New Technology for High Pressure H2 Transmission and Storage

2nd Annual Kentucky Hydrogen Summit
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June 26, 2024

Our Companies

BrainDrip

- The safe and effectual transition of the world's transmission and distribution pipeline infrastructure for the high-volume conveyance of H_2, NG, NG/H_2 blends, ammonia, and CO_2
- The safe and effectual localized storage of H2, NG, RNG, and CO2 at elevated pressures
- The meaningful reduction in carbon emissions from all materials and processes

IQ4H2

- Assist businesses by making their energy products future-ready in a constantly evolving market
- Support getting energy projects in the ground by working with developers and other stakeholders on optimization, permitting, and key cost considerations
- Key areas:
  - Technology Acceleration
  - Advanced Sensors and Health Monitoring
  - Safety, Optimization, & Regulation

Who We Are

Kent Weisenberg

- Managing Member of BrainDrip and IQ4H2
- Systems Architect
- 30 years of experience in pipeline & vessel product development
- 50+ patents in pipeline/vessel materials, devices and methodologies

Cory Kreutzer

- Member and Technical Director at IQ4H2
- Hydrogen system design, safety, and risk analysis
- 10+ years of hydrogen experience

Mike Peters

- Member and Team Principal at IQ4H2
- Hydrogen system optimization, planning, and safety
- 10+ years of hydrogen experience

BrainDrip's ITC

Custom Built for the Hydrogen Market

Our Solutions

Energy Transmission SG Liner

- On site installation
- Distribution of high-pressure H2, natural gas, CO2, and most other gases and liquid medias
- Purpose built for the pipeline transmission sector
- Legacy pipeline transitional liner or greenfield installations
- Multi-mile continuous installation
- Continuously embedded Heath & Risk Monitoring System (HRMS)

Energy Storage GigaVault

- On site installation
- Conforms to energy storage requirements
- Multiple Design Layout Options

  (E.G., Horizontal, Vertical, Coiled)
- Targeted for Large Scale Storage

  (E.G., 10,000+ kg H2)
- Pressure ratings from 50 -400+ bar
- Diameters 6 in. to 36 in.

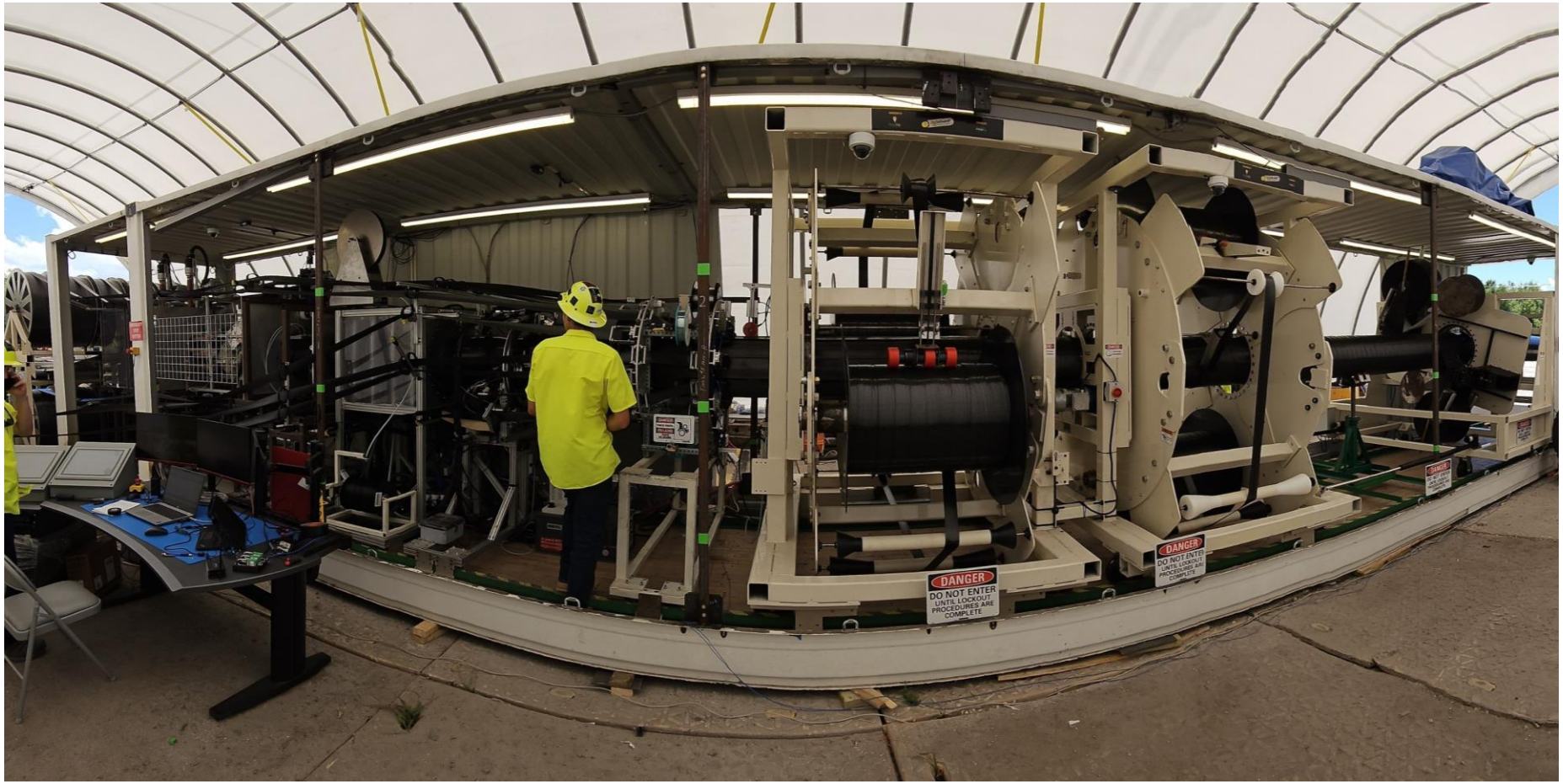
Portable Manufacturing Platform

Innovation Highlights

Onsite Manufacturing:
Elimination of DOT and or dimensional constraints due to shipping prefabricated segments. Continuous vessel lengths in the 10's, 100's, 1,000's, and 10,000's of feet. Customization to unique site footprints

Quality Management:
ML vision AI systems integrated into the manufacturing sequence and quality control and assurance processes

Continuous Improvement Method:
Manufacturing data aligned with real-time health and risk monitoring system to accelerate product iterations.



