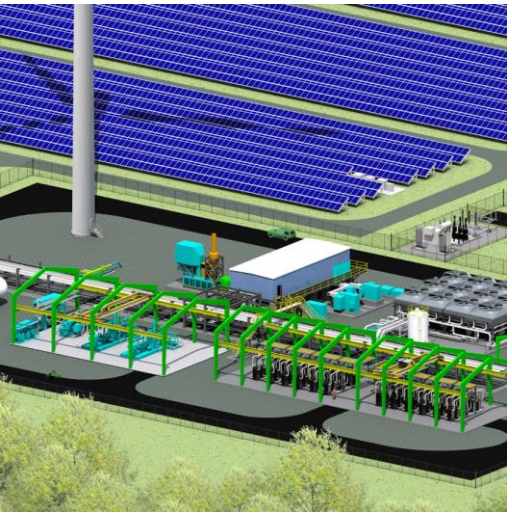
Large Scale Liquid Hydrogen Storage

Mark D. Butts, VP Engineering

CB&I Storage Solutions





MCDERMOTT | CB&I STORAGE SOLUTIONS

SNAPSHOT OF OUR BUSINESS

CB&I STORAGE SOLUTIONS

CB&I Storage Solutions - designer and builder
of storage facilities, tanks and terminals

200+
Active Contracts

~$18.5 million
Average Contract Size

