Energy independence through Renewables
Using Hydrogen as an Energy Carrier

Hydrogen Engine Center Inc

Cabo Verde Wind, EPC, Giner & HEC for Hydrogen

100% Renewable Power and Water for Brava Island

Cape Verde

Why Hydrogen is the Solution

- Hydrogen as an energy carrier is the end game
- Hydrogen is everywhere
- The technologies to generate and use hydrogen are now commercially available


NREL National Wind Test Center - 2008

What's wrong with alternate options?

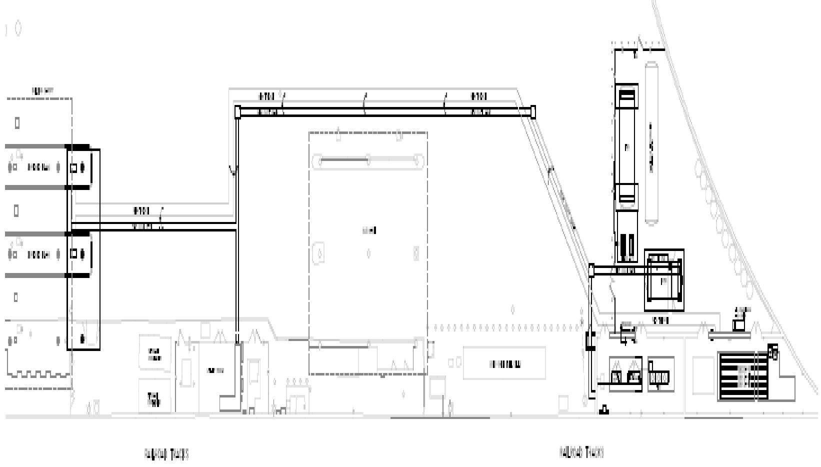
- Batteries (are cheap but…)
  - Limited life specially when fast charging
  - Degraded performance immediately after deployment
  - Not scalable to GW – only DC without efficiency loss
  - Hazardous waste for disposal
  - Less Energy Density than H_2
- Ammonia, Wave Energy, Cyanobacteria, others:
  - Commercially available but costs not ideal for commercialization yet

Hydrogen 101

- Colorless odorless non toxic gas
- 45 times lighter than helium (when released travels upward at 45 mph)
- Burns very rapidly with a colorless but very hot flame
- US Codes and Standards for safe design and use are mature:
    - NFPA 2 (2016 edition) Hydrogen Technologies Code
    - ASME B31.12 (2014 edition) Hydrogen Piping and Pipelines
    - CGA G-5.4, Standard for Hydrogen Piping Systems at Consumer Locations (2005)
    - CGA G-5.5, Hydrogen Vent Systems (Compressed Gas Association, 2004)
- Hundreds of FCV fueling stations and other hydrogen using facilities already in service around the world

EPC - Engineering Procurement & Construction for Hydrogen storage dispensing & reconvertion to energy through ICE's or Fuel Cells

Engineering Procurement & Construction, LLC



Hydrogen systems are the core business – since 2003

Engineering, Design, & Consulting

- Feasibility Studies
- Plant design – Civil, electrical, structural and mechanical
- Permitting- Code Compliance
- Controls (PLC) design and programing

Construction of Hydrogen and Fuel Cell Plants and Systems

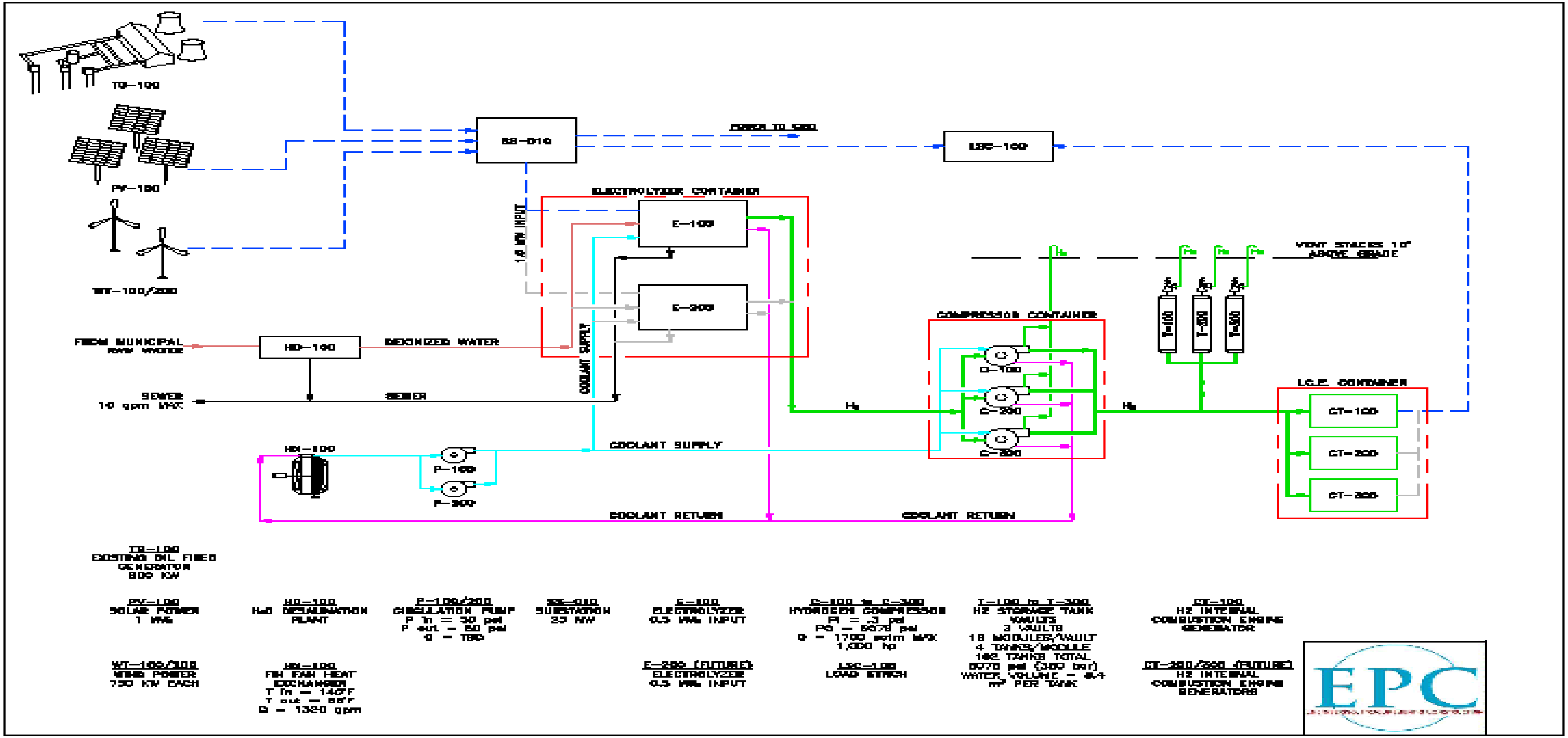
- Material procurement
- Installation of civil, electrical, controls, process equipment
- Pressure testing
- Specialized tube straightening, bending, cone and threading

Operations and Maintenance of Hydrogen stations and Fuel Cell systems

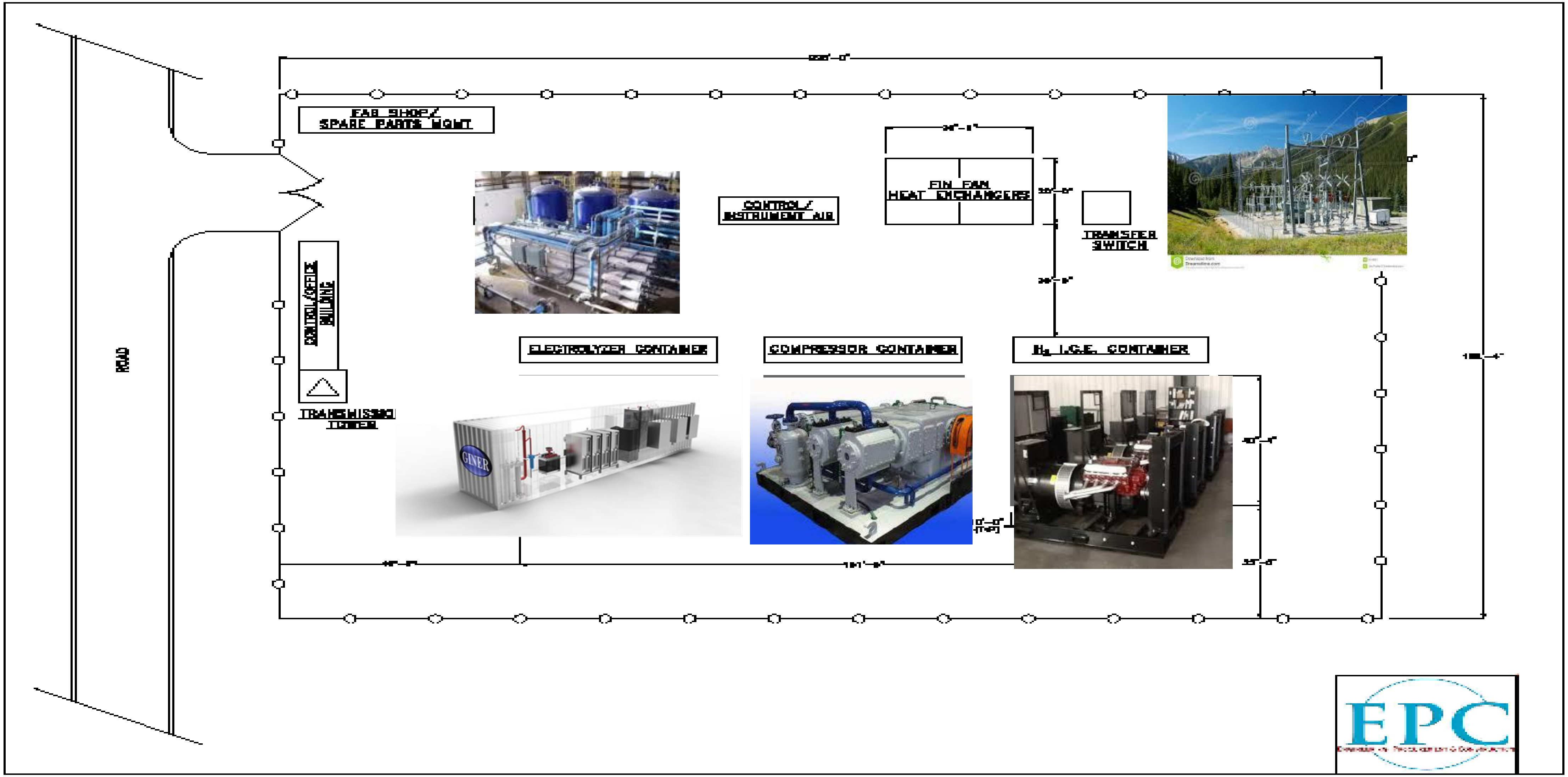
- Compressors
- Electrolyzers & reformers
- Fueling and event reporting

