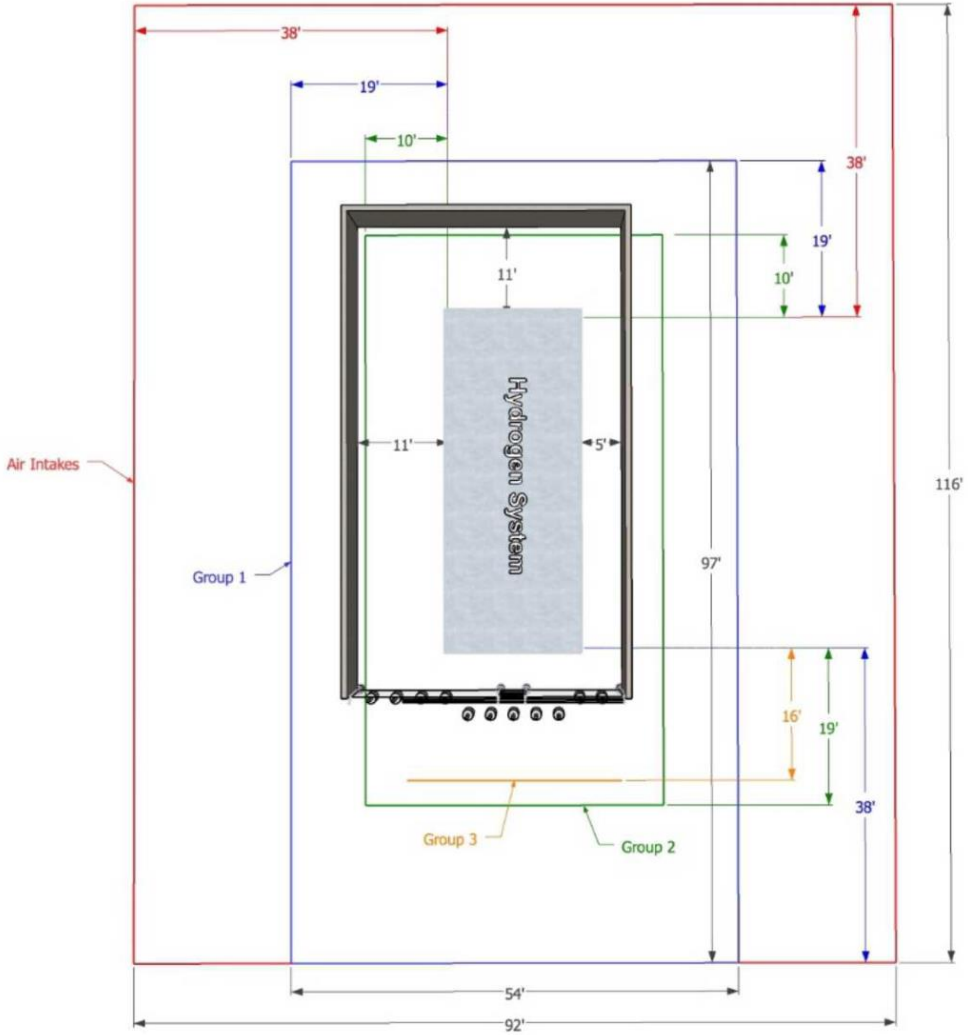
- Setback distances define **a prescribed distance** between a potentially hazardous system and different types of other systems, people, buildings, or materials
- Risk-informed separation distances by themselves are not meant to completely eliminate risk
  - Rather to limit the risk to an acceptable level
  - Separation distances alone may not be adequate protection against very unlikely worst-case scenarios
  - Setback distances are **in addition to** many of the **other necessary safety design features** of the system
- For NFPA 2, risk analysis informed the Technical Committee's choice of basis for leak size
  - 1% pipe area for gaseous bulk hydrogen
  - The distance to a selected "harm criteria" then estimated by model
  - Safety factor included in final distance



LaChance et al. SAND2009-0874, March 2009

SETBACK DISTANCE EXPOSURES

- For bulk gaseous hydrogen setback distances, exposures grouped by type of protection:
  - Group 1: “general public”
  - Group 2: “people on site”
  - Group 3: “fire spread”
- Required distances away from system can vary by what is nearby
  - Different distances for “lot lines” (Group 1) and “parked cars” (Group 2)
  - Different distances for “air intakes” (Group 1) and “buildings” (Group 3)
- Distances the same within groups:
  - “Air intakes” and “operable openings in buildings and structures” both Group 1
- Distances to most* exposures can be reduced by blocking line-of-sight with fire-rated wall
  - * Except air intakes



