GINER ELX
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Advanced Electrochemical Hydrogen Compressor

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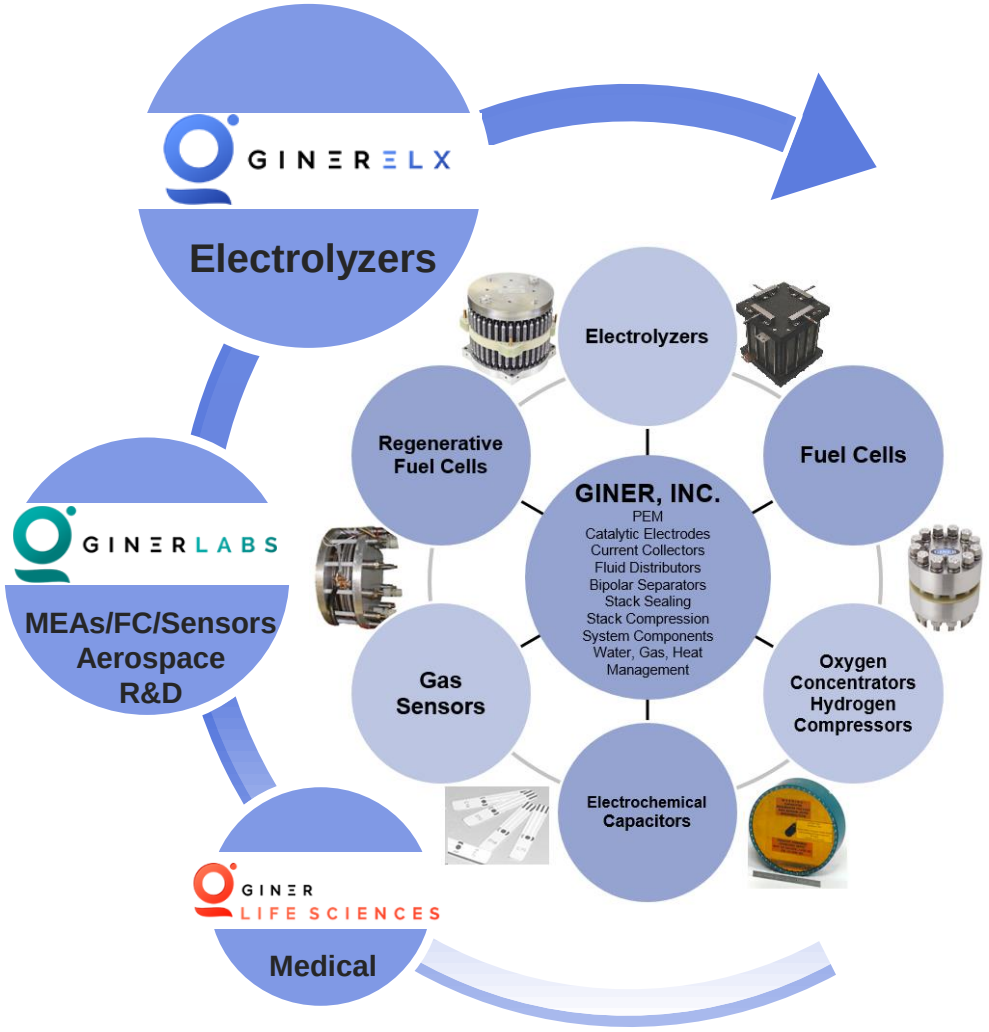
Giner ELX Profile

- Giner has been a world leading innovator in electrochemical technologies for over 40 years
  - Life support in space and undersea
  - Implantable oxygenators to support cell therapies
- We span out **GINER ELX** in April 2017 to focus on multi-MW PEM electrolysis stacks and systems for commercial applications
  - Renewable energy storage



Synergy of Giner, Inc. Technologies

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 MEA's. We are able to produce single cell to 20-cell Pemisewassett stacks that perfectly mimic the operation of our larger platform stacks at a fraction of the cost. Rated at up to 250 Amps this device has been a workhorse for our internal electrolysis development as well as NASA, DOE, and DoD programs.

Specifics

- 50 cm^2 nominal active cell
- Single-cell to 20-cell stacks
- Custom MEAs
- Up to 290 psig (20 bar)
- Individual cell voltage tabs available

Goddard

Overview

Giner has a leading position in aerospace regenerative fuel cells (RFCs) through its collaborations with NASA, 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)
- Diffferential or balanced pressure
- Weighs 83% less than other commercial stacks
- 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 KWe nominal input)
- 0-40 bar (580 psig)
- Differential or balanced pressure
- CE Mark with PED and ASME BPVC

Allagash

Overview

New for 2016, Giner proudly introduces our megawatt scale stack. The Allagash platform offers the best-in-class price-performance in the production range from 30 Nm^3/hr to 400 Nm^3/hr within an extremely compact single assembly. The break-through rectangular pressure vessel design optimizes our material utilization while maintaining our market leadership in stack performance. Boasting a cell active area over four times larger than our Merrimack platform and fluid handling capabilities to match, we have not just broken but have shattered the $1,000/kW price barrier. The Allagash offers an exceptional combination of price, efficiency, scale, durability and packaging. Already subject to many thousands of hours of laboratory testing, we anticipate that this stack will lead the hydrogen refueling station, power-to-gas, and power-to-product demonstration markets in the near term.

