



HYDROGEN Solid-State Storage

Breakthrough technology in
low-cost, convenient storage
of hydrogen in a solid media



Green Fortress Engineering

Origins

- Incorporated 2016 as a C-corp. (GFE, Inc.)
- Launched as university spin-up (Indiana University)
- Presently 100% owned by P. Schubert, CEO & President
- **NINE** US Patents – all are issued & active:

8,691,115	8,456,562	9,416,326	8,845,772	
8,518,856	7,721,601	7,833,418	8,673,811	10,093,875

**Develop and
deploy
sustainable
energy self-
sufficiently
around the world**

GFE Mission Statement





Targeted User Problem

Fast, light, convenient, safe high-density energy storage

Military & Industrial

- Fuel cell auxiliary power
 - Base and portable ultra-quiet gensets
 - Clean, pollution-free baseload power
 - Personal power packs
- Fuel cell vehicles
 - Highly-efficient and nearly silent
 - Long range, lightweight storage
 - Rapid refueling

Civilian Applications

- Materials handling equipment
 - Warehouses – fork lift trucks
 - Ground support equipment - airports
- Passenger vehicles – extended range
- Portable electronics and drones
- Electric aircraft
- Heavy-duty trucks

About Us

Energy Self-Sufficiency for Everyone

- Four (4) patents in the U.S.
- Technology Readiness Level **TRL 3-4**
- Seek partner & funding for pilot
- Funding from NSF + State of Indiana
 - \$225,000 + \$50,000
- Support from Sumitomo (Japan)
 - \$60,000
- H2 Shot Winner (DOE)
 - \$60,000 (January 2023)
 - \$400,000 (April 2024)



NSF Funded



DOE Funded

A scanning electron microscope (SEM) image showing a highly porous, interconnected network of silicon particles. The structure is dark and textured, with many small voids and channels. The image is set against a dark blue background with white geometric shapes.

High surface area porous
etch on a silicon particle

x33,000

5.0kV



Our Promise

Low-cost, convenient, hydrogen storage

Green Fortress Engineering, Inc.

- Established in 2016 in Indiana (U.S.)
 - Four US patents in hydrogen storage
 - Partnership with university (IUPUI)
 - \$360k in funding
- Porous Silicon with catalyst
 - Earth-abundant materials
 - Benign and safe for humans
 - Scalable from nano-scale to utility-scale