www.epc4h2.com

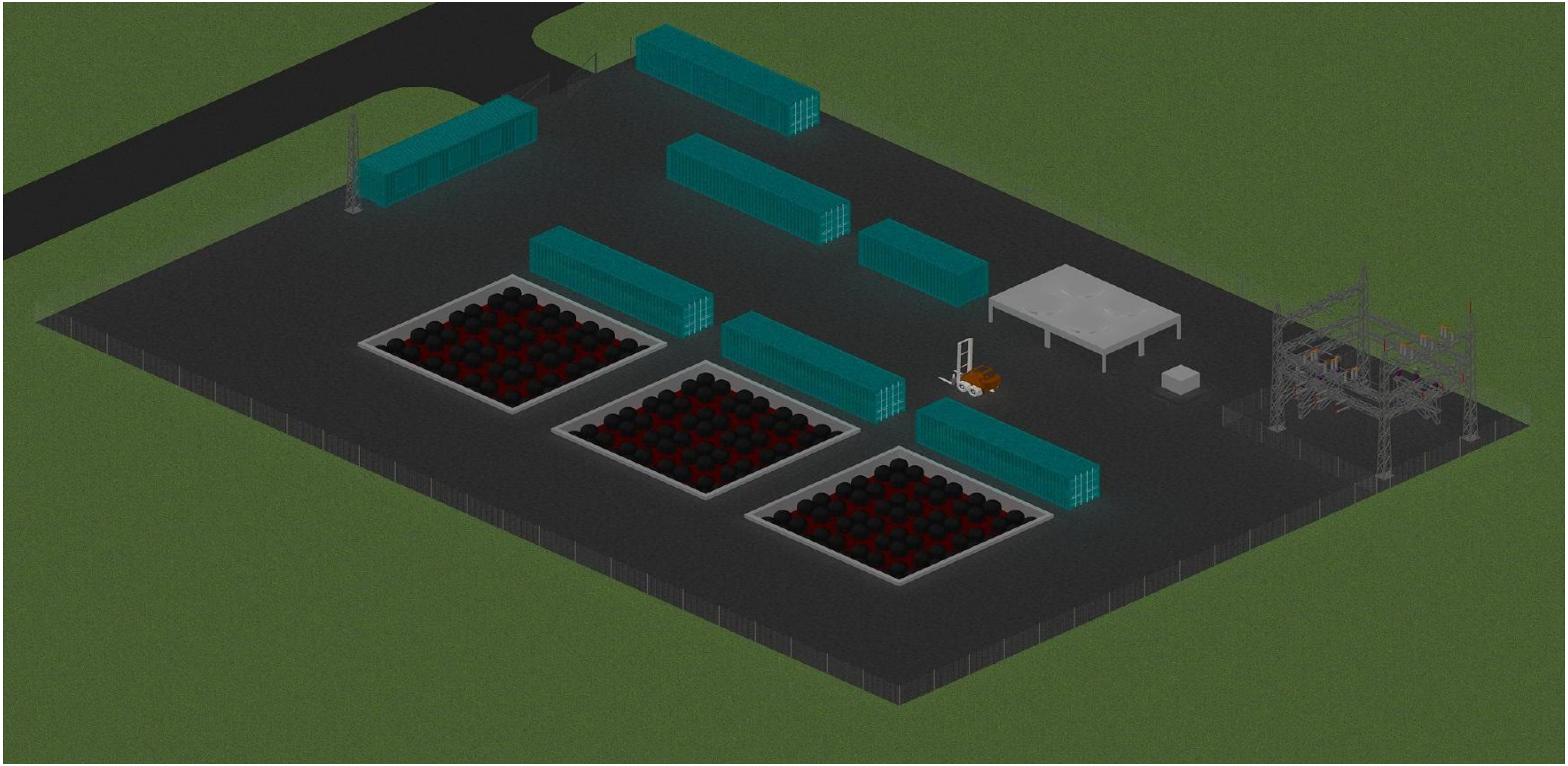
Brava Island 100% Renewable Energy and Water Process Flow Diagram



Brava Island 100% Renewable Energy and Water Conceptual Site Plan



Plant Layout – Concept Rendering



The technologies for this project are already commercial

- Giner Electrolyzer 43 years experience for DoD/US Navy
- Hydrogen Engine Company (HEC) Internal Combustion Engine (ICE) Gensets – established 2006
- Hydrogen Compressors – multiple US and German manufacturers (i.e. Hoffer, etc..)
- Hydrogen Storage Tanks – multiple US and Europe manufacturers (i.e.Fiba, Hexagon, etc..)
- Water purification – multiple US manufacturers (i.e Milipore, etc)

Cape Verde

Integrating Energy Solution

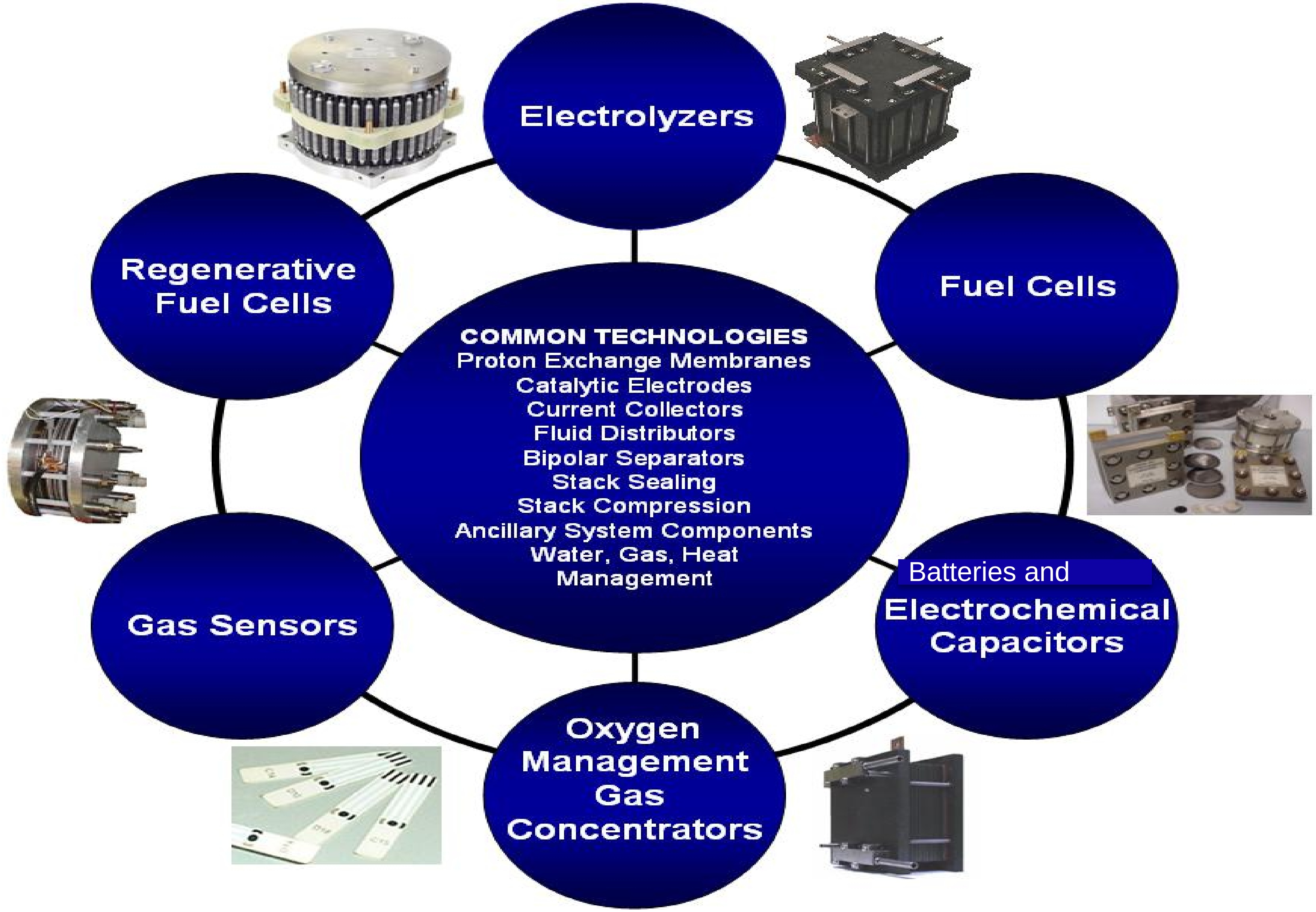
May 30th 2016. Praia, Cape Verde

Giner Inc
Hector Maza
VP, Business Development

Summary

- Giner Inc. - founded in 1973
- Leader in electrochemistry, selling over 3 decades thousands of PEM stacks and systems to military and commercial customers
- Profitable every single one of these 43 years.
- Multiple Technology Awards including DoE, NASA, and others
- Collaboration with major US & European Partners
- Global presence: Asia, Europe, Americas & Africa