Innervated Tubular Composite

Innovation Highlights

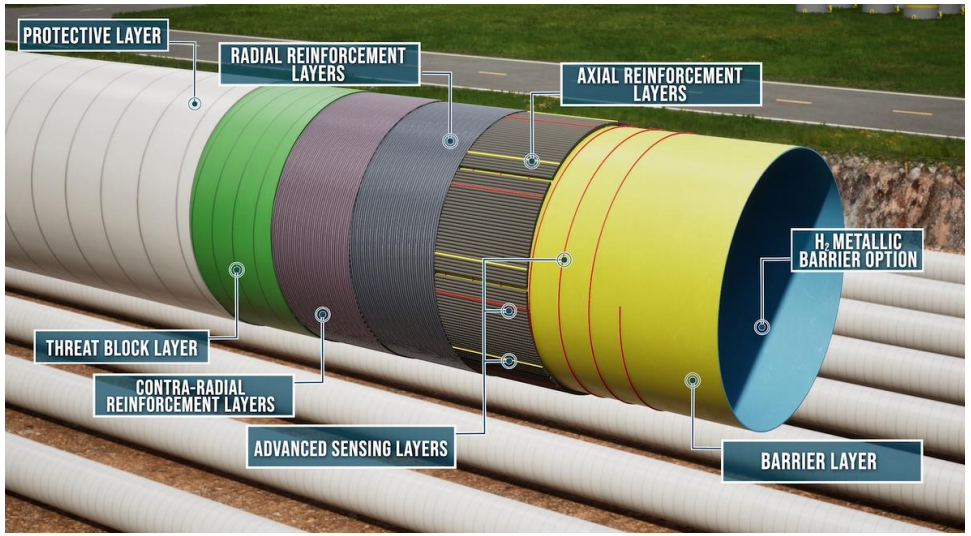
MicroRope™ Reinforcement:
BrainDrip novel design
3.5x the breaking efficiency of tow & bidirectional reinforcements
2.5x the breaking load of tow and bidirectional reinforcements

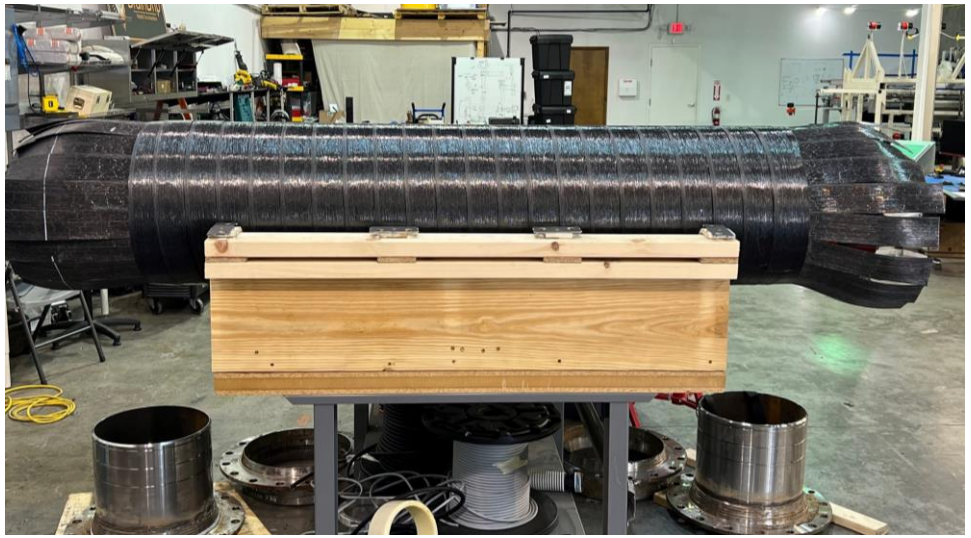
Independent Axial and Radial Reinforcement:
Substantial increase in pressure rating
Substantial reduction in cyclic fatigue
Substantial increase in design life

Elastomeric Infusion:
Eliminates composite microfracture from cyclic, strain/fatigue, and impact events
Substantial increase in design life

Permeation Resistance:
Novel barrier layer radically minimize permeation of gases such as H2
HDPE & MDPE (neat)
MDPE with Polyamide (PA)/Ethylene Vinyl Alcohol (EVOH) coextrusion*
MDPE with Aluminum and or Beta Silicone Carbide laminate coextrusion*

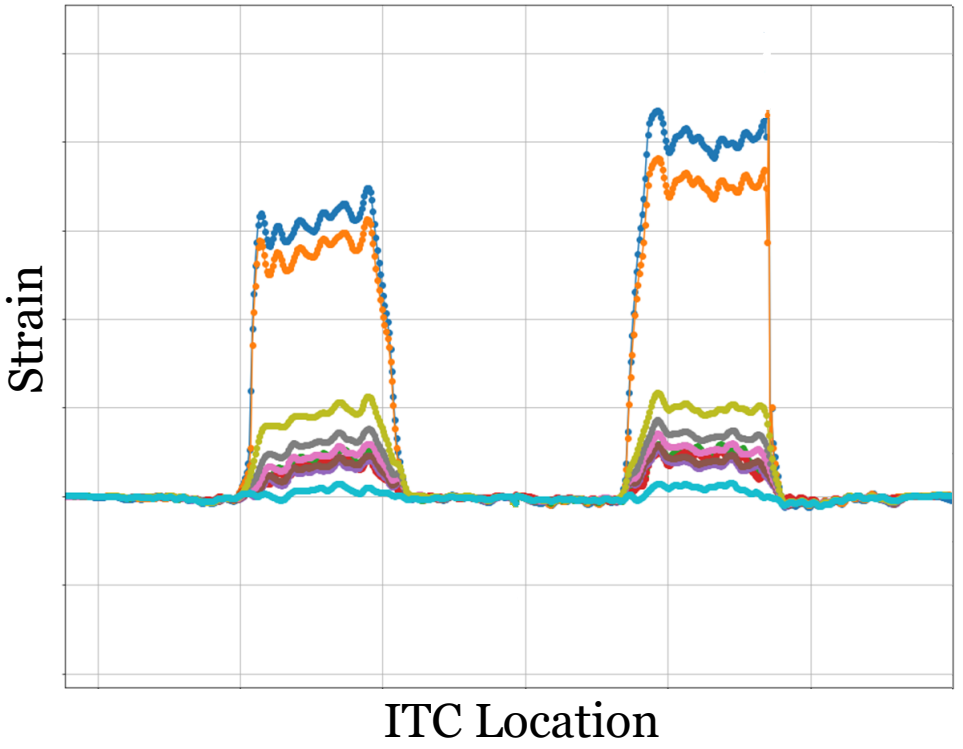
*ITC internal diameter





Health and Risk Monitoring System (HRMS)

- Sensors embedded during the manufacturing process
- Continuous interrogation of the ITC with ML based event classification and localization
  - Impacts, ground quality, third-party threats, strain, flow, pressure, temperature, leaks
- Operational systems architecture
  - Field-deployed A.I./ML edge computing for light-weight classification
  - Cloud-based storage and modeling for classification refinement
  - Cloud-based threat notification for site operators

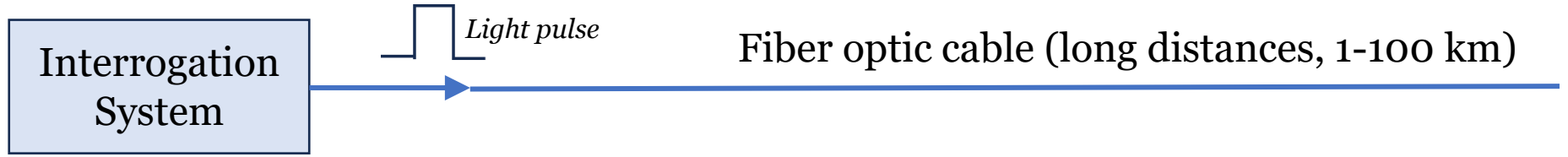


Distributed Strain Sensing of ITC Pressurization Experimental Validation

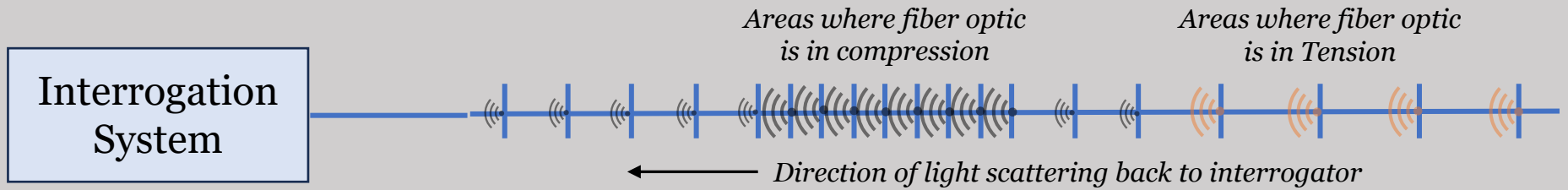
HRMS – Fiber Optics

Fiber optic interrogation is both simple and complex, with relatively complex optical physics being leveraged to implement relatively simple instrumentation methods that have major advantages over traditional sensors.