International Presence

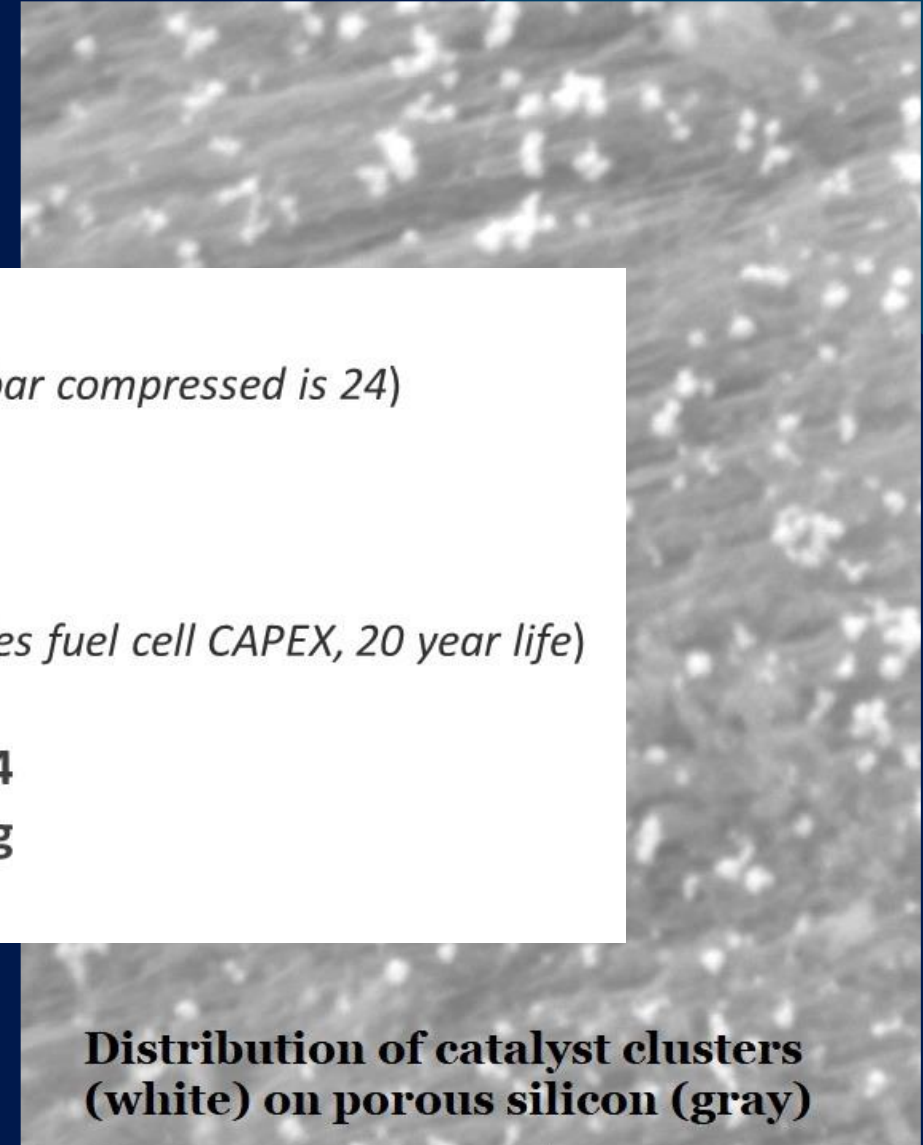
- Business Development Manager in CH
- Business Development Manager in DE
- Funding from Japan
- Sister company formed in Estonia
- ROW sees potential for hydrogen
- Leaders: Japan, EU, Gulf States