Synergy of Giner, Inc. Core Technologies



Markets Introduction

Giner with its world-leading PEM electrolysis technology based on decades of experience and substantial investment now focuses on three commercial market opportunities:

1. Ultra-lightweight and efficient RFCs regenerative fuel cell systems for high altitude aerospace: project underway with several Global Corporations
2. Miniature implantable oxygen generators for preservation of encapsulated cells; as well as large O2 Gen Systems for Life Support.
3. Large hydrogen generation systems for grid-level energy storage, P2G and hydrogen refueling systems (Mobility market)

Main products are

a) 30 Nm3/h or (65 kg/d Stacks), the largest and highest efficiency PEM Stacks in the market today, 30, 60 and 90 Nm3/h (200kg/d) Systems.

b) 1 MW producing 207 Nm3/h (450 kg/d) Stack & System Development Program (2016)

Some of Giner's Customers are …

Giner Electrolyzer Technology

Electrolyzer Stacks

Electrolyzer Systems

Applications of Giner’s PEM-Electrolyzers

Military : US Navy, NASA and DoD

Life Support Oxygen Generators

Energy Storage

Low Cap Ex → Rapid Response time

<u>MW Stacks, 2 MW – 5 MW Systems</u>

Industrial Hydrogen

High efficiency → Low Cap Ex

15 N →, 210 Nm^3/h

Aerospace / Space Electrolyzers

Radar Platforms; DARPA and MDA

Space Exploration; NASA

RFC Electrolyzers UUV

20 Nm^3/ Backup Power

Distributed Hydrogen

Analytical Hydrogen

Laboratory :30 -120 l / h

Giner's Experience in Electrolyzers and FC: HAPs and Spacecraft

AeroVironment's Helios

Lightweight Electrolyzer

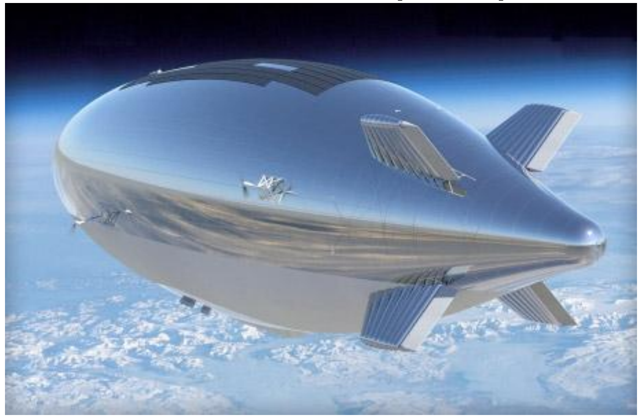
Lightweight Fuel Cell

NASA

400 psi

1,200 psi

DARPA High Altitude Radar Platform (ISIS)

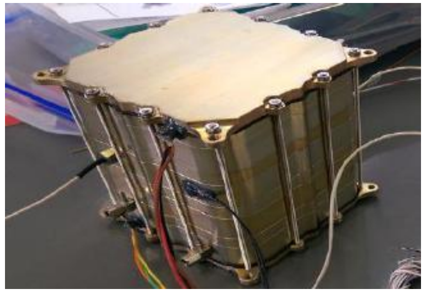


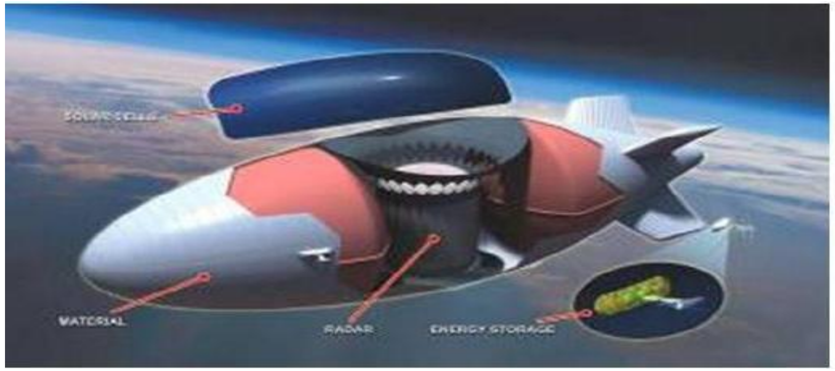
	ISIS	Internet Co
Pressure (psi)	1200	500
Number of cells	168	70
System energy density target (Wh/kg)	600	400

- All of these stacks have been tested for tens of thousands of hours

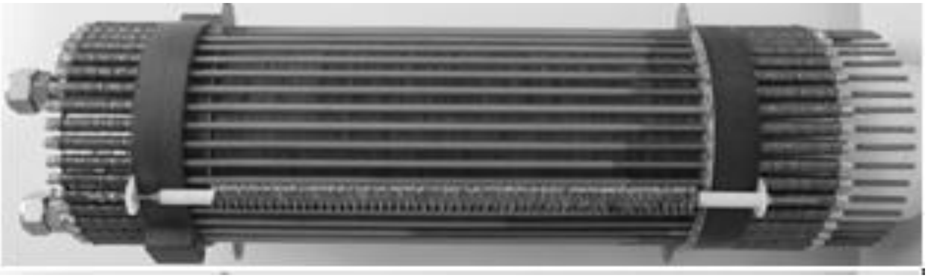
Giner Aerospace

Miniature Regenerative Fuel Cell
for 1 liter Satellite





DARPA Ultra-lightweight high
energy electrolyzer

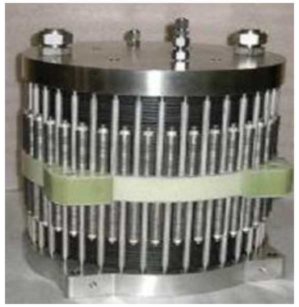


Life-Support O_2 for ISS

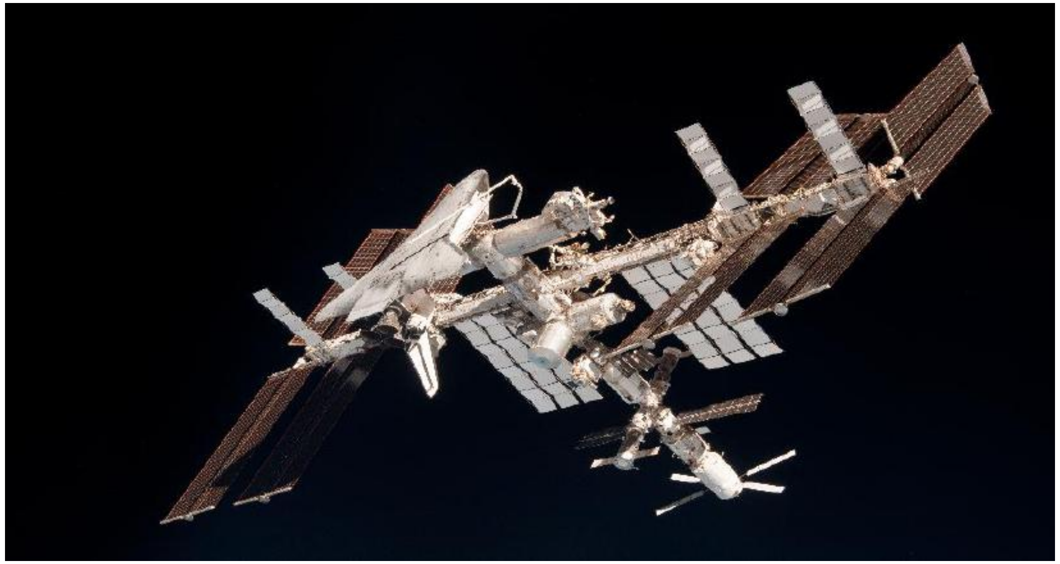
Electrolysis for Life Support Oxygen

Life Support on Nuclear Submarines

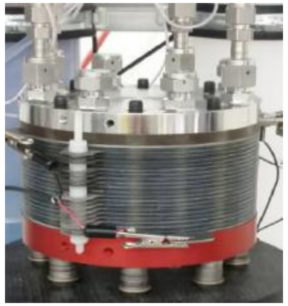
- Delivers Ambient O_2 for ~ 150 submariners
- Stores high pressure H_2
- Lifetimes in excess of 30,000 h
- High Current Density