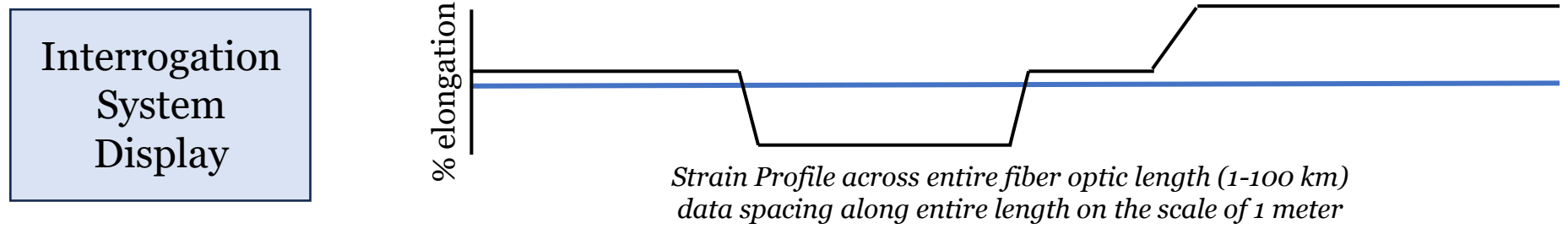
Step 1: Interrogation system sends a laser light pulse down a fiber optic cable



Step 2: Light interacts with the cable and some scattered light comes back to the interrogator. The signal coming back is a function of the strain environment in the cable.



Step 3: The transit time and intensity of the scattered light is precisely measured, providing measurements along the entire fiber optic cable length



HRMS

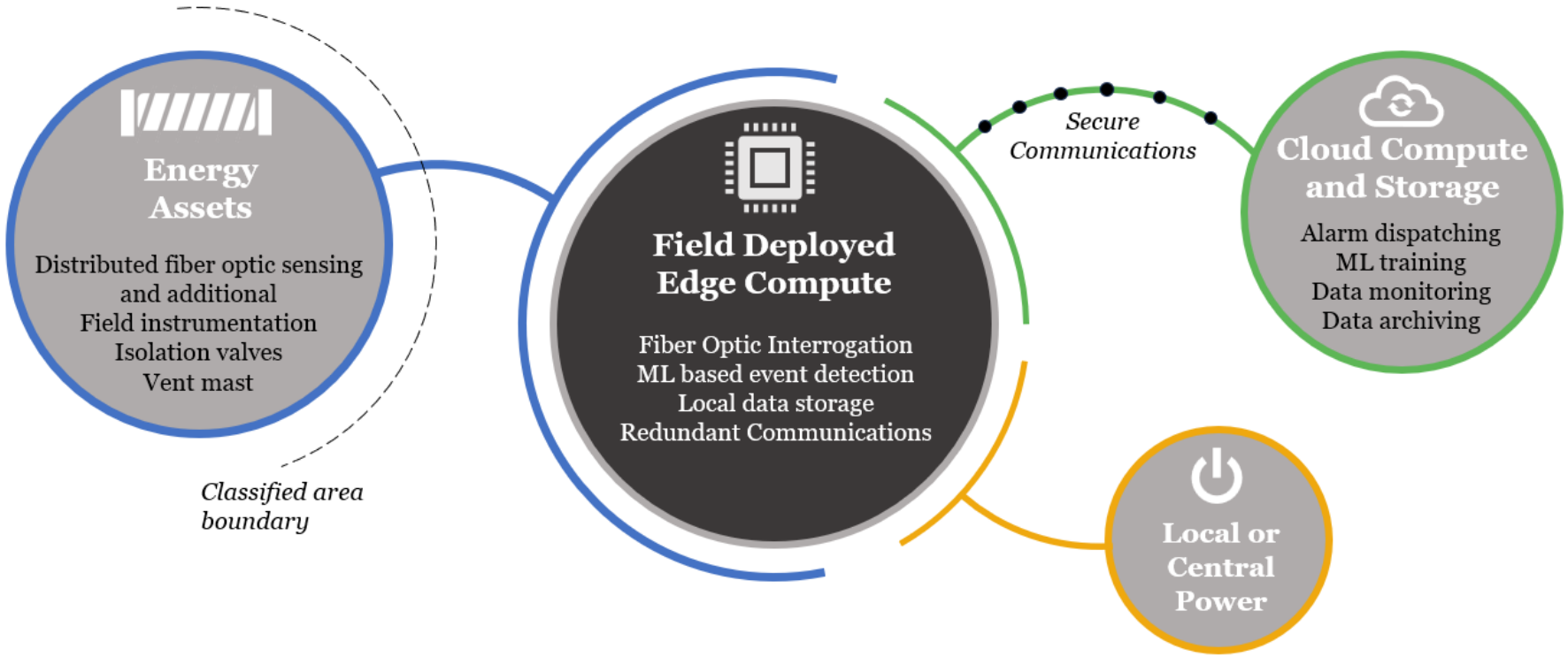
Innovation Highlights

Real-time Monitoring:
Embedded sensors enable continuous interrogation of the ITC with ML based event classification

Diverse Data:
Impact events, ground quality, third-party threats, pressure, flow, temperature, leak localization

Reduced OpEx, Reduced Liability :
Identify and mitigate risk before consequence becomes severe

Continuous Product Optimization:
Manufacturing data aligned with real-time health and risk monitoring system to ensure product optimization



Getting H2 Projects in the Ground

What we have learned and where we know the market is heading

One Issue We Deal With

"Hydrogen is like natural gas, so the technical aspects, safety considerations, and costs will be comparable."

Can be true, however, we really need to understand our projects goals and levers within each hydrogen project

- Aspects of the O&G sector are standardized or have clear procedures/regulations, this is **not** the case for hydrogen
- Project developers need to understand the entire value chain of hydrogen to ensure they don't have blind spots.
- Gaps in Codes and Standards will lead to delays in approvals.
- Everything starts at the planning process, don't get caught off-guard!

Source: https://www.nrel.gov/news/program/2022/fast-flow-future-heavy-duty-hydrogen-trucks.html

Let's Go Through a Scenario

Set up a quick case study:

- Pretend we are a supporting a generic hydrogen hub
- Demonstration Plan:
  - Onsite production
  - Support small Class 7 or Class 8 truck fleet: 5 – 10 trucks per day
  - Local bus demonstration: 5 – 10 buses per day
- Expansion Plan:
  - Large M/HD fueling station
  - Local and regional bus fleet fueling
  - Prime or back-up power support in surrounding area

Quick Case Study

High-Level View, What do we need to do?