$19.5 billion
Tracked Market

650
Tracked Opportunities

59,000+
Storage Structures Built

~4,000
Employees Worldwide

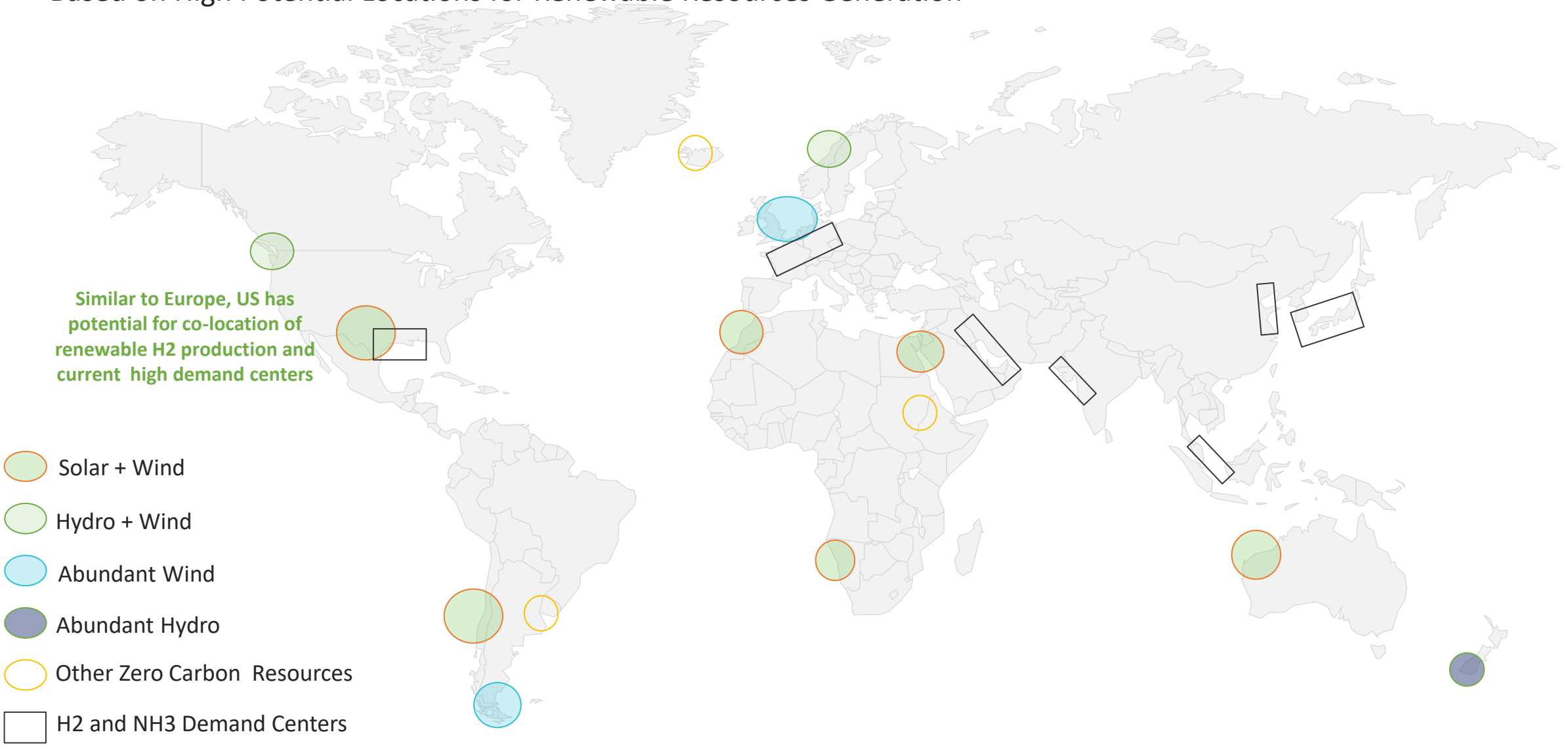
30+
Locations Worldwide

~100
Countries Served

HYDROGEN MARKETS – GLOBAL VIEW

CB&I STORAGE SOLUTIONS

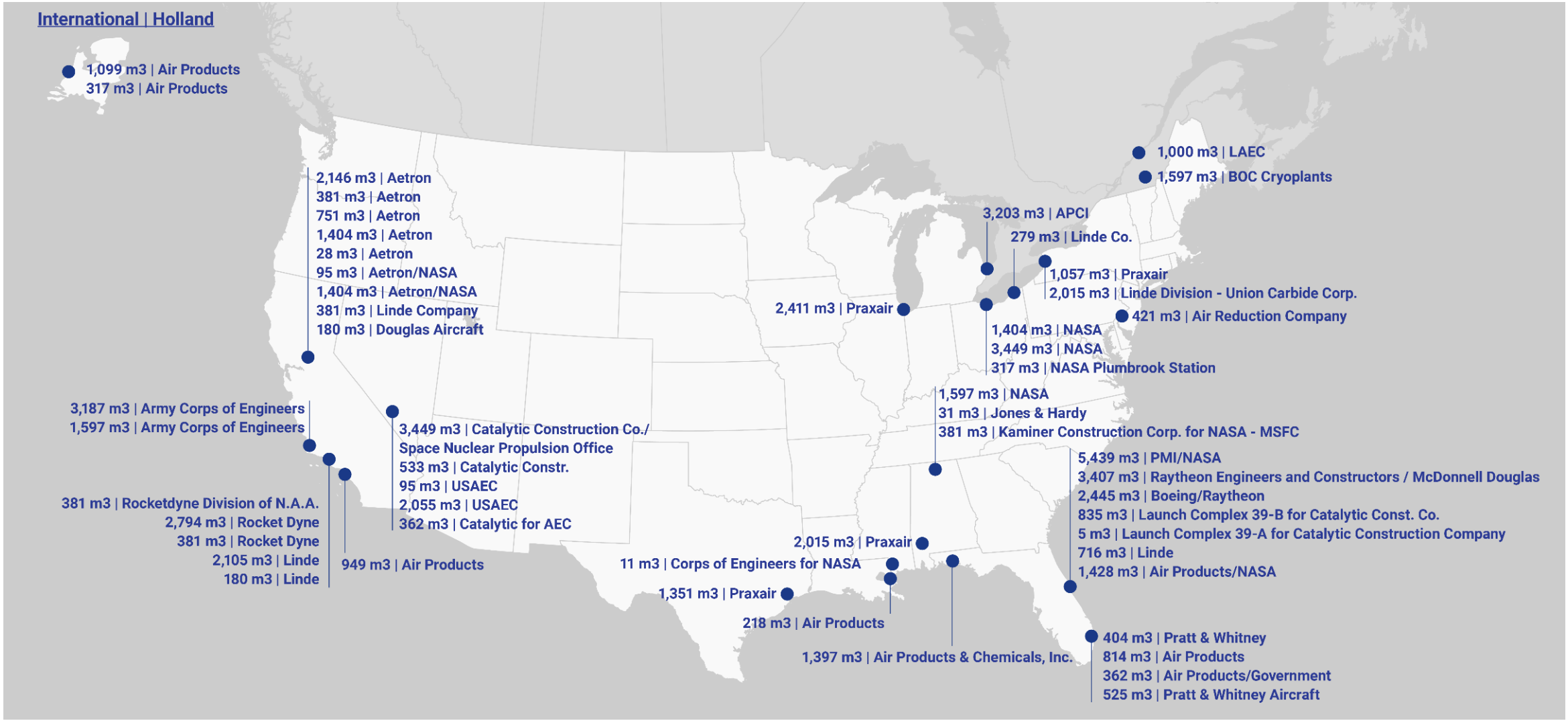
Based on High Potential Locations for Renewable Resources Generation