Ehrhart et al. SAND2020-2796, March 2020

OXYGEN STORAGE

- **May or may not be applicable, depending on if oxygen output is collected and stored**
- Requirements for bulk oxygen systems covered in NFPA 55: Compressed Gases and Cryogenic Fluids Code
  - Chapter 9 of 2023 Edition
  - Bulk defined as 20,000 scf (566 Nm^3) of oxygen
- Similar types of requirements, but specifics differ
  - Setback distances to different exposure types
    - Fire-rated walls allowed to reduce some distances but not all
  - Points to ASME code for piping requirements

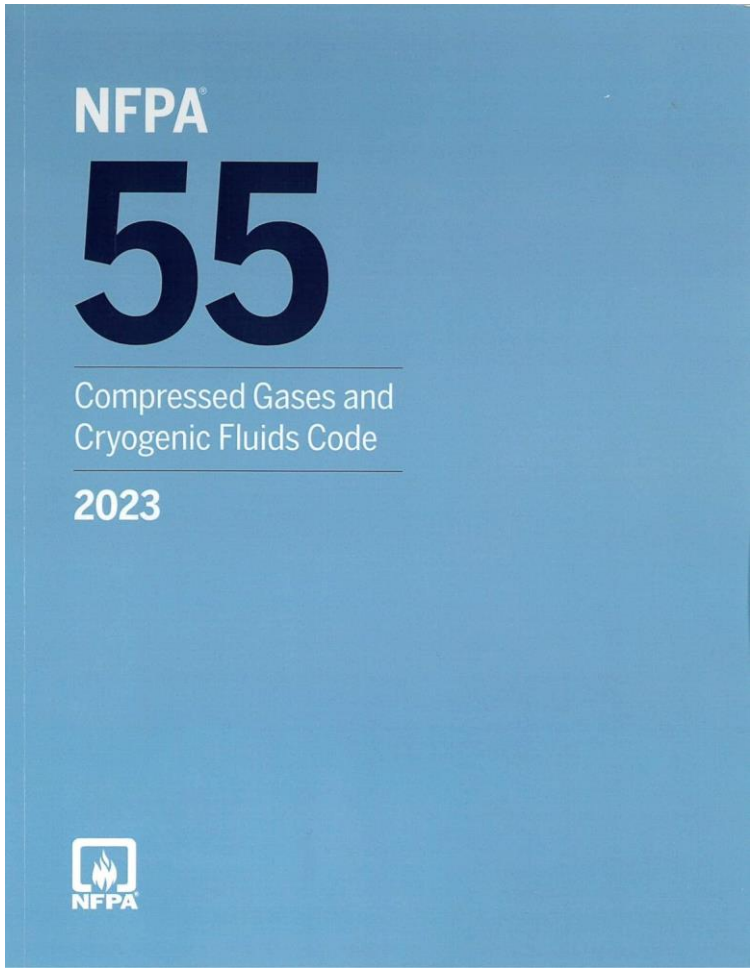


Image: https://www.amazon.com/NFPA-Compressed-Gases-Cryogenic-Fluids/dp/1455929220?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=A17VKTJBU5DGMM

ELECTRICAL CLASSIFICATION AREAS

- Different than setback distances
  - Setback distances protect against consequences of unintentional leaks
  - Classification areas protect against potential ignition sources
  - Electrical area classification for Hydrogen Generation System refers to intentional exhaust
- Hydrogen generation systems must be located outside electric classified areas
  - Unless listed and approved for those areas
- Refer to NFPA 70: National Electric Code for more details

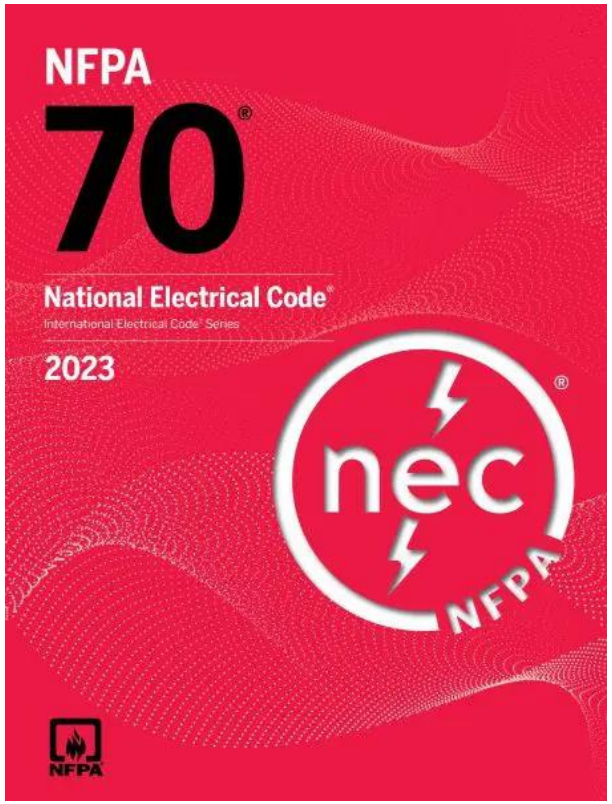


Image: https://shop.iccsafe.org/nfpa-70r-national-electrical-coder-necr-2023-edition.html