1. Set preliminary goals, timelines, and budgets to establish success metrics. Perform high-level check on feasibility

2. Detailed cost and technical analysis (feasibility):
   - Production type (CI if important), H2 demand, system sizing, project footprint, safety considerations
   - Technoeconomic analysis – need to include CapEx and Opex, understand scaling, timelines, and supply chain risk

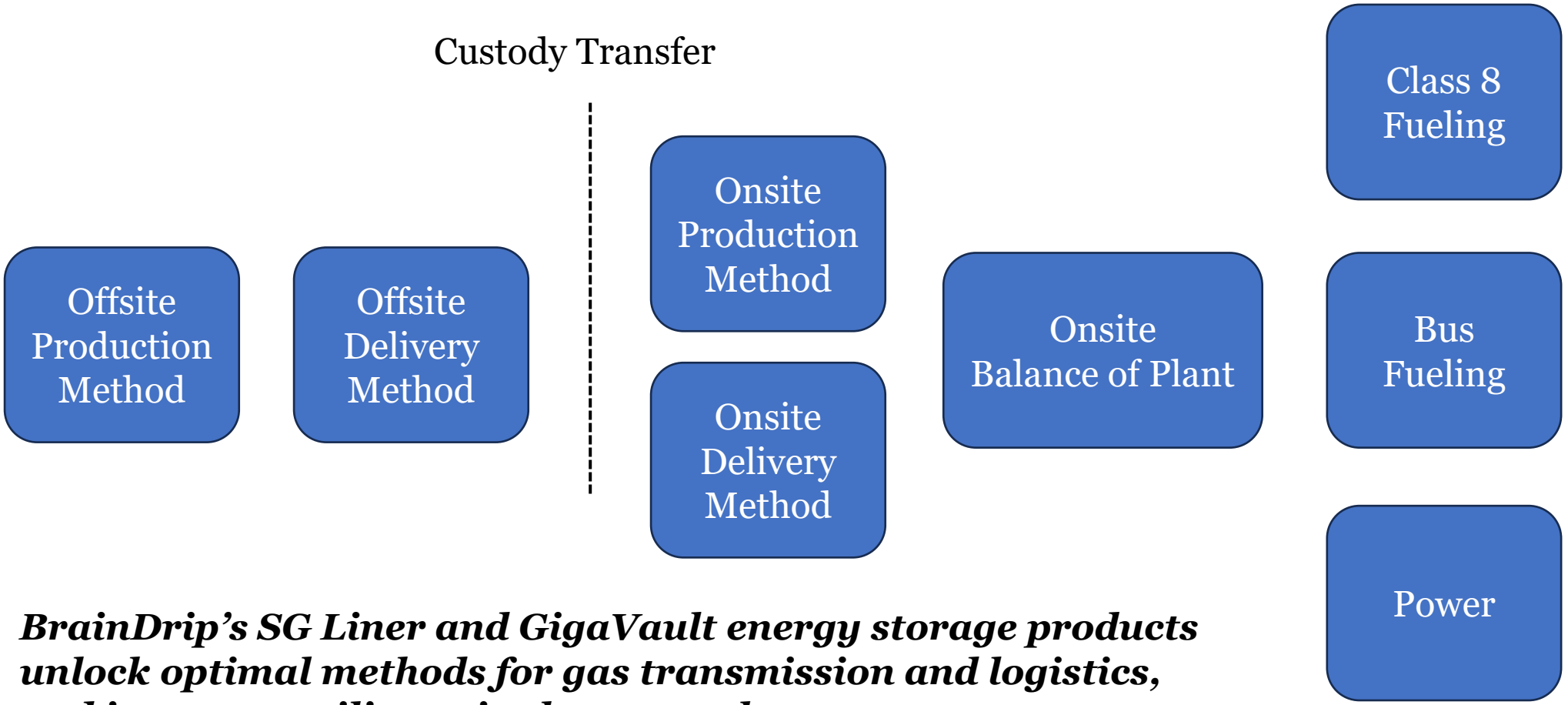
Quick Case Study

High-Level View, What do we need to do?

3. Deep dive into the technical aspects of the project (FEED)
   - Evaluate preferred hydrogen delivery method (GH2, LH2, carriers)
   - Supplier RFQs and evaluations
   - Initial drawings
   - Risk assessment/s
   - Decision making on path forward

4. Execute the project

Block Diagram



BrainDrip's SG Liner and GigaVault energy storage products unlock optimal methods for gas transmission and logistics, and improve resiliency in these complex energy systems

Pitfall #1 – Delivery Methods

It matters… A LOT!

- What is useful for today and scalable for the future?
- What is the Hydrogen production method? What mechanisms do you have to scale?
- What are your end-use applications?

1.3-mile-long, 16” ITC installed at 8 ft./min. during pilot program with strategic partner.