Source: Global CCS Institute and Center on Global Energy Policy- Columbia University

LIQUID HYDROGEN STORAGE EXPERIENCE

CB&I STORAGE SOLUTIONS

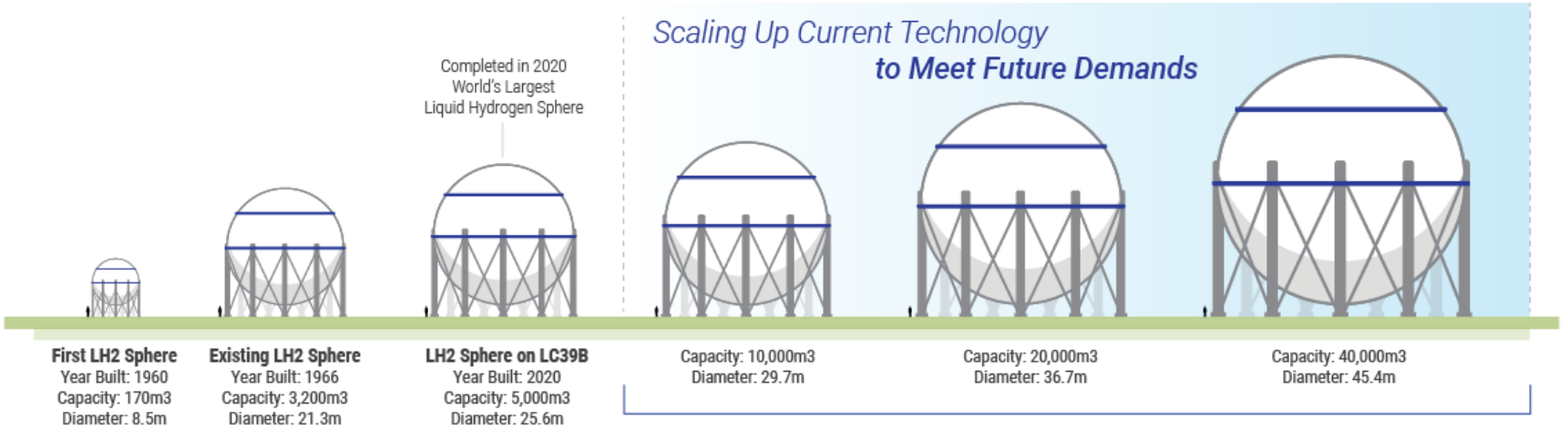


Liquid hydrogen storage built by CB&I Storage Solutions 1960's to Present

CB&I SNAPSHOT 2021 – LIQUID H2 STORAGE

CB&I STORAGE SOLUTIONS

- CB&I Storage Solutions can now offer 40,000 m^3 LH2
- Developing up to 100,000 m^3 under a US DOE funded study
  - Shell, CB&I, NASA, GenH2, and University of Houston
  - 2021 - 2024