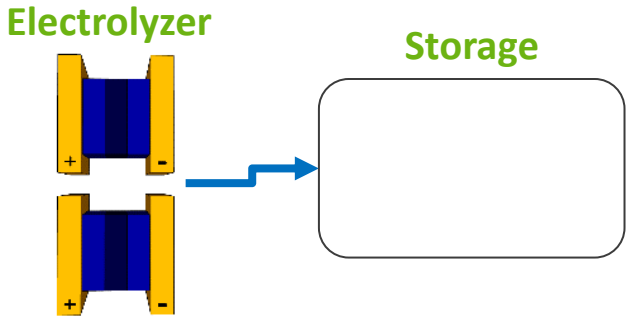
VENT PIPES FROM ELECTROLYZERS

- For example, from pressure relief devices
- Vent pipe terminations follow CGA G-5.5: Hydrogen Vent Systems
- NFPA 2 requires a minimum of:
  - 10 ft (3 m) above grade
  - 2 ft (0.6 m) above nearby equipment
  - 5 ft (1.5 m) above rooftops
- Electrical classification area determination required
  - Using standardized modeling per IEC 60079-10-1
- Horizontal separation distances based on hazardous volume
  - Using standardized modeling per IEC 60079-10-1

Images:
https://www.techstreet.com/standards/cga-g-5?product_id=2001146
https://h2tools.org/bestpractices/venting

ELECTROLYZER AND STORAGE SITING SIMILARITIES

- Multiple similarities high-level requirements:
  - Allowable location (especially indoors)
  - Setback distances
  - Vent pipe terminations
  - Access control
  - Weather protection
- Some differences:
  - Foundation/support
  - Electrical bonding/grounding
  - Vehicle protection
- Generally electrolyzers likely to be sited with hydrogen storage nearby



Graphic adapted from: Ehrhart et al. SAND2020-0754 PE, January 2020

WHAT ABOUT EQUIPMENT ENCLOSURES?

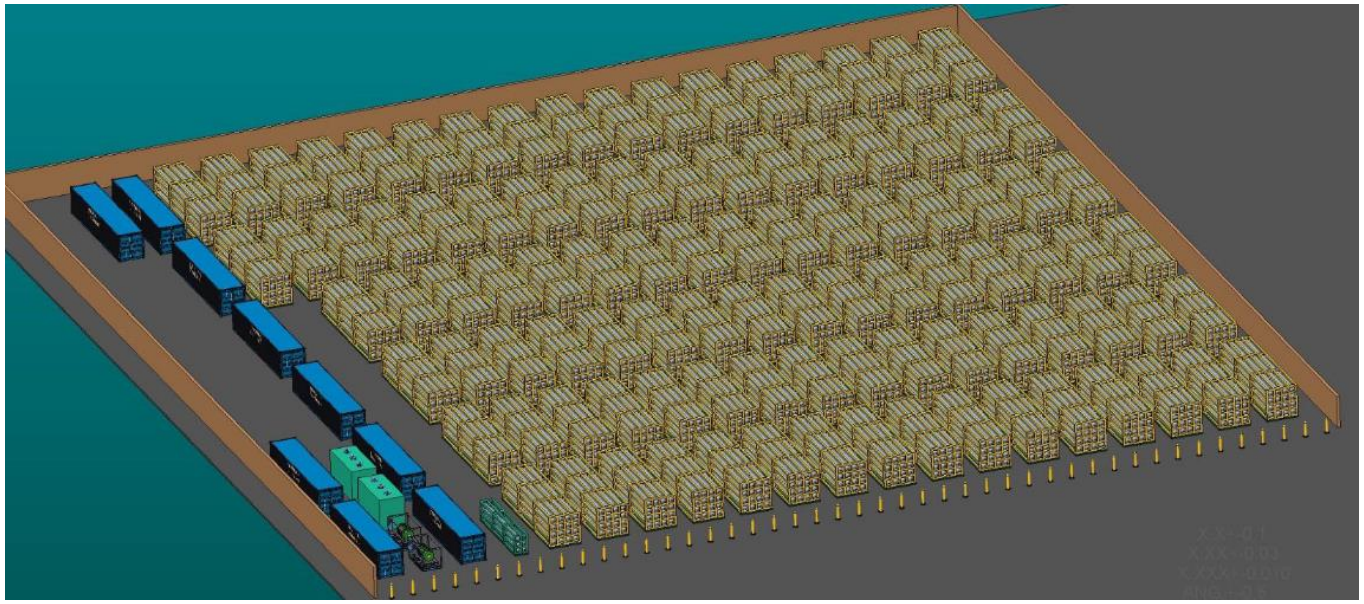
- NFPA 2 (2023 Edition) Section 7.1.23 describes Hydrogen Equipment Enclosures
  - Many different requirements, including
    - Sensing/monitoring and alarms
    - Materials of construction
    - Ventilation
    - Emergency shutdown
  - Some requirements differ for hydrogen storage connected to a generation system
- One relevant requirement to note:
  - 1-hour fire-rated barrier must separate bulk gaseous hydrogen storage from hydrogen generators