Life Support for Space



- Delivers Ambient O_2 without liquid water
- Nearly 20,000 hours of operation



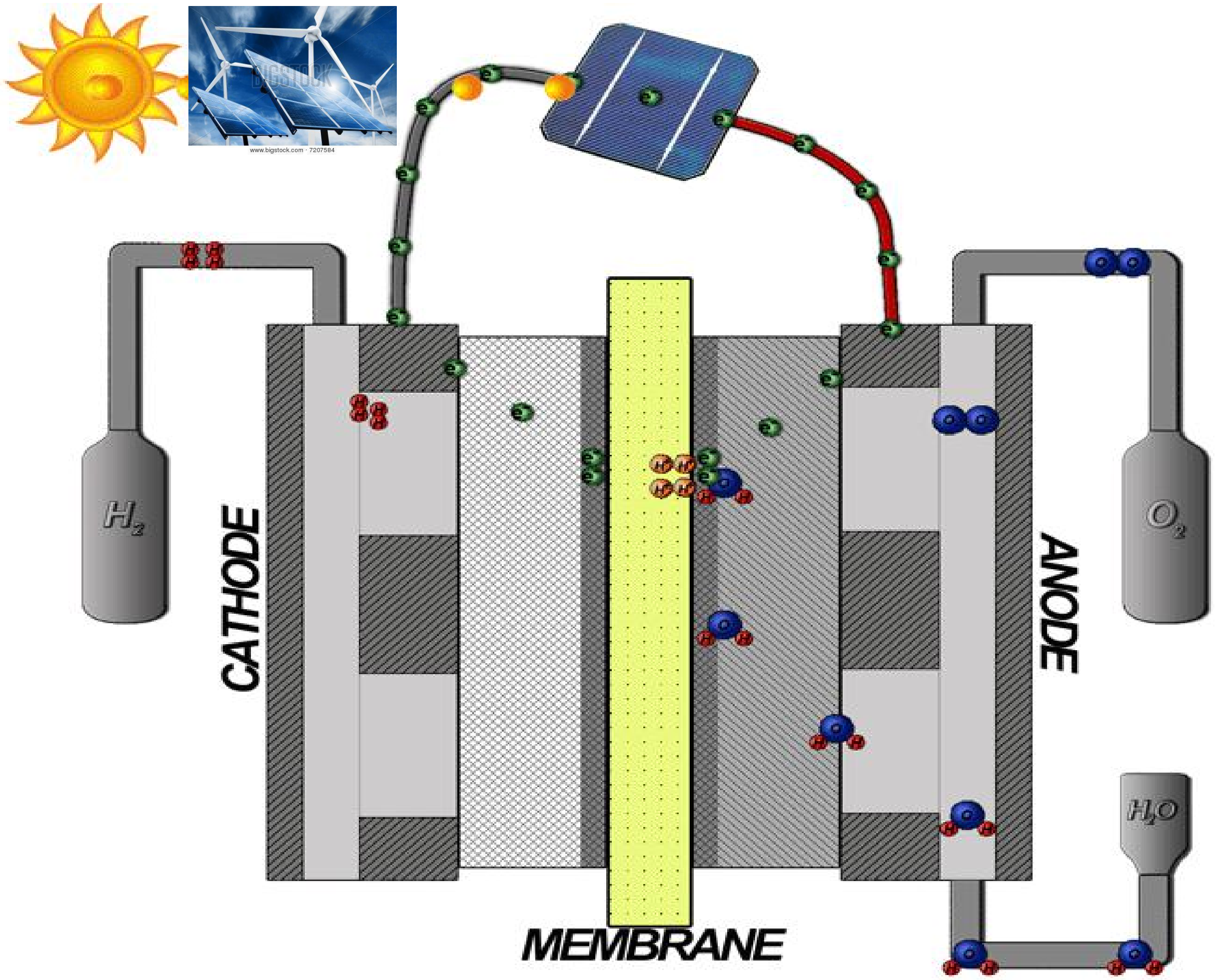
Giner Commercial: Laboratory Hydrogen

- On-site, on demand hydrogen generators for laboratory equipment
- The leading manufacturer of laboratory generator components and stacks world wide
- Distribution network consists of international OEMs who provide all sales and service support
- Key opportunity is to gain share for on-site generators *vs.* delivered supply (≈96% of the market)

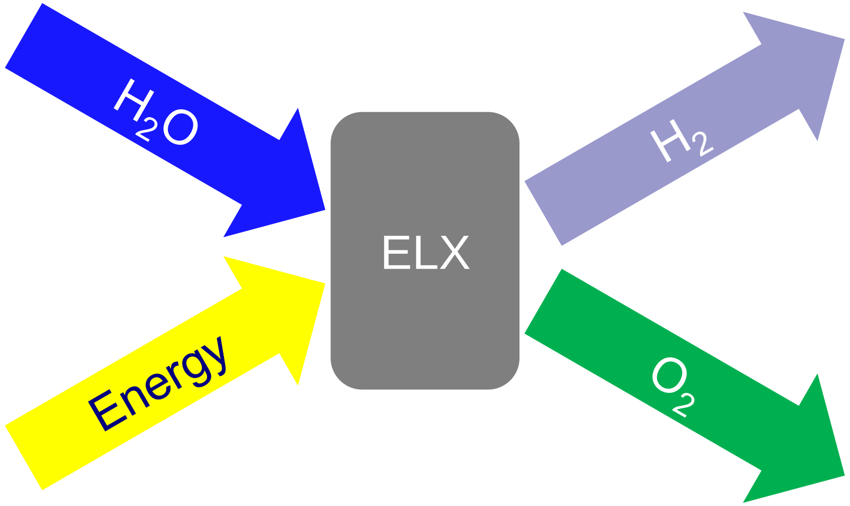
Electrolyzer Products - Specific Markets

Energy Storage, P2Gas, P2Product, P2Mobility.

What is an Electrolyzer ?



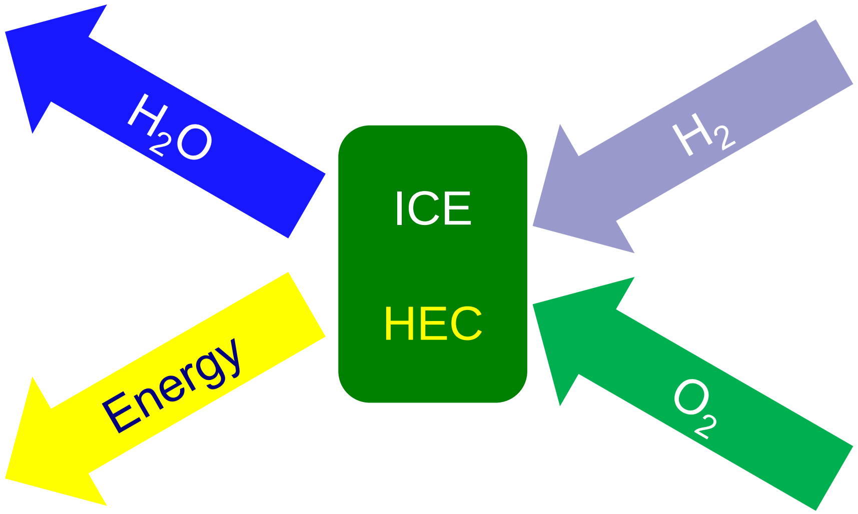
Electrolyzer



- Low CapEx
- Easy to scale
- Easy to Maintain
- High Efficiency ~ 80% to 95+%

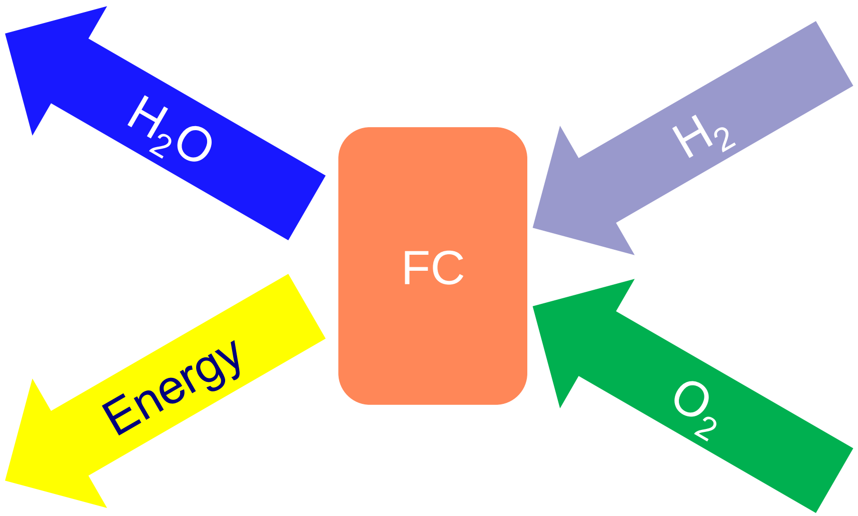
Why ICE and not Fuel Cells?

H_2 Internal Combustion Engine



- Easy to scale
- Low CapEx ~ 1X / kW
- Easy to Maintain
- Efficiency ~33%

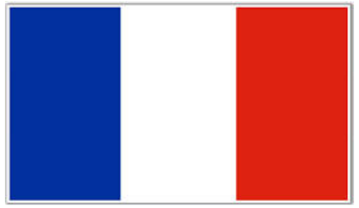
Fuel Cell



- Dificult to scale
- High CapEx ~ 4X /kW
- Delicate to Maintain
- Efficiency ~45%

Energy Storage : Electrolyzers for H_2 from renewables since 2010 in the Island of Corciga, France

AREVA
forward-looking energy



- Provided Areva's Elecrolyzer Stacks for

"Myrte & Green Box projects' High efficiency: 47 kWh/kg (2010 – 2013)
Efficiency 85%+

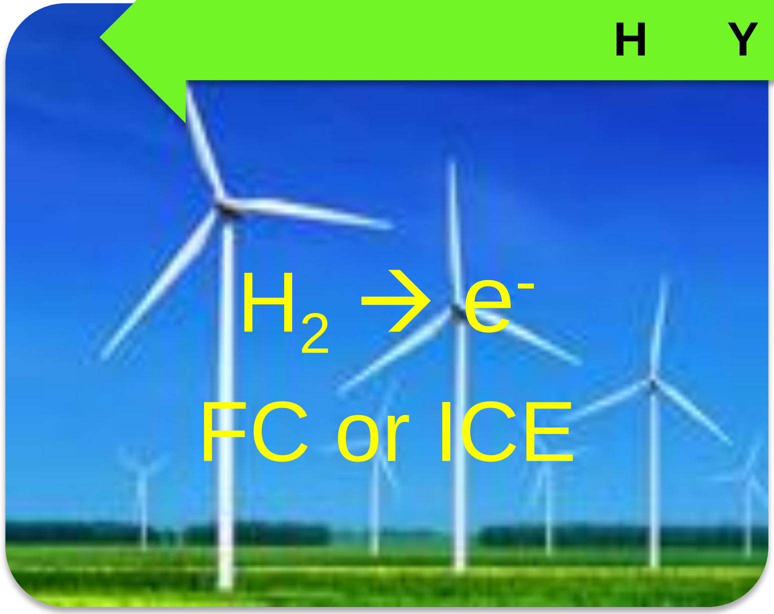
- Provided Viessmann / Audi with same for Bio-Methanation H_2 (2015 - 2016)

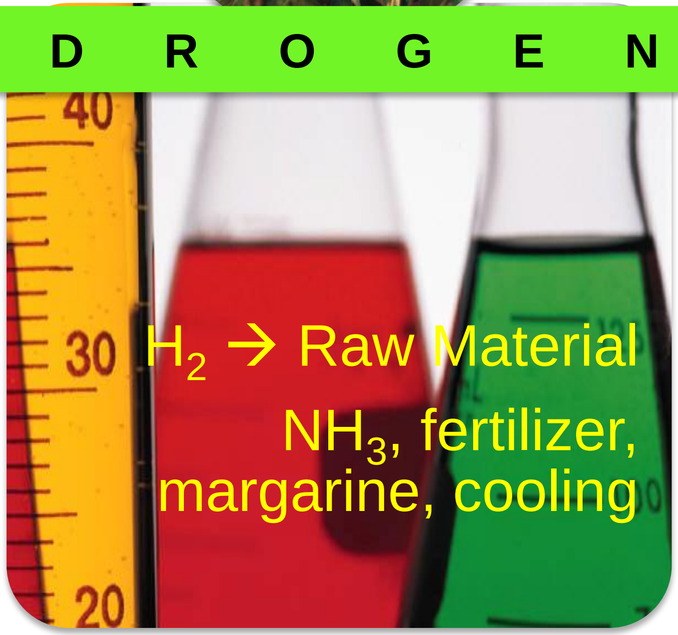
at 1/3 cost and 3X scale

What other uses may allow rapid integration of clean energy systems?