Hydrogen Storage

... by the numbers

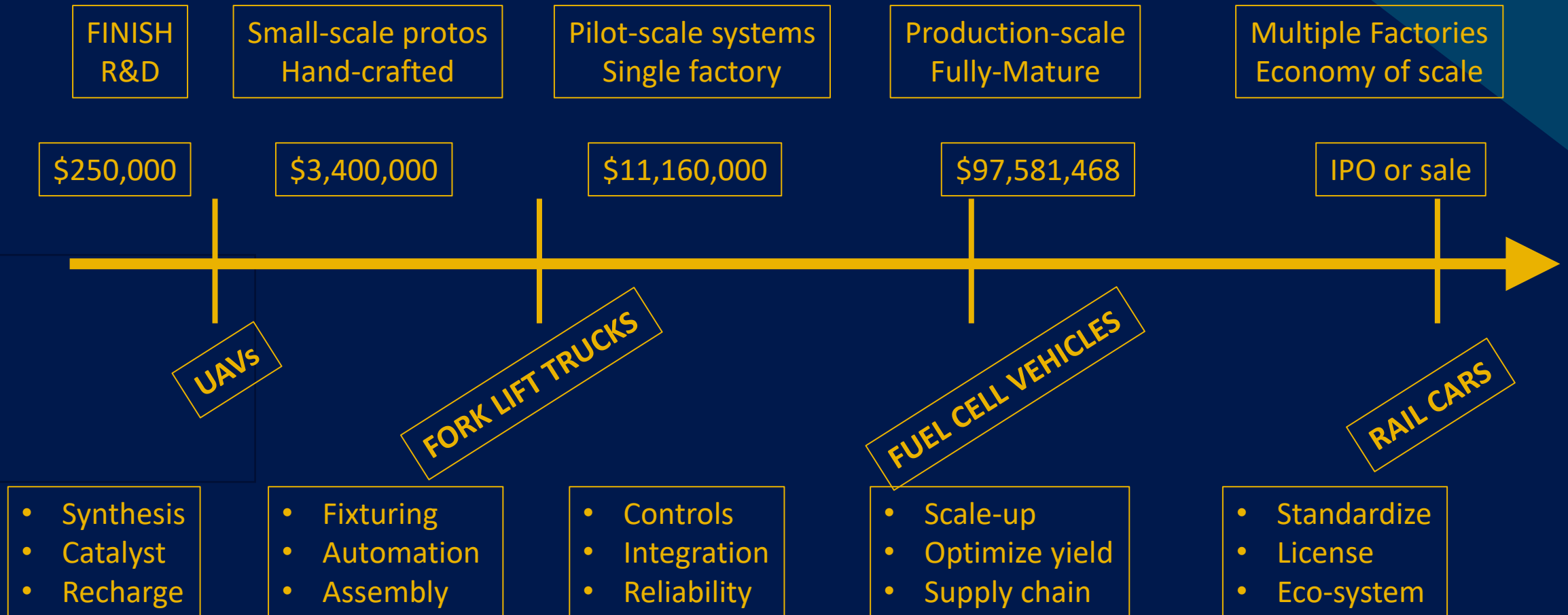
- Gravimetric storage density (system): **5.8% w/w**
- Volumetric storage density (media): **37 g/liter** (*700 bar compressed is 24*)
- Fill **5 kg** in **3.5** minutes with **8** bar at 200 C
- Specific cost (at maturity): **7.72 \$/kWh**
- Recharge energy (round trip): **2.5 kWh/kg**
- Levelized Cost of Storage (system): **80 \$/MWh** (*includes fuel cell CAPEX, 20 year life*)
- Silicon is earth-abundant: **#2** element in Earth's crust
- Patents (issued) on hydrogen storage in porous silicon: **4**
- Scales from Smart Dust to Grid Level Storage: **$\mu\text{g} \rightarrow \text{Mg}$**



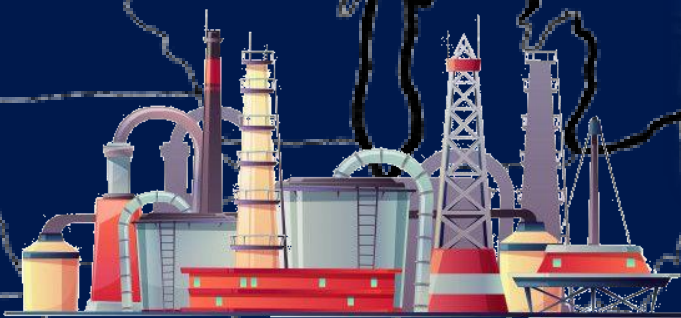
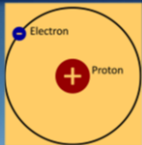
**Distribution of catalyst clusters
(white) on porous silicon (gray)**