Extended Capacity Range We Can Now Offer

DOE H2@Scale

100,000m3
future capacity

Industry partners to develop feasible materials

Next generation insulation systems

Remove requirement for vacuum annular space

Build demonstration vessel to prove the technology

This is the target of our Shell/NASA/DOE project

1960 → 1966 → 2020 → Q1 2021 Development → 2021 and Beyond

ADVANCING THE STATE OF THE ART – 40,000 M^3 LH_2

CB&I STORAGE SOLUTIONS

Vessel	40,000 m^3 liquid hydrogen storage
Storage System	Double wall vacuum insulated storage sphere
Ready for Market	CB&I's design and constructability study is complete for 40,000 m^3 storage sphere.

Storage Technology

- *Liquid hydrogen stored at -253°C (-423 °F)*
- *Vacuum insulated annular space made possible at large scale with proprietary design and construction innovations*
- *Optional glass bubble bulk fill insulation instead of perlite to reduce boil-off*
- *Optional integrated refrigeration and storage heat exchanger to keep hydrogen liquefied and minimize boil-off*

LH_2 Storage for NASA, Cape Canaveral, FL

CB&I STORAGE SOLUTIONS

Client: Precision Mechanical, Inc.
Location: Cape Canaveral, Florida
Services: Design, Fabrication & Construction
Size: 1.25 Million Gallons (~5,000 m^3)

Technological Advancements

- *Use of glass bubble bulk fill insulation instead of perlite to reduce boil-off*
- *Internal Integrated Refrigeration and Storage heat exchanger to keep hydrogen liquefied and minimize boil-off*

LARGE SCALE LH2 – DOE H2@SCALE

CB&I STORAGE SOLUTIONS

Goals and Challenges

3-year study – Shell, CB&I, NASA, GenH2, U of Houston

Develop a first-of-its-kind large-scale LH2 storage vessel

- *Ultra-low boiling point (20K)*
- *Insulation systems*

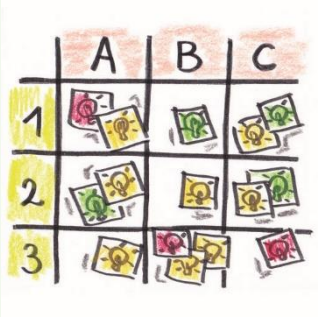
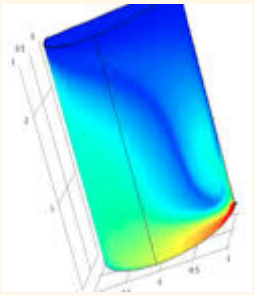
Safety & Integrity
Regulatory Bodies

CAPEX
Relative Costs

Boiloff Rate
%/Day target

H2@Scale - Project Outline and Targets

CB&I STORAGE SOLUTIONS

Concept Development	Cryogenic **Testing** and Vessel **Design**	Thermal **Modeling**	Construction **Methods**	Demonstration Tank **Construction**	Startup, Testing, **Evaluation**
					

End-of-Project Targets (3 years)

- *Affordable large-scale (up to 100,000 m3) LH2 storage tank*
- *3D thermal model for both the demonstration and large-scale LH2 tanks.*
- *Build a LH2 based cryogenic testing apparatus to measure insulation thermal properties down to 20 K*
- *The technology demonstration through construction, startup, and testing for a small-scale LH2 storage tank*


CB&I
STORAGE
SOLUTIONS