Stranded Power → H_2 → $, €, £, ¥…

H Y D R O G E N





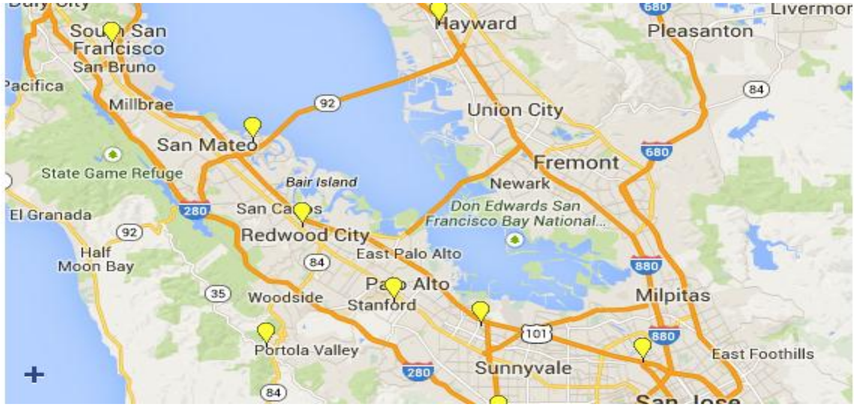
Energy Storage

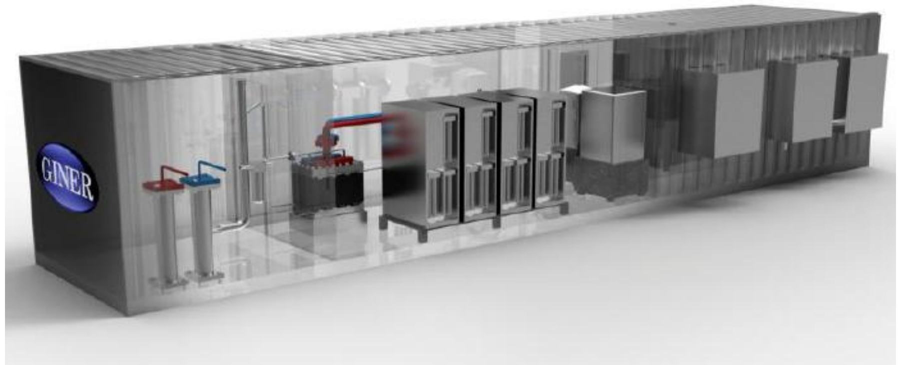
Product / Raw Material

Fuel

Mobility : Electrolyzers for HRS - Automotive H_2

- In Collaboration with CEC, in 2016 Giner installs Onsite H_2 gen Systems for 3 HRS hydrogen refueling stations in CA





- Lack of standards make permitting process slower than optimal but always the first time is more challenging

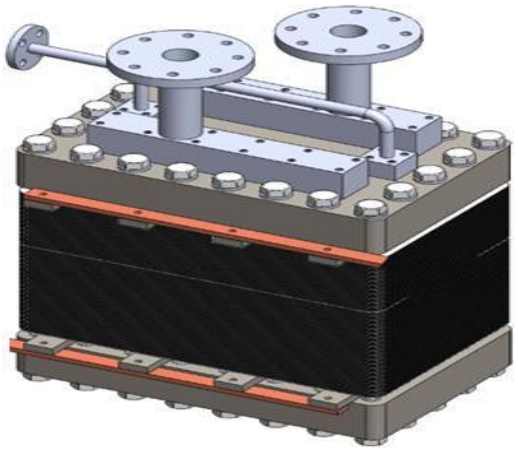
- Succesful commisioning of HRS in Seville Spain

R&D priorities to ensure market success

- Increase Scale
- Reduce Total Cost

} MW Scale Stack

- Increase Differential Pressure (DSM™) to reduce overall system Capex



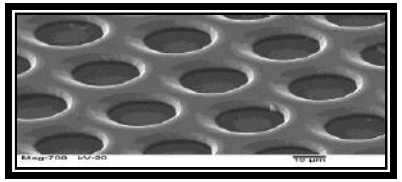
210 Nm^3/h Electrolyzer Stack

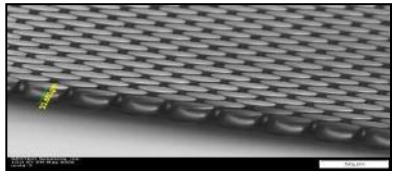
Today's R&D focus:

a) MW Scale Stacks

b) **Dimensionally Stable Membranes (DSM™)**
High-strength, High-efficiency membranes

- Superior Mechanical Properties than regular PEM
- No x-y dimensional changes upon wet/dry or freeze-thaw cycling
- Stronger Resistance to tear propagation than PEM
- Superior to PTFE based supports, 10x stronger base properties
- Enabling technology for high pressure applications
- Commercial viability in 2015





R&D funded U.S. Department of Energy

Energy Storage demands Scale-up…

GINER ELECTROLYZER STACKS COMPARISON

Our product names are often inspired by the New England region's whitewater rivers.

These distinctive native American names connote purity, ecological renewal, old-fashioned Yankee industrial ingenuity and the raw natural power that emotes our aspirations for a clean energy future utilizing the simplest chemistries (water and electricity).

We are proud of our region, its natural beauty, the inventiveness of it people and just as proud of the excellence, commitment and spirit of the Giner team.

G5

Overview

Our next generation commercial electrolyzer stack. Designed specifically for our lab scale hydrogen generator OEMs using the latest technologies developed for our larger products. Also popular with academic institutions and for use in specialty water electrolysis applications.

Specifics

- 50 cm^2 nominal active area
- 450 sccm – 1800 sccm
- Higher flow rate stacks available
- Differential or balanced pressure
- CE Mark
- In stock

Pemi

Overview

The R&D version of our G5 comes available with cell voltage tabs and customizable MEAs. We are able to produce single cell to 40 cell Pemigewasset stacks that perfectly mimic the operation of our larger platform stacks at a fraction of the the cost. Rated at up to 250 Amps this device has been a workhorse for our internal electrolysis development as well as NSA, DOE, and DoD programs.

Specifics

- 50 cm^2 nominal active cell
- Single cells to 20 cells stacks
- Custom MEAs
- Up to 715 psig (50 bar)
- Individual cell voltage tabs available

Goddard

Overview

Giner has a leading position in aerospace regenerative fuel cells (RFCs) through its collaborations with NSA, DARPA, US Navy and a broad range of industrial clients. Our electrolyzer stack offers extraordinary efficiency, power density and pressure capability that facilitate RFC systems to capture design wins where even the most advanced batteries fail to deliver. These stacks are unsurpassed in their efficiency and performance metrics.

Specifics

- Dual feed, cathode feed, anode feed capability
- 0 to 1200 psig (82.7 bar)
- Differential or balanced pressure
- 3200 w/kg stack power density
- Production energy cost of 44 kw-hr/kg-H_2
- Individual cell voltage tabs available

Merrimack

Overview

The largest commercially available stack currently on the market. This device offers unprecedented operating efficiencies at high current densities to provide the optimum price performance for our customers. The Merrimack offers world-class lifetimes with stable operating voltages. High operating temperatures and pressures minimize the size of heat exchangers, and post electrolysis compression equipment. Turn-down ratios of 10:1 and rapid ramp times enable demand management to the millisecond scale.

Specifics

- 300 cm^2 active area
- To 66 kg/day (160 KW_e nominal input)
- 0-725 psig (50 bar)
- Differential or balanced pressure
- CE Mark with PED and ASME BPVC

Kennebec

Overview

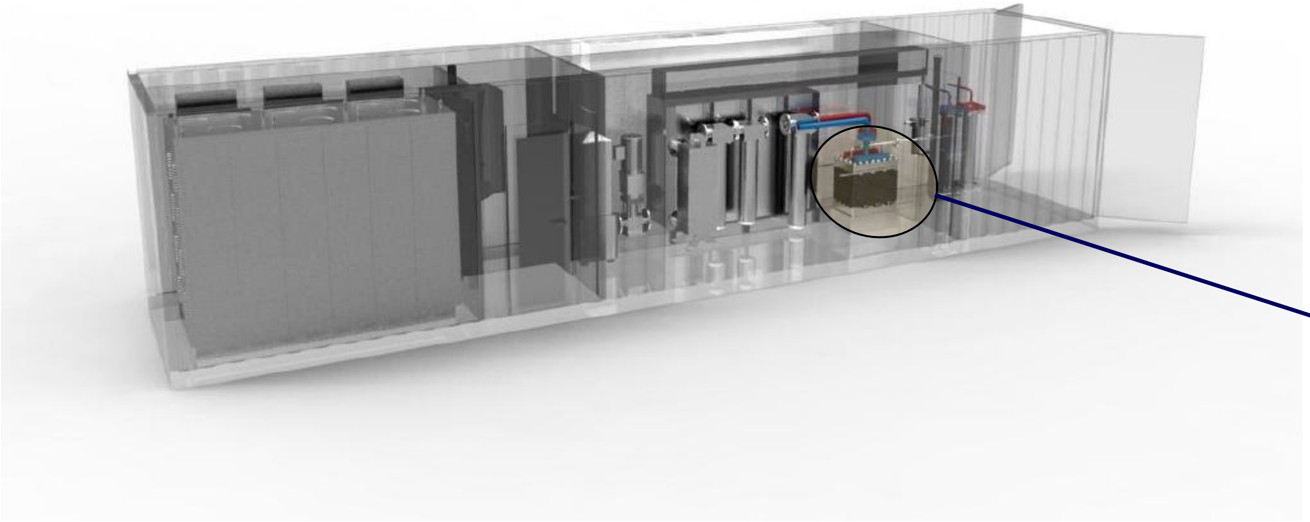
We are developing a range of large electrolyzer stacks to address the nascent power to gas and Power 2 Mobility™ markets. Giner's Kennebec stacks span the range from 60 kg/day to 2200 kg/day (5 MW nominal input). Giner is driving PEM electrolyzer technology forward to meet the needs of tomorrow's green hydrogen economy.