Product Development & Funding



HYDROGEN ECOSYSTEM





FAQs

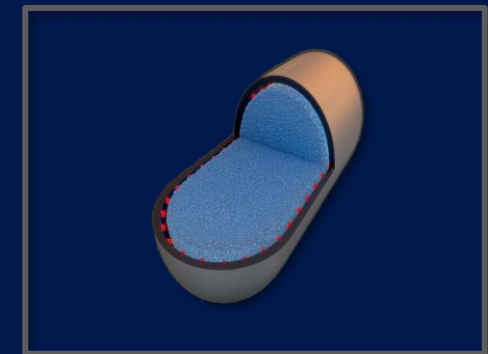
- **What do the patents protect?** Four patents cover the following: (1) tank design; (2) particle formation and etch; (3) catalyst action; and (4) system design. Eleven additional IP topics pending.
 - **What's in a name?** Variously called the “Hydrogen Sponge”, the Hydrogen (H₂) Ultra-Storage (H2US) or the “Hydrogen Solidifier”. The technical description is: solid-state hydrogen storage on catalytically-modified porous silicon.
 - **How does the product help in transport and storage?** H2US has three advantages: (1) low energy overhead (high efficiency); (2) low cost, safe, and recyclable; and (3) fits in any shape. Neither cryo-liquid or high-pressure gas has any of these. H2US is double the storage of metal hydrides and does not suffer exothermicity.
 - **Does converting large quantities of H₂ into product have advantages over other conversion systems?** Hydrogen is an energy carrier, so you MUST have storage and transport which has low parasitic energy. Else, it will be uneconomical versus alternatives.
 - **How costly are projections for conversion?** Expensive materials? Cost of **\$7.72/kWh** is extremely low - 30% better than the DOE goal.
- **Product can be transported by rail, truck and air in greater quantities due to density.** Yes, exactly. There exist lab materials with higher storage density, but they are exotic, and ill-suited for volume production and rugged operation.
 - **Explain the bicycle pump comparison?** The H2US re-charges at the pressure of a bike tire pump – it can even be manually operated. Compare to DOE composite tanks, which require huge, noisy, power-hungry compressors costing \$2M+ per re-charge station.
 - **Amplify the value of the product for the hydrogen production plants such as cost, efficiency, speed of delivery, competition.** H2US is best-in-class among ALL competing hydrogen storage.
 - **What does an investment cover?** Product development, lab, talent, labor, testing? Each tranche of investment advances technology readiness and retires risk. No show-stoppers found. However, this is still high-risk tech, suited to savvy investors who do not shirk on due diligence.
 - **How long to bring the product to market?** Time to market is under two years when funding is not the gating pace.



Competitive Analysis

Specific Performance Metrics for Hydrogen Storage

Hydrogen Storage Technology Comparison					
METRIC	<i>GFE/H₂US</i>	<i>Metal Hydrides</i>	<i>Compressed H₂</i>	<i>Organic Liquid Carrier</i>	<i>Cryogenic liquid</i>
Capacity	Yellow	Red	Yellow	Yellow	Green
Cost	Green	Green	Yellow	Green	Red
Speed	Green	Red	Green	Yellow	Yellow
Volume	Green	Red	Green	Yellow	Green
Density	Green	Red	Green	Yellow	Green
Parasitic Energy	Green	Yellow	Red	Red	Red
Lifetime	Green	Yellow	Green	Green	Yellow
Toxicity	Green	Yellow	Green	Yellow	Green
Thermal Mgmt	Yellow	Red	Green	Yellow	Red



Artist's illustration of capsule-style hydrogen storage vessel

Beachhead Markets



- Drones, Aviation
- Vehicles, Heavy Trucks
- Portable Electronics
- Materials Handling & Dreyage
- Utility-Scale Energy Storage





SWOT

Strengths, Weaknesses
Opportunities, Threats

<ul style="list-style-type: none">• Low-cost• Fast charge• Highly efficient• Scalable• Safe	<ul style="list-style-type: none">• Hydrogen generation• Fuel cell adoption• Infrastructure• Regulations• Early-stage R&D
<ul style="list-style-type: none">• Mobile & portable use• Stationary & backup use• Super-clean, super-green• Distributed, global solution• Universal energy storage	<ul style="list-style-type: none">• Battery breakthrough• Supercapacitor breakthrough• MOF breakthrough• Disinformation campaign• Status quo defenders





Meet the GFE team



Peter Schubert, Ph.D., P.E.
CEO



Felix Trojer, Ph.D.
Business Development Exec



Randall Gatz, Ph.D.
Business Development Exec



Cyrus Summerlin
Chief Operating Officer



Tom Marchok
VP Sales & Marketing



Megan Headean
Finance



John Christenson
Innovation



Thank You.



Peter J. Schubert



+1 630 470 7797



greenfortressengineering@gmail.com



www.greenfortressengineering.com



517 Worth Ct., Carmel, IN 46032-4402



Green Fortress Engineering