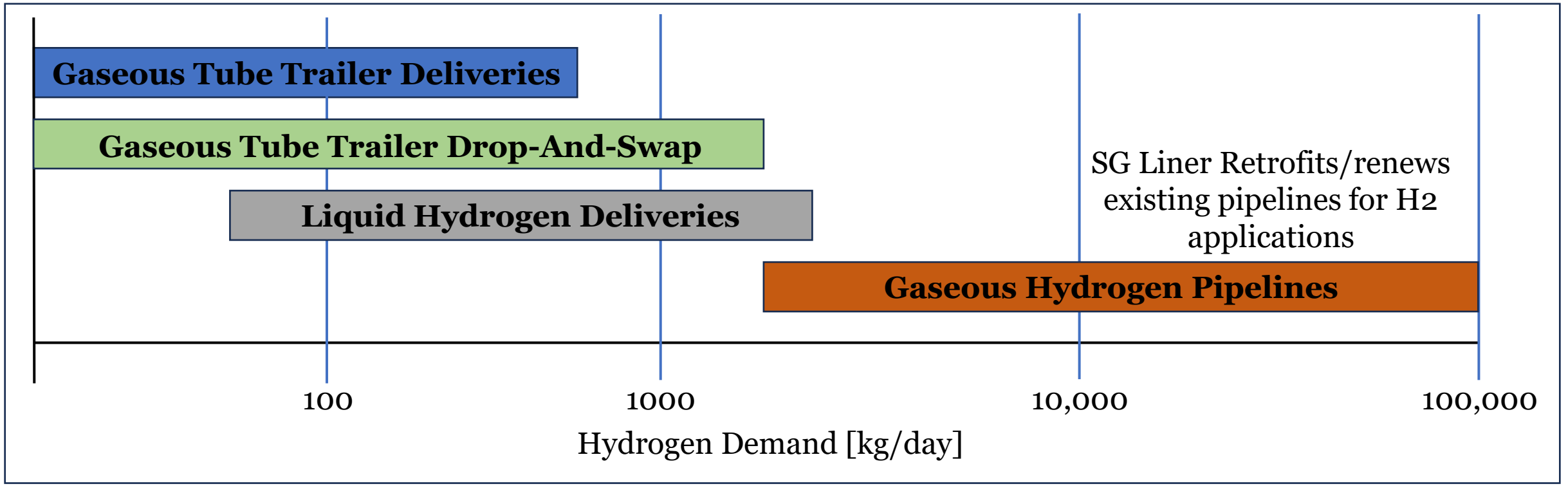
Pitfall #1 – Delivery Methods

Trends and Lessons Learned

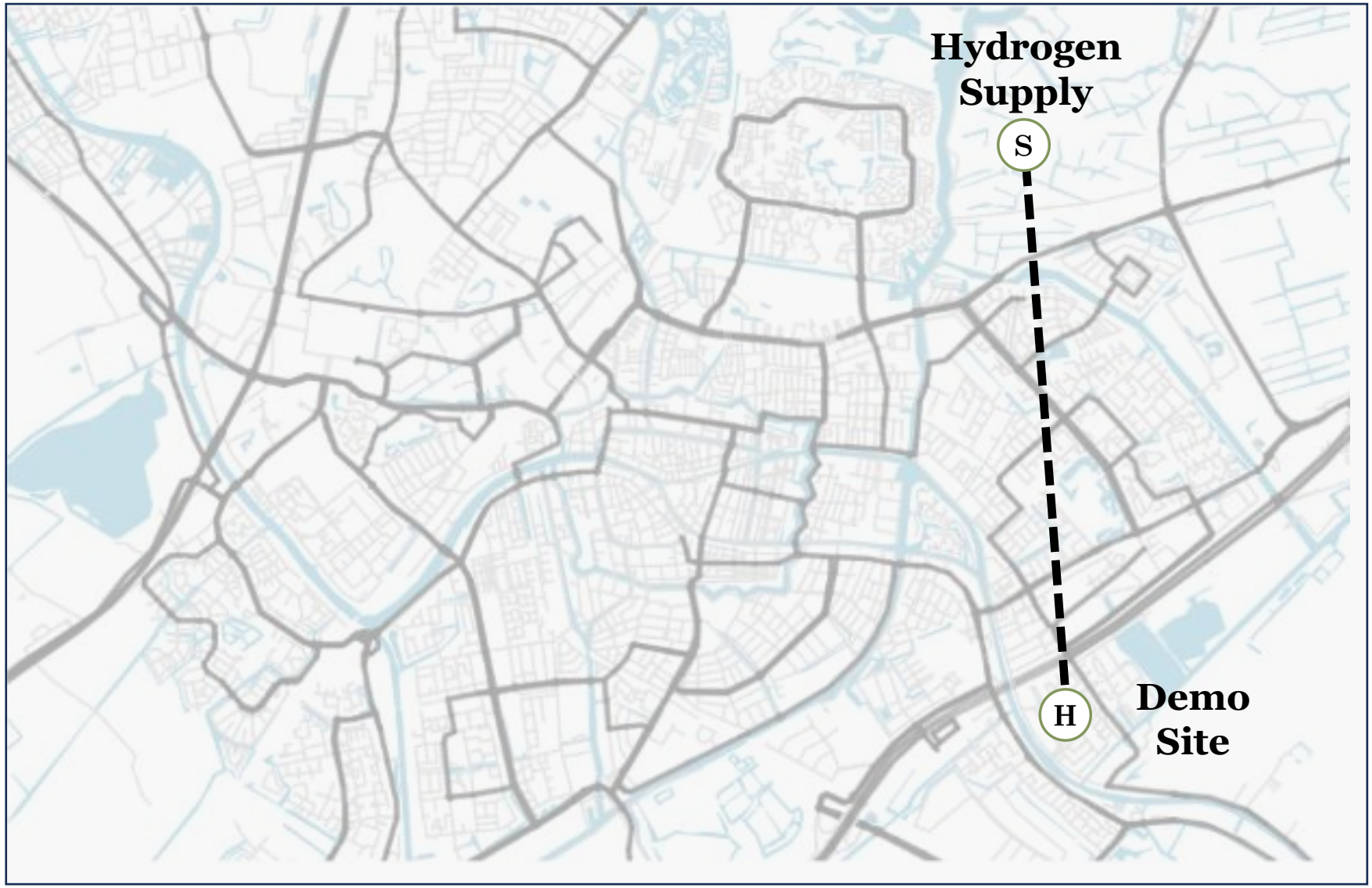
- People are loving LH2 today… but will the hype fade?

- Trends in the early market: small stations (100 kg/day), slightly larger small stations (300 kg/day), now targeting another step change (1,000 kg/day)
  - The next step change is dictating a move towards LH2 – but what happens with another step change?
- BrainDrip's products overcome the challenges of gas delivery, reenabling GH2 as an advantageous alternative to LH2 as market applications scale to and beyond local LH2 storage

Delivery Technology Limitations

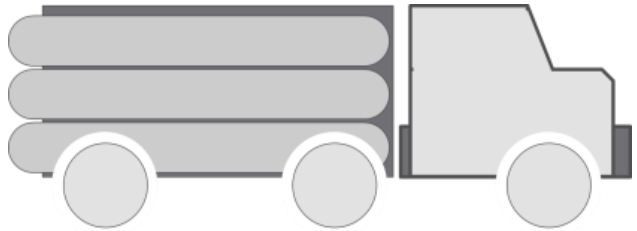


Hydrogen Network Progression



EARLY STAGE

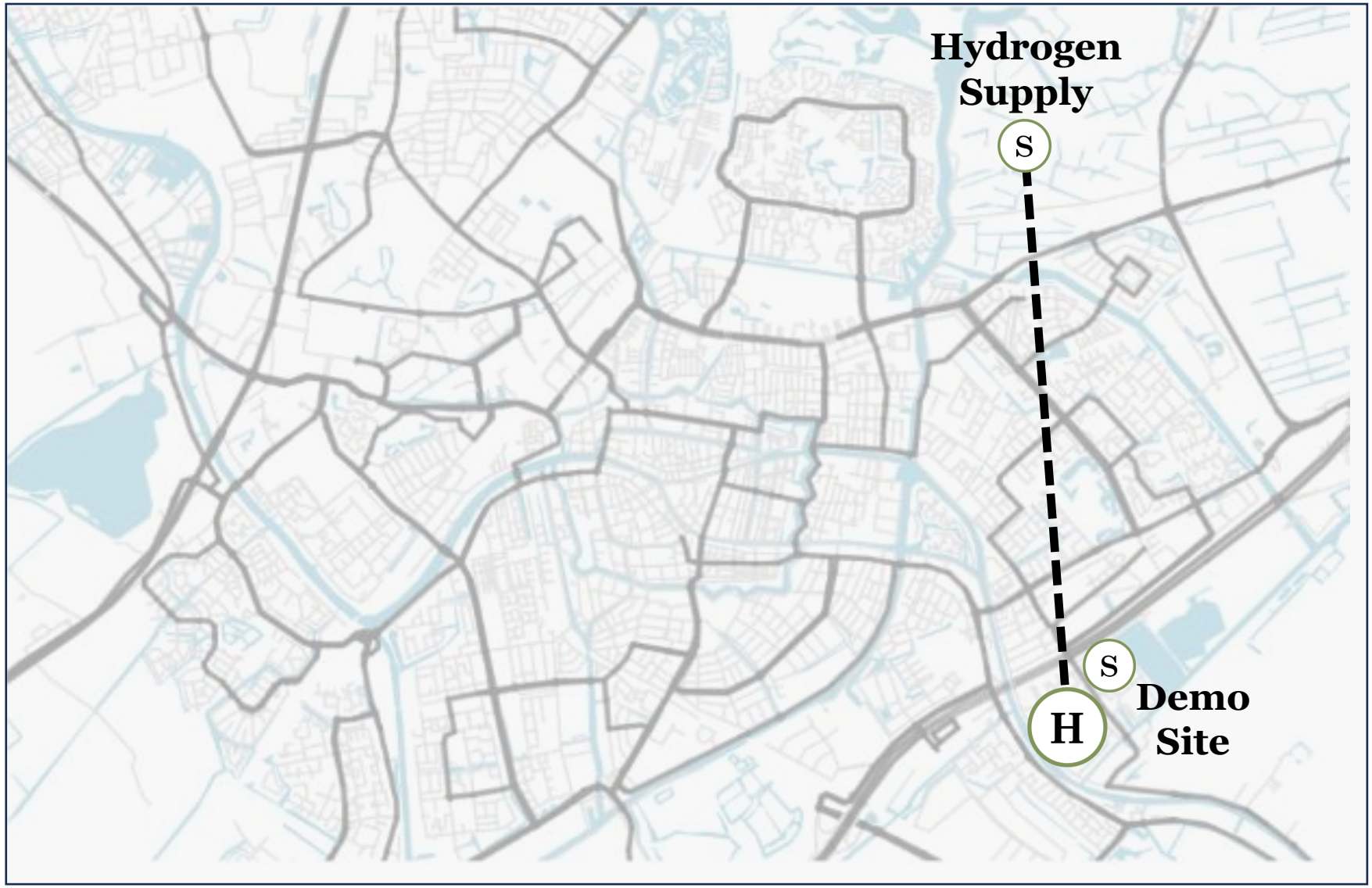
Gaseous Tube Trailer: Pilot Project/Demo