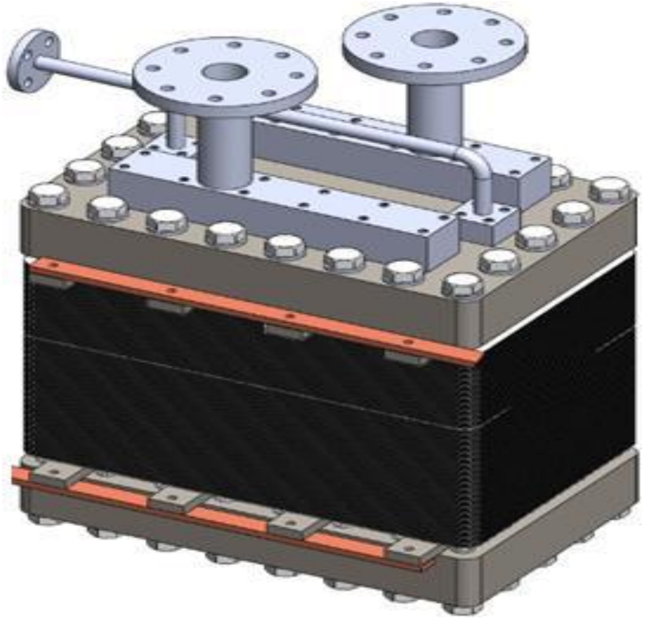
Specifics

- 3000 cm^2 (nominal) active area
- 40 years of satisfied customers
- To 1350 kg/day
- 0 to 225 psig (155 Bar)
- Customizable

MW Scale PEM Electrolysis

- Giner will complete Development of MW Electrolyzer Stack in Fall 2016,
- System in Dec 2016
- Mass Production 2017

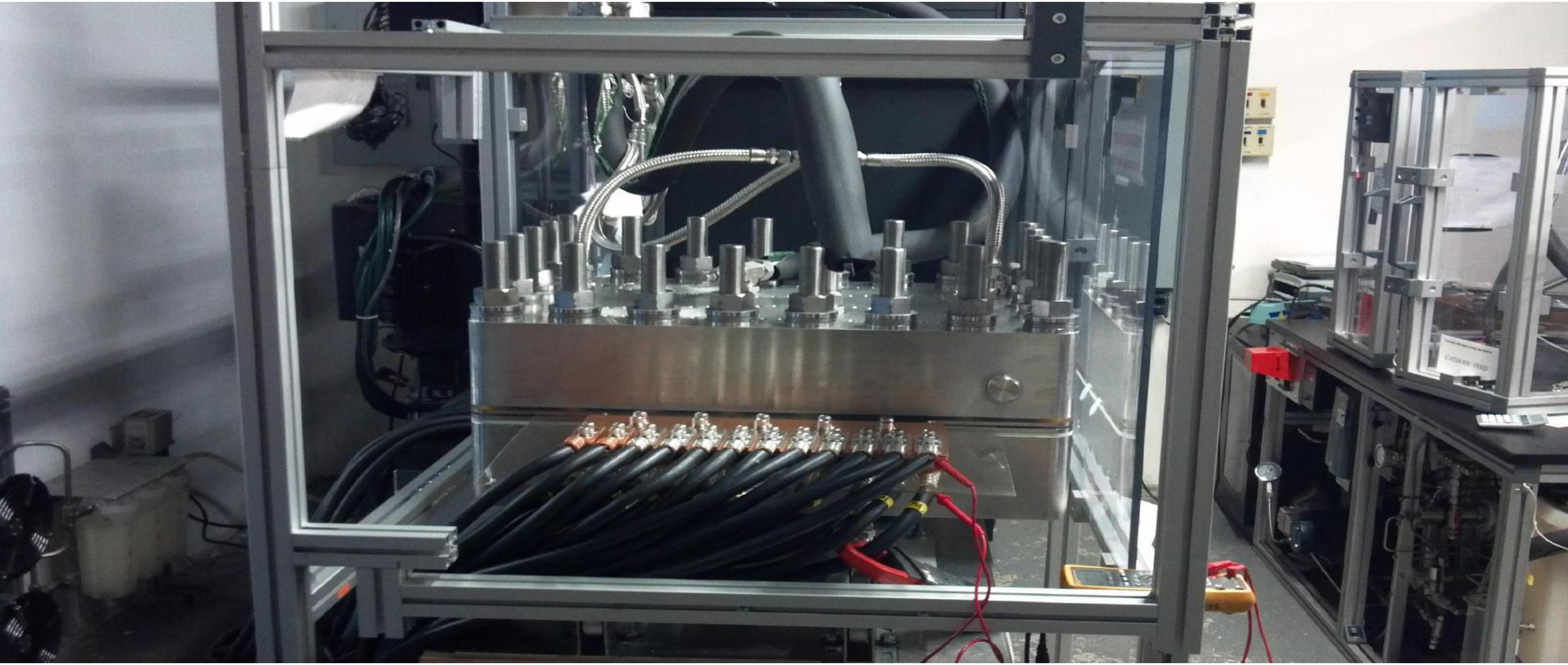




Single Stack
210+ Nm^3/hr

MW Electrolyzer Stack

1 MW - Stack running 4,000 mA/cm^2 & 50 bar



GINER

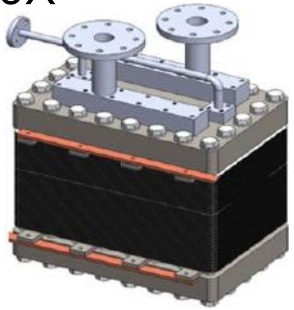
We understand that hydrogen solutions need Be a true cost competitive alternative to Gasoline, Batteries and Nat-Gas (CH_4) ….NOW!