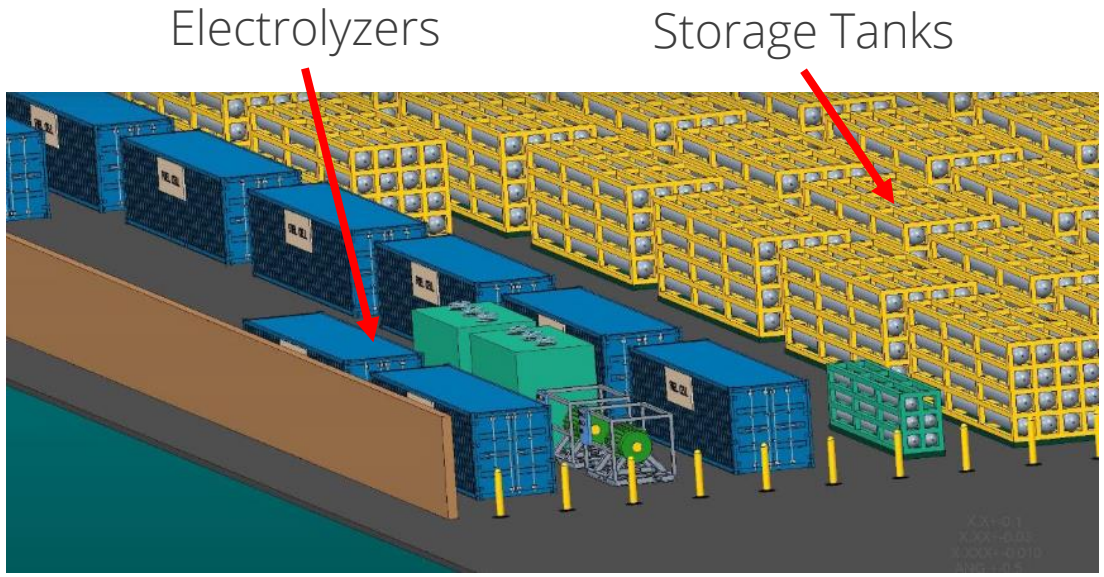
Example Image Only

Image: https://fuelcellsworks.com/news/haskel-hydrogen-systems-partners-with-nanosun-to-refuel-hydrogen-electric-aircraft-trials-under-hyflyer-ii/

EXAMPLE ELECTROLYZER SYSTEM FOOTPRINT

- Example taken from large-scale hydrogen production and use system
  - Storage capacity of approximately 10,000 kg at 30 bar
  - Only 2 electrolyzer units used – slow refill of resiliency backup
- ~1 acre footprint dominated by hydrogen storage
  - Footprint can vary widely depending on production vs. storage requirements