Site Requirements

Fleet Size:	Small
H_2/day:	650 kg

Hydrogen Network Progression



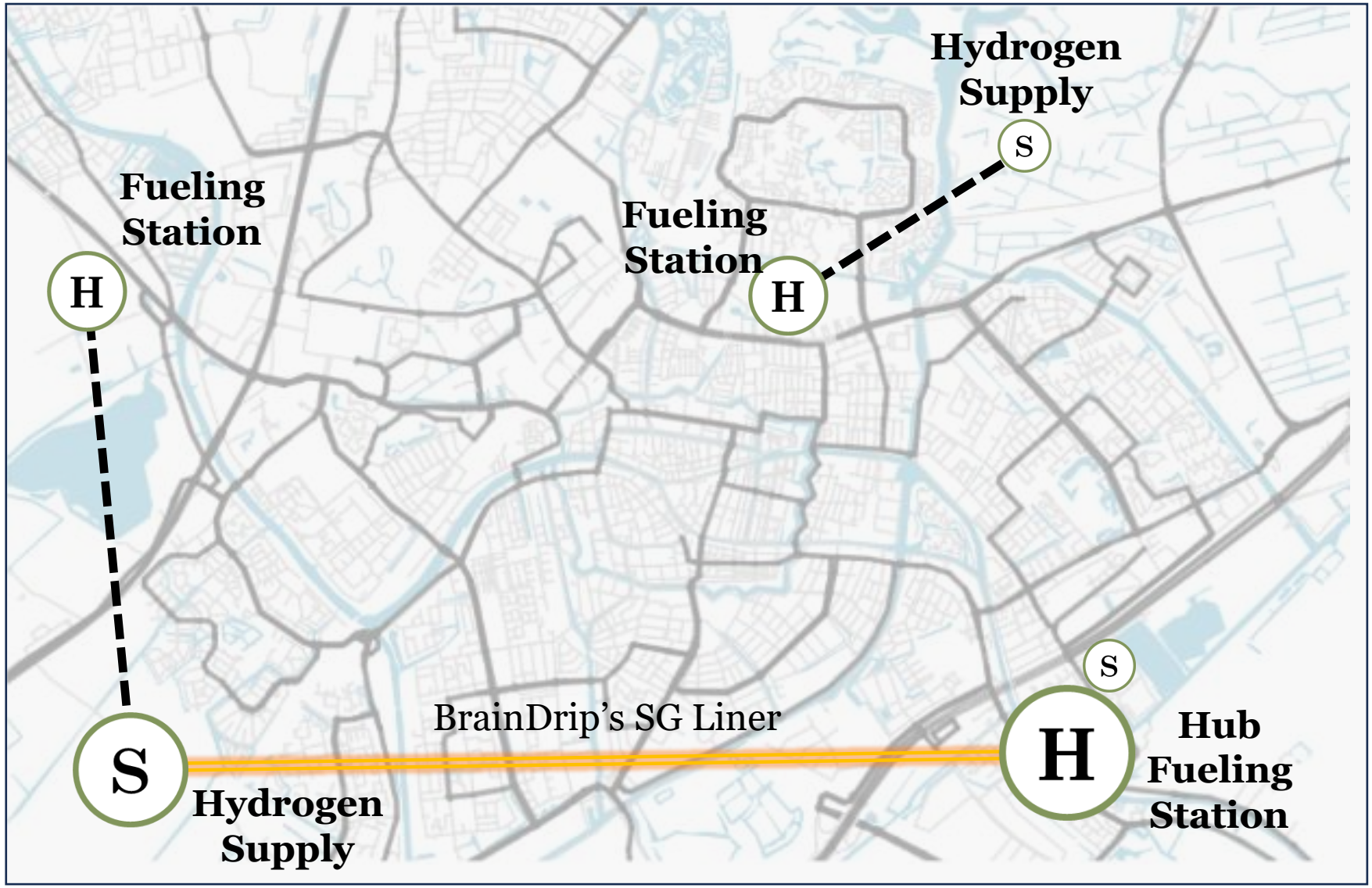
EARLY STAGE EXPANSION

- Addition of vehicles
- Bring on site production
- Tube trailer supply maintained