Year : 1995 2000 2010 2015 2020

Scale : 1X 30X 200X 1,000X

2 kg/d
5kW

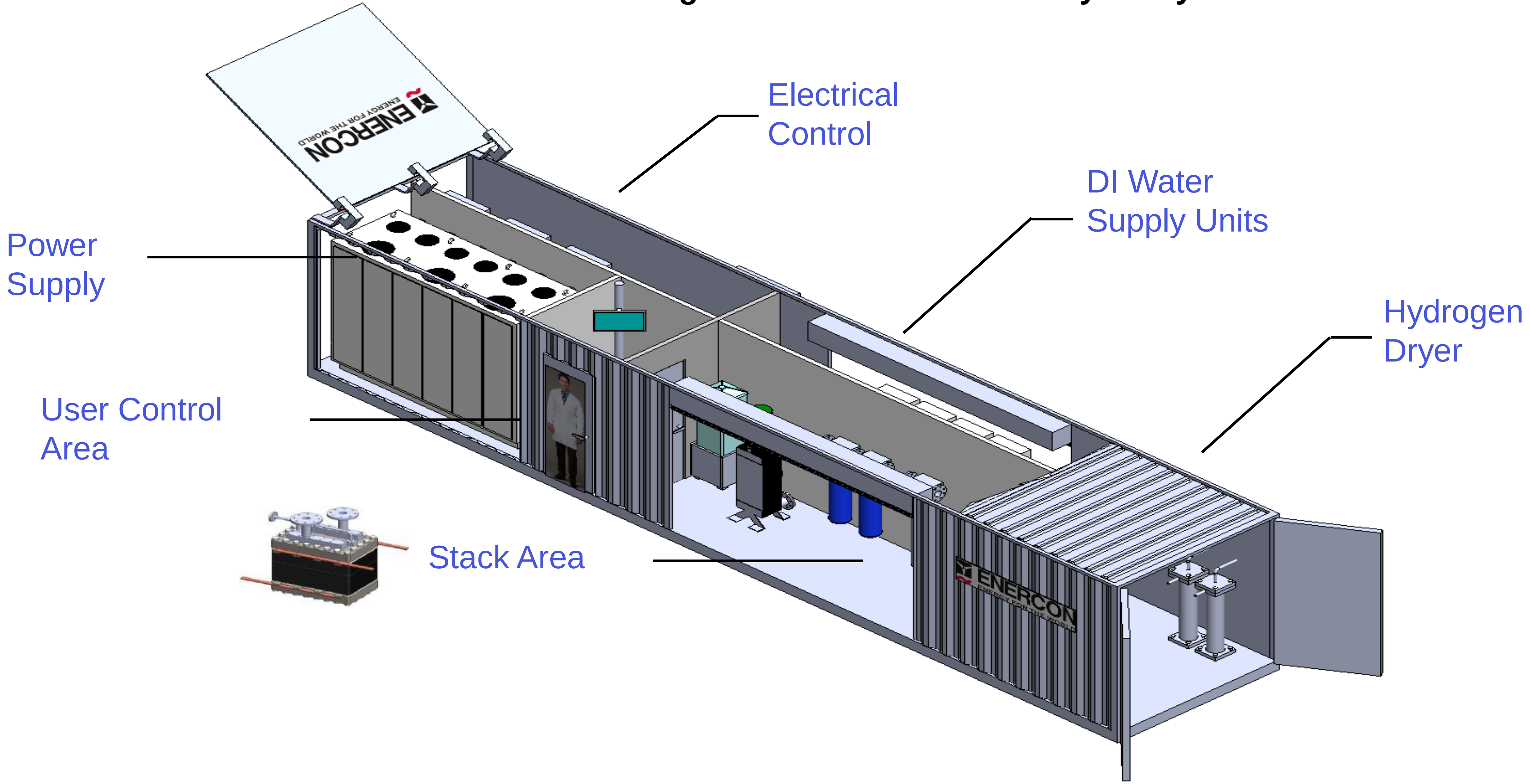
65 kg/d
150kW



450 kg/d
1 MW Stack

2,250 kg/d
5 MW Stack

Giner addresses Global customers building MW & Multi-MW Electrolyzer Systems



Current Systems

30S: 30Nm³/h System

- 20 ft container
- 150 kW System

90S: 90Nm³/h System

- 30 ft container
- 450 kW System

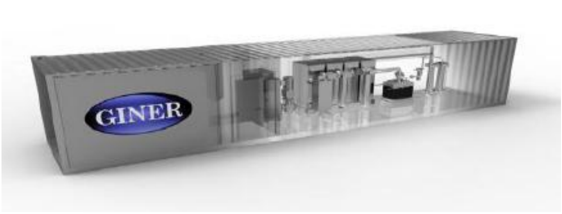
Product Roadmap

2013 - 2014 - 2015 - 2016 - 2017 - 2018

Manufacturing & Sales 50kW – 150kW (24 – 65 kg/d) Stacks

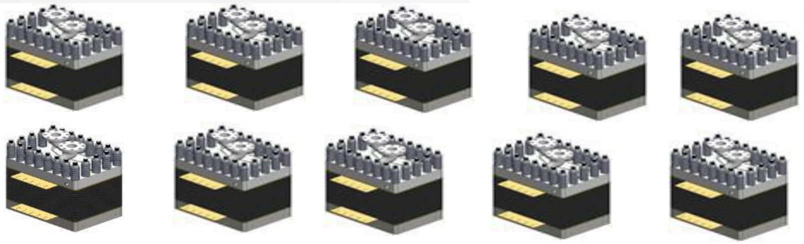
130 – 260 kg/d Systems
CA H_2 Refueling Stations

1 MW (480kg/d) Stack Development & System Integration



MW Stack (480 kg/d) & MW System Sales "PtG"

MW System Demonstrations
(i.e. V W / Audi plant)



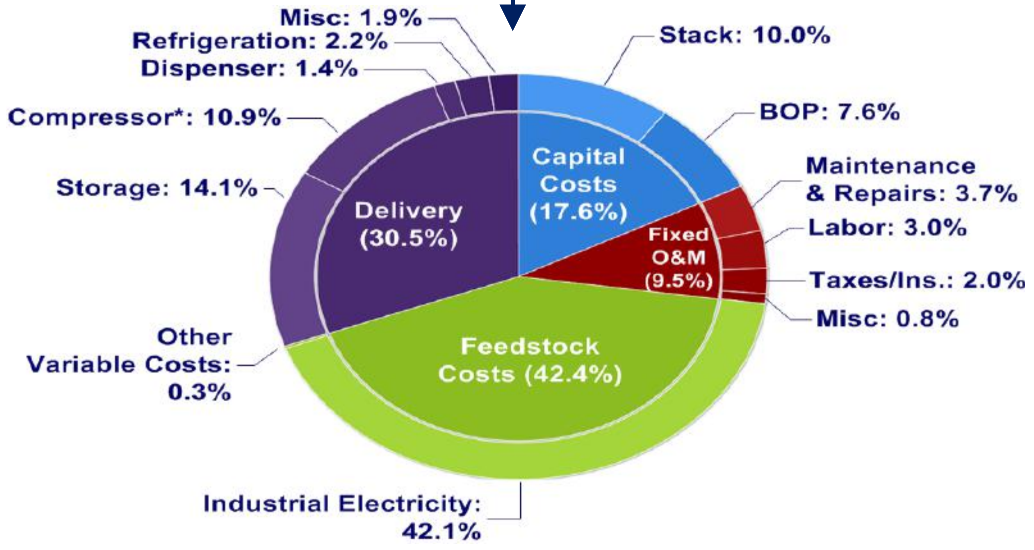
Muti-MW to GW Demo's
(4,800 kg/d to 480,000 kg/d) Systems Integration

H_2 Cost Breakdown

H2A Forecourt Model Analysis

H_2 Production Cost Contribution	H2A Ver. 2.1.1 (FY 2012)	H2A Ver. 3.0 (FY 2013)	Distributed Forecourt Water Electrolysis[1] DOE Target (2020)
Capital Costs	$1.06	$1.30	$0.50
Fixed O&M	$0.59	$0.70	$0.20
Feedstock Costs @ Efficiency: 50.5 kWh$_e$/kg-H_2	$1.97 ($0.039/kW)	$3.09 ($0.057/kW)	$1.60 (46.9kWh/kg) ($0.037/kW)
Other Variable Costs (including utilities)	$0.01	$0.02	<$0.10
Total Hydrogen Production Cost **($/kg)**	**3.64**	**5.11**	**2.30**
Delivery (CSD)	$1.80 (300 psig output)	$2.24 (600 psig output)	$1.70
Total Hydrogen Production Cost **($/kg)**	**5.43**	**7.35**	**<4.00**

Design Capacity: 1500 kg H2/day. Assumes large scale production costs for 500th unit



*Mechanical compressor can be up to 21% of H_2 Production Cost (70% of Delivery) depending on maintenance

- **Progress inline with achieving *new* 2015 Target of \$3.90/kg-H_2**

Actions to enable the use of clean energy technologies:

Mid Term coordinate a Large Multi-MW+ DoE led "P2M^{TM} Partnership"

- ($$$) & Ideal Location site
- Wind / Solar Farm

Utility Co.

- Equipment & Labor @ Cost Share (in-kind)

Electrolysis Manufacturer

+

Engineering Construction

Legislative Bodies

- **Tax Incentives & regulatory support**

Auto Manufacturer

Cash $ to enable Infrastructure Acceleration

HEC – Hydrogen Engine Center Inc

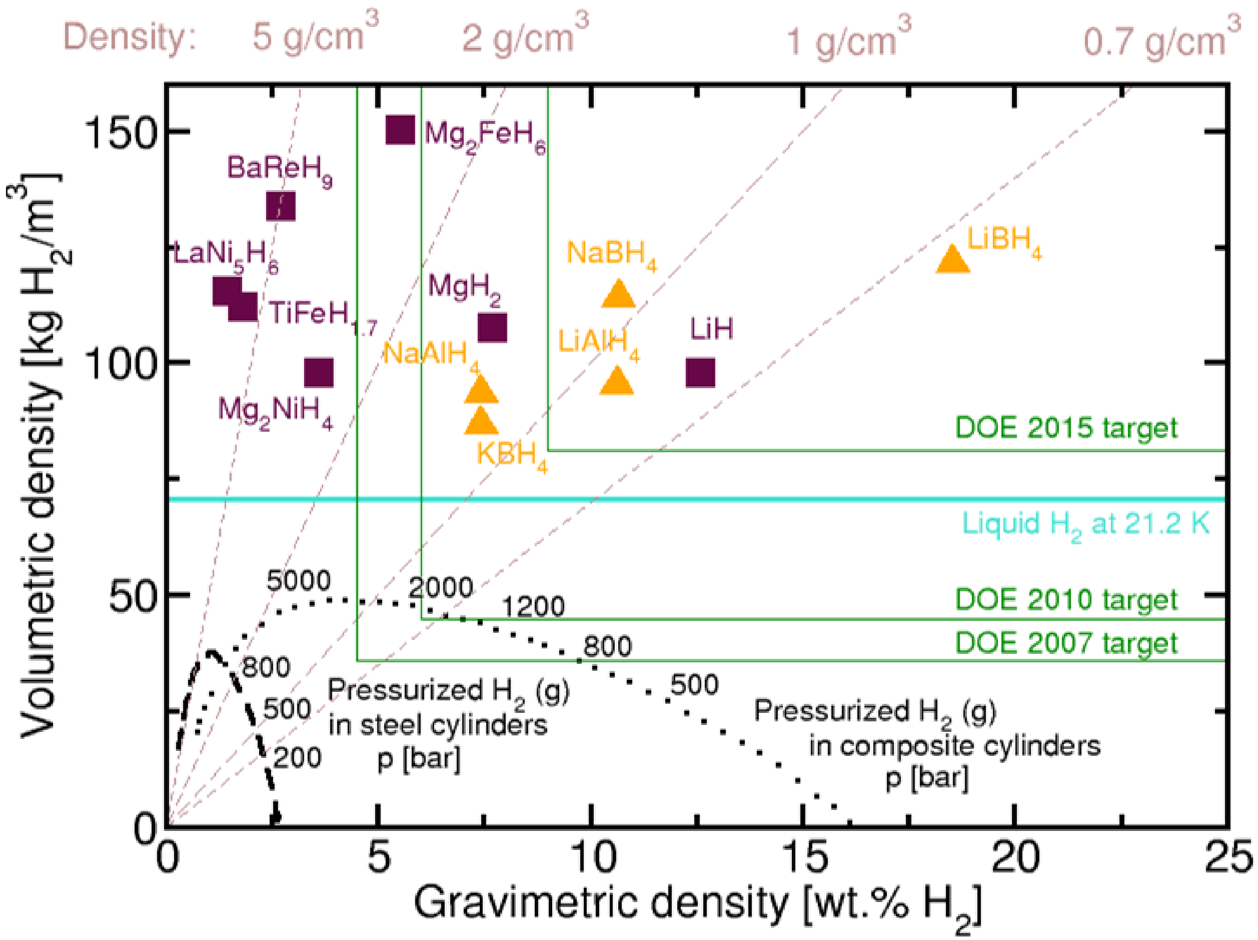
Hydrogen powered Gensets

- Company established in 2003
- Tens of units in operation world wide
- Very low emissions
- Most exhaust is water
- Proven technology