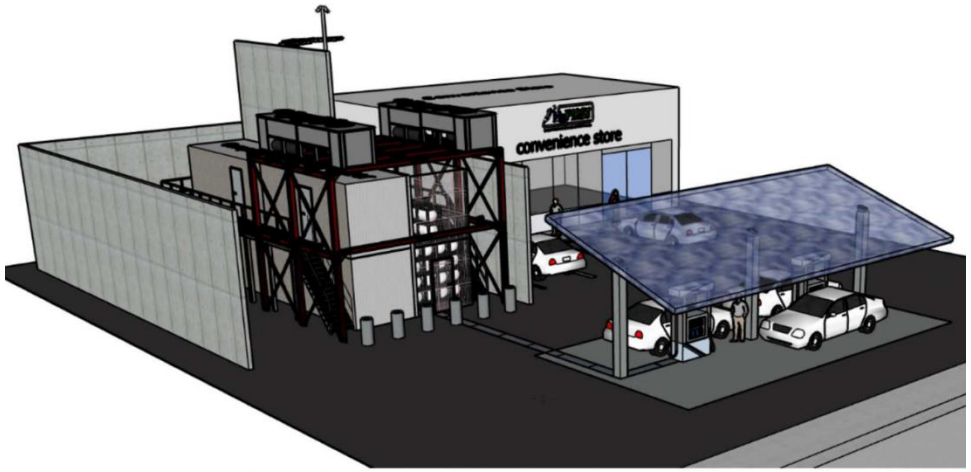


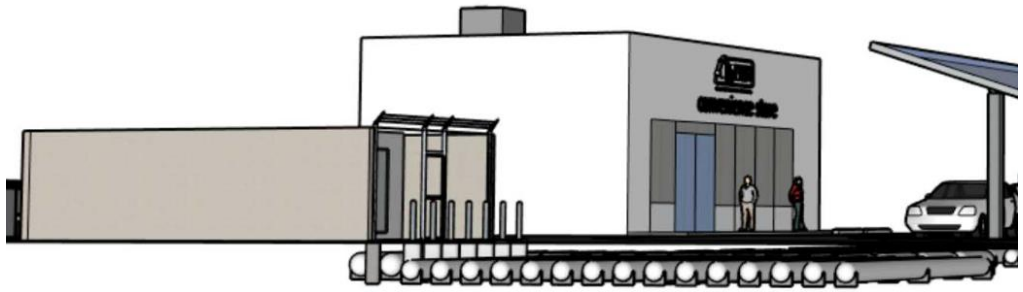


Wall et al. AMR Project ID IN039, June 2023, https://www.hydrogen.energy.gov/pdfs/review23/in039_wall_2023_p.pdf

POSSIBLE WAYS OF REDUCING SYSTEM FOOTPRINT

- Increasing hydrogen density
  - Higher pressure gas storage
  - Cryogenic liquid storage
- Less on-site storage (e.g., pipelines offsite)
- Making system more “vertical”: aboveground or underground storage
  - May have logistical, economic, or visibility concerns

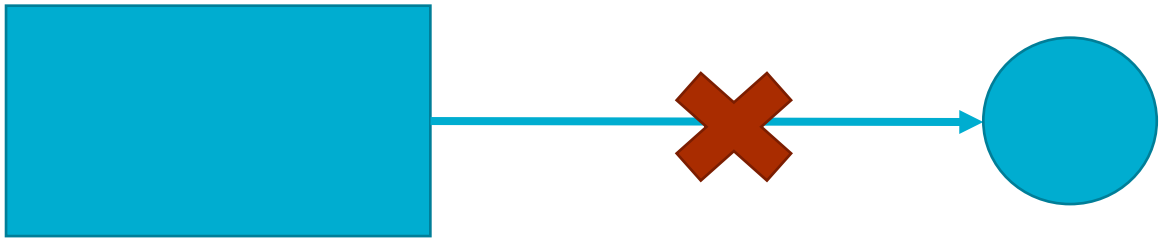




Ehrhart et al. SAND2020-2796, March 2020

SITING THROUGH ALTERNATIVES

- Alternative means and methods
  - If most prescriptive requirements can be met except for a few
  - Modeling/analysis along with additional protections or mitigations
  - Subject to approval by local authority having jurisdiction
- Performance-based design
  - For completely unique systems
  - Don’t need to follow any prescriptive requirements
  - Modeling/analysis to justify safety of entire system “from scratch”
  - Subject to approval by local authority having jurisdiction



SUMMARY

- Electrolyzers and storage treated different in most regulations codes and standards
  - Some similarities in high-level requirements
- Electrolyzers often co-located with at least some storage
- Setback distances can dictate siting decisions
  - May not protect against worst-case scenarios by themselves
- Footprint determined by generation and storage capacity
  - Footprint can be reduced in some ways, but potentially more expensive
- Alternative methods for siting approvals always possible

HYDROGEN PERMITTING/SITING BEST PRACTICES

Have planners, fire departments, hazardous response teams, & community members involved from the start

Develop a thorough understanding of hydrogen and hydrogen technologies

Everyone involved in the planning process should be educated on hydrogen safety materials

It is best to start early, engage often, and be transparent with the local community

Courtesy of Natalie Alvarado, DOE HFTO Fellow

THANK YOU!
QUESTIONS?

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BACK UP SLIDES