Site Requirements

Fleet Size:	S/Med
H_2/day:	1,000+ kg

Hydrogen Network Progression



NETWORK DEVELOPMENT

- Increase production
- Additional fueling stations
- Pipeline connecting to hub

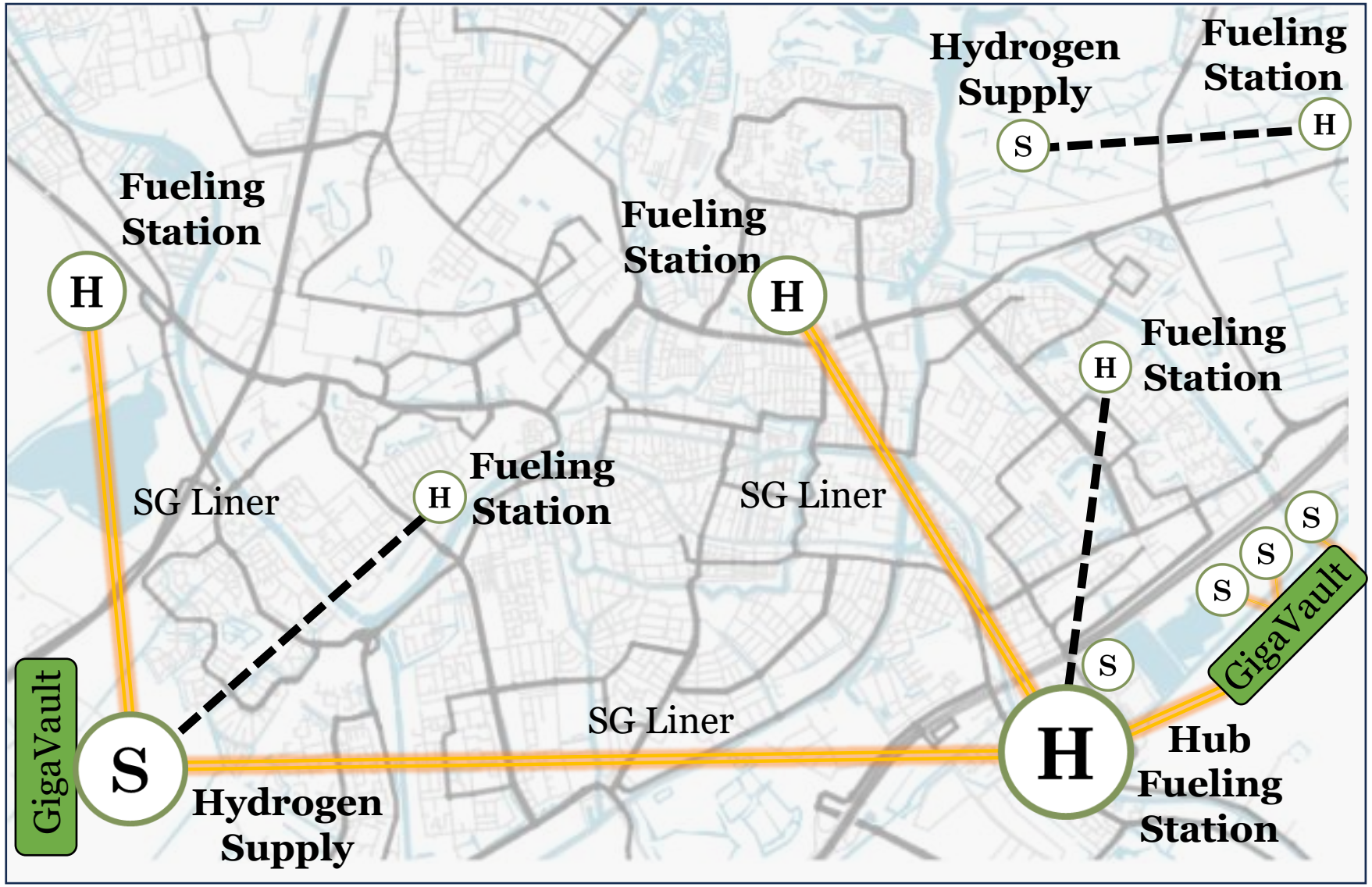
Network Requirements

Fleet Size:	Medium
H_2/day:	5,000+ kg

Tube Trailer

Pipeline

Hydrogen Network Progression



NETWORK MATURATION

- Distributed production
- Large scale storage capacity additions
- Additional pipelines
- Additional stations
- Redistributed tube trailer gas deliveries

Tube Trailer

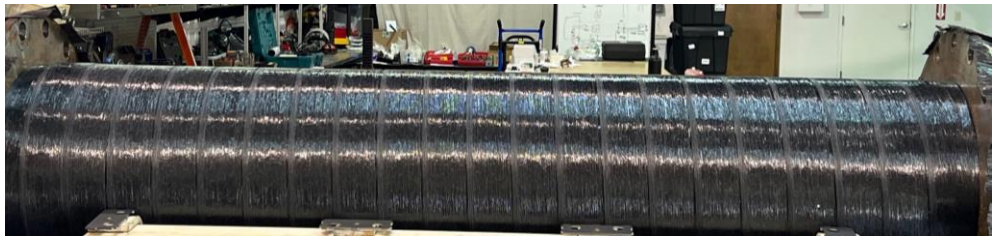
Pipeline

GigaVault — Large Scale Storage

Pitfall #1 – Delivery Methods

Don't get caught up in trends of today

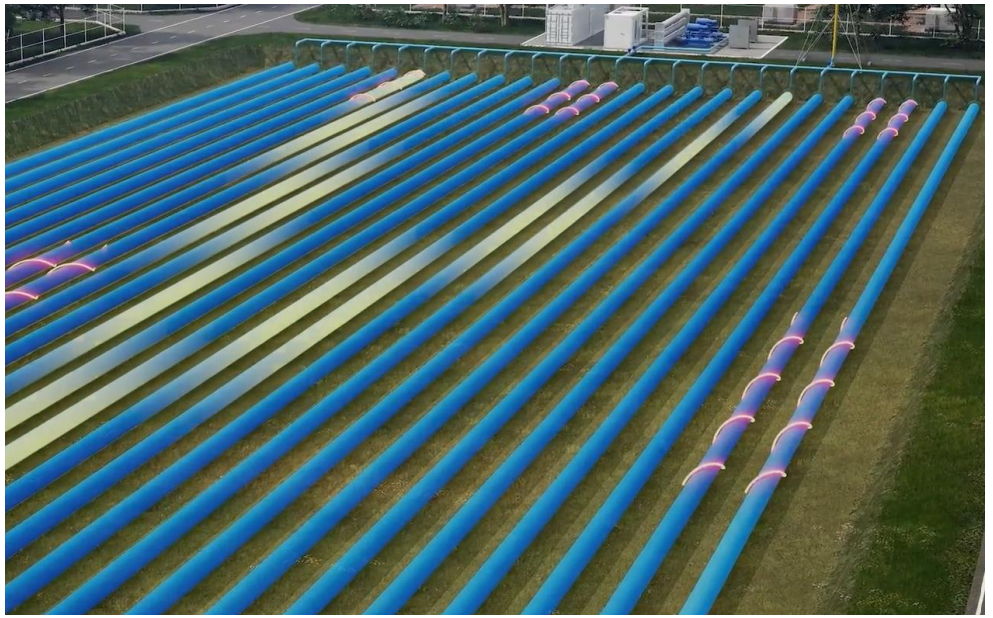
- "There is a reason the natural gas network looks the way it does"
- As hydrogen scales, pipelines are the future – early projects must find ways to incentivize hydrogen pipelines
- In many cases, these pipelines exist today, they just need a product like SG liner to make them hydrogen ready



Pitfall #2 – Onsite Storage Needs

Don't underestimate the need for significant onsite storage

- Variance in delivery availability could mean time without fuel coming in.
  - There isn't a pipeline to tie into (likely) – need "resiliency"
- Different applications will require different pressure levels:
  - Class 8 fueling - 700 bar
  - Bus fueling - 350 bar
  - Prime/backup power - 10 bar



BrainDrip's Pitchfork GigaVault energy storage solution, offering flexibility in scale and storage pressures

Pitfall #2 – Onsite Storage Needs

A pet peeve with storage:

Capacity ≠ Useable

- A site could have 1,000 kilograms capacity but only a few hundred kilograms are useable for a high-pressure application