Hydrogen and Oxygen Storage

At moderate to high pressures

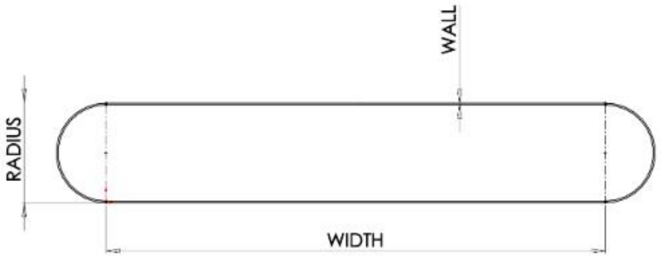
Storage Forms

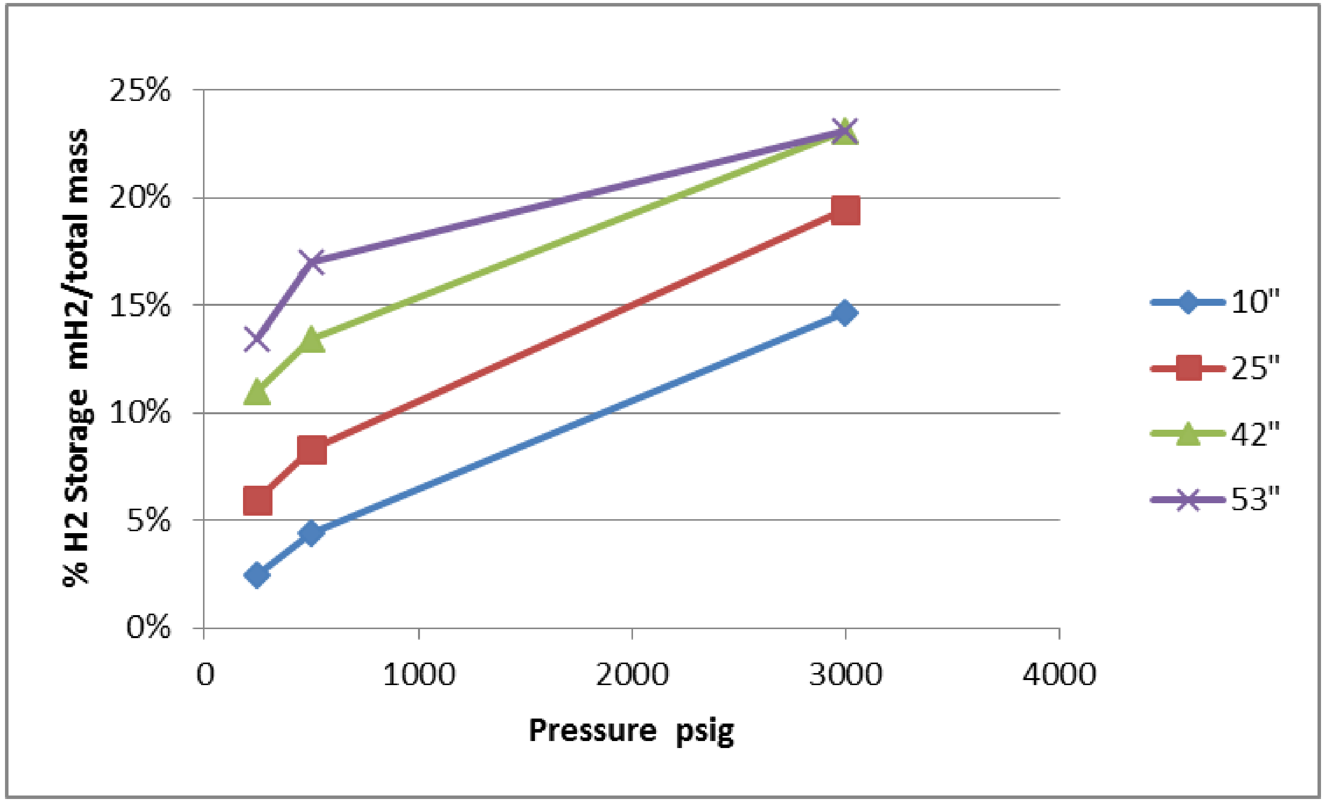


- Liquid storage option but high energy cost (Extreme low Temps)
- Chemical hydrides not reversible and need to be extremely dry
- Reversible metal hydrides have high volumetric storage, but are very heavy and have substantial heat flows
- Compressed gas storage is lightest feasible.
- Adsorbents offer only modest improvements

Cylindrical Tanks (carbon fiber) for H_2

$$M_{tank}=2\pi R^2 (R+W)P\rho/\sigma$$





ρ = density of tank wall material
σ = is the maximum working stress of tank wall material

Due to extremely high tensile strength-to-weight ratios for glass and carbon fibers, composite tanks are preferred solution

Commercial OTS Composite Tanks

Hexagon Lincoln

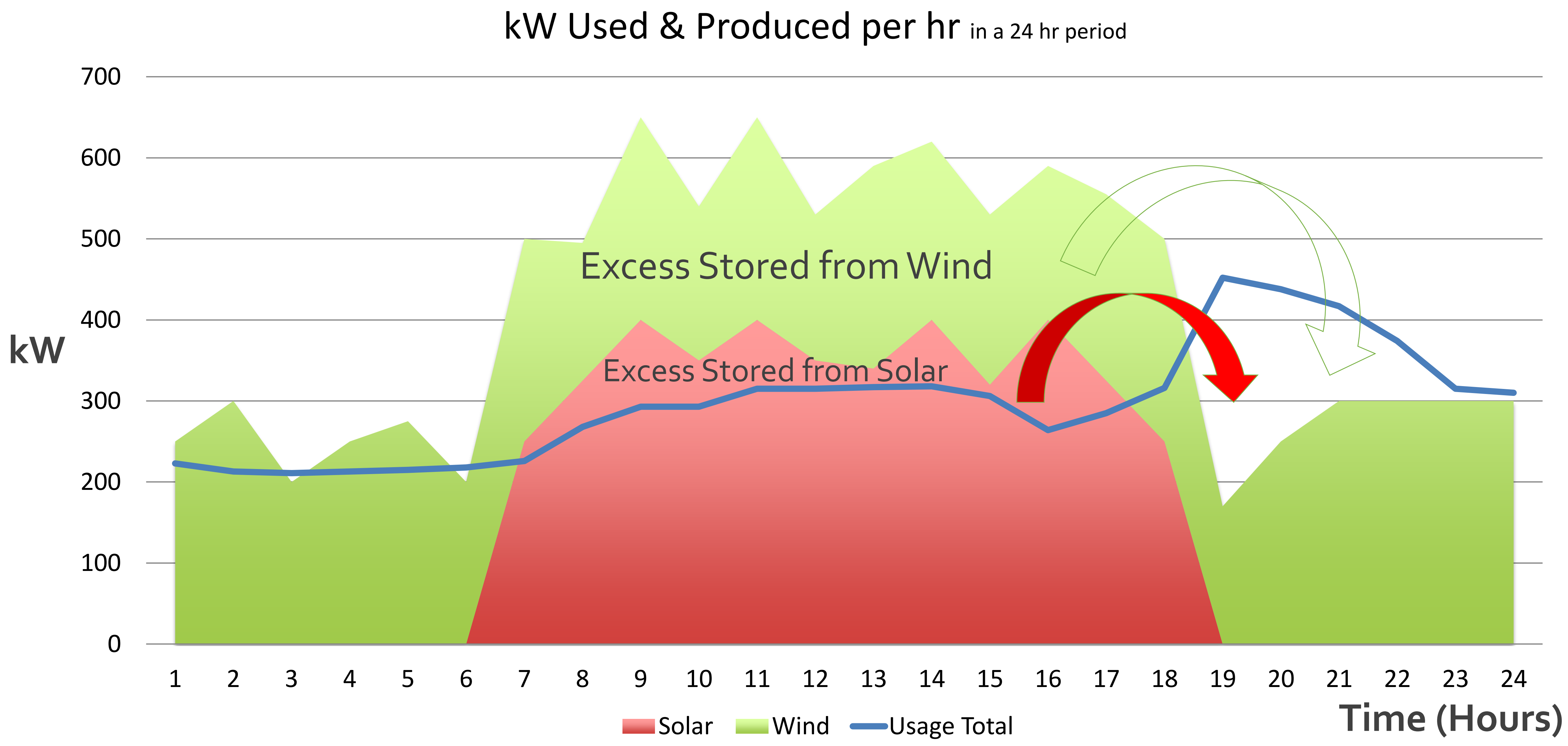
- Carbon wound composite
- DOT-approved for CNG to 3600 psig
- Offerings in the **1.5 kg** H_2 range

P_{fill}	R x W	H_2 Stored	Wt-% H_2	Tank Volume	Tank Mass
1200 psig	21 cm x 213 cm	1.61 kg	1.8 %*	***320 L***	89 kg
3600 psig**	16 cm x 183 cm	1.95 kg	4.4 %	145 L	42 kg
3600 psig extr	16 cm x 131 cm	1.40	4.4%	104 L	30 kg

* Lower P_{max} tank can have lower mass, but is not COTS
** Higher P_{fill} requires compressor or high weight electrolyzer with decreased efficiency

Other vendors include Quantum, Viking and many others

The excess Wind and Solar would be stored as H_2



Add on potential for future Brava development similar to Europe or USA

- Airport tugs for emissions reduction
- Light duty FCEVs fuel cell electric vehicles (zero emissions)
- Stationary power (fuel cell) systems around the island with convenient fuel source including emergency generators for hospitals, police, schools, hotels

Conclusions

- ✓ The technologies are now commercially available
- ✓ The team has decades of experience
- ✓ The world is waiting for this project

Let’s get started in Cabo Verde !

GINER

Energy independence through Renewables using Hydrogen as an Energy Carrier

CABO VERDE wind
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Electrochemically Driven, Helping store and convert Green Energy

Thank you !