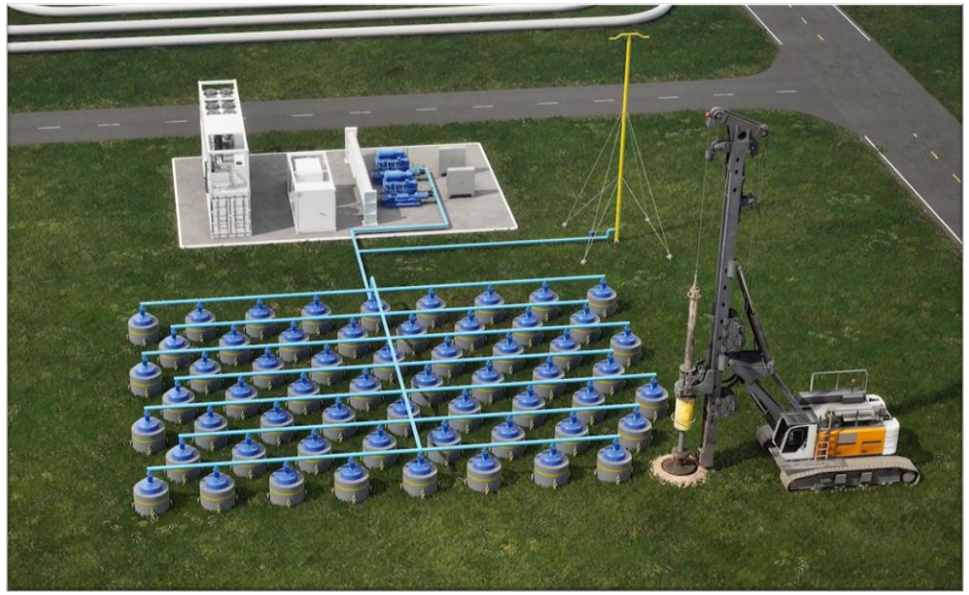
- Our case study:
  - Class 8 trucks: high-pressure, fast fills
  - Buses: medium pressure, fast(ish) fills
  - Power: low pressure, consistent flow

Source: https://www.nrel.gov/news/program/2022/fast-flow-future-heavy-duty-hydrogen-trucks.html

Pitfall #2 – Onsite Storage Needs

Understand your storage requirements

- Hubs will need significant storage and variability in deliveries could mean days worth of backup storage
- It is cheaper to store large volumes at lower pressures if you have the footprint
- For fueling, need switchable hydrogen at high-pressure.
  - E.g., the you need a lot of individual vessels at high pressures that the station switches between rapidly
- Much to optimize between storage and compression

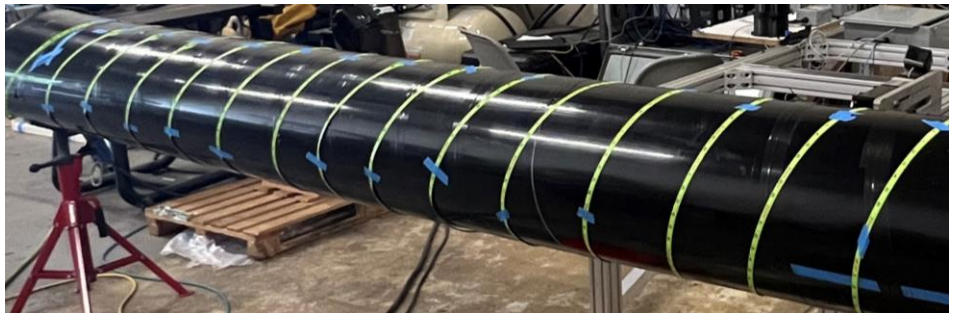


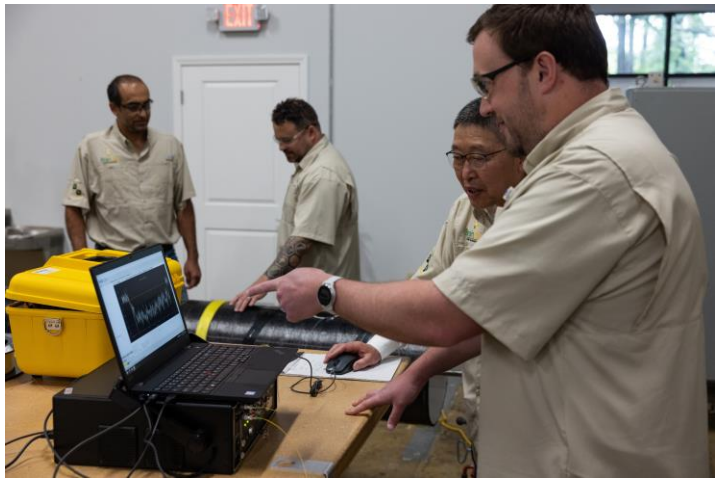
BrainDrip's Silo GigaVault energy storage solution, offering high storage densities while minimizing footprint

Pitfall #3 – Underestimating Approval Process

You will need:

- Code evaluations and interpretations
- Risk assessments
- New safety & training modules
- Optimization of designs and applications
- More engagement of an AHJ than any other project you have worked on previously

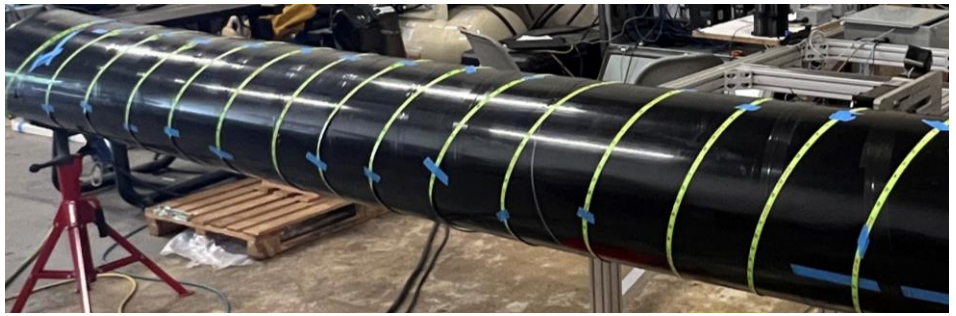


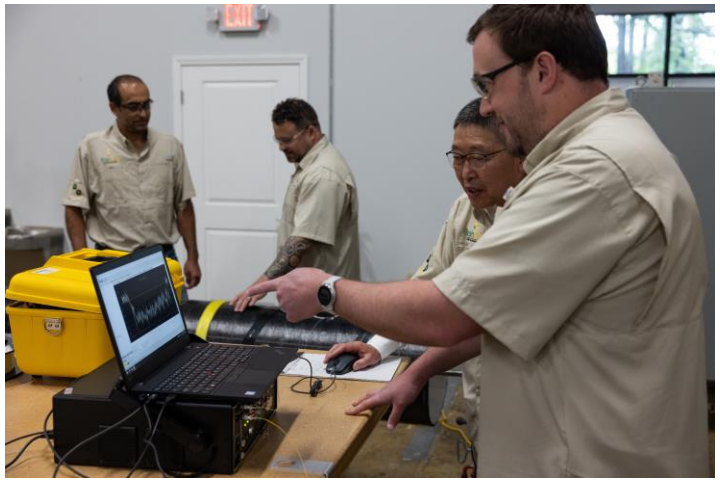


Pitfall #3 – Underestimating Approval Process

Advanced Safety Systems and Testing Will Accelerate Approvals

- Fiber optics for operational and safety assurance
- Holistic, systems-based approach to risk modeling
- For hydrogen, understand your materials and failure mechanisms





BrainDrip's Health and Risk Monitoring System provides continuous monitoring of SG Liner and GigaVault products

What will it take to get hydrogen projects in the ground?

- People that are willing to take the time to understand the technical and financial risks but still are willing to take that risk - **The Defiant Ones that see opportunity**

- People willing to put in the hard work once decisions are made

Advantages of Working with BrainDrip

Made in the U.S.A.

- Headquarters & Manufacturing facility in Jacksonville, Florida
- Offices in Denver, CO
- Ability to source 100% of materials within the U.S.

16” ITCs at field site during demonstration project

Thank you!

Contacts

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