Specifics

- 1250 cm^2 active area
- To 900 kg/day ($2ME_e$ nominal input)
- 0-40 bar (580 psig)
- Differential pressure operation
- 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 2350 kg/day
- 0 to 225 psig (15.5 bar)
- Customizable

Electrolyzer Systems

Giner ELX electrolyzer systems incorporate our world-leading PEM electrolyzer stack technology. They deliver pure hydrogen (99.9995%) safely, cleanly, noiselessly and efficiently at pressures up to 40 barg or 580 psi.

Applications include:

- Energy storage: storage of surplus electric energy—particularly of stranded solar or wind energy—as hydrogen for later use:
  - to power fuel cell vehicles or hydrogen turbines
  - as an industrial gas
  - by blending into the natural gas supply network
- Hydrogen fueling stations (for fuel cell powered buses, cars, trains, trucks, fork-lifts…and trains!)
- On-demand hydrogen production for industrial users:
  - Electric turbine cooling
  - Hydrogenation for food manufacturers
  - Float glass processing
  - Semiconductor fabrication
  - Gas chromatography and other laboratory devices

30S: 30Nm^3/h System	60S: 60Nm^3/h System	90S: 90Nm^3/h System	200S: 200Nm^3/h System
20-foot container	20-foot container	30-foot container	40-foot container
150 kW System	300 kW System	450 kW System	1,000 kW System

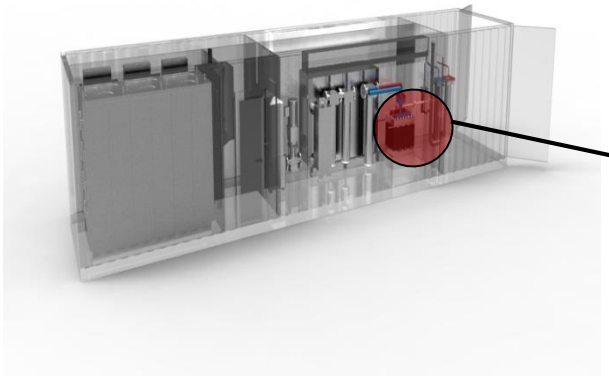
Commercial Hydrogen Stacks & Systems

www.GinerELX.com

The Giner ELX Advantage

Highest performance and lowest cost

- Giner ELX"s commercial electrolyzer portfolio achieves industry leading specifications:
  - Current density: 3 A/cm2
  - Temperature: 70 C
  - Pressure: 40 bar diff standard
  - Highest efficiency
  - **Lowest total cost of ownership**
- Clear development roadmap to green hydrogen at a cost of $1.50 per kilogram (assuming power at 2 cents per kWh)
  - Based on technology advances **already being demonstrated in our labs**



220+ Nm³/hr

(MW Scale)

Active Area: 1,250 cm²
Pressure: 40 bar
Nominal Current: 3,750A
Current Density: 3A/cm²

30 Nm³/hr

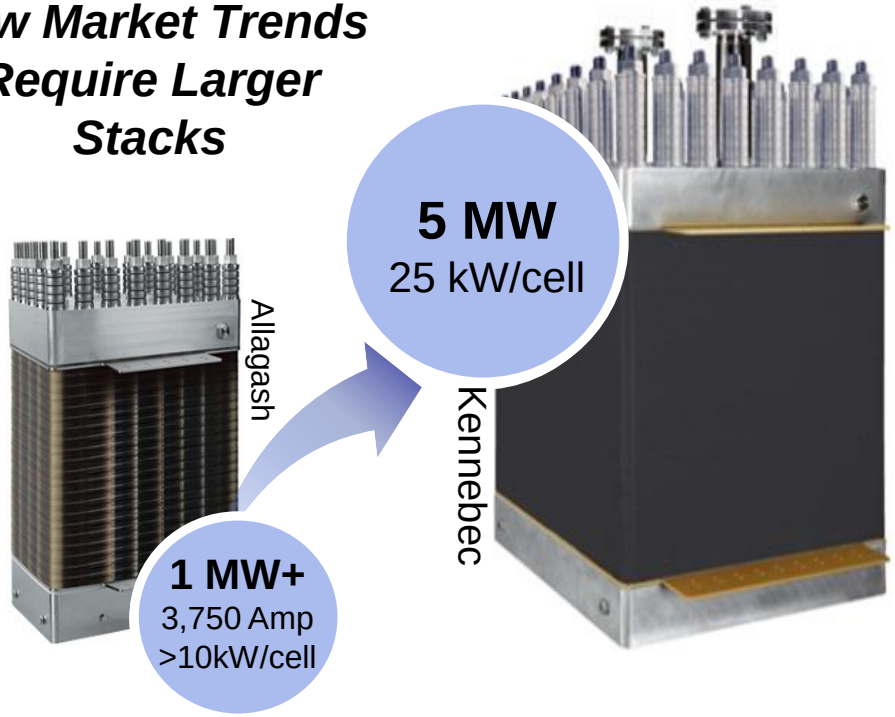
3 Nm³/hr

0.05 Nm³/hr

Aerospace/Military Applications — Commercial/Industrial Applications

Emerging Designs for Future Applications

New Market Trends Require Larger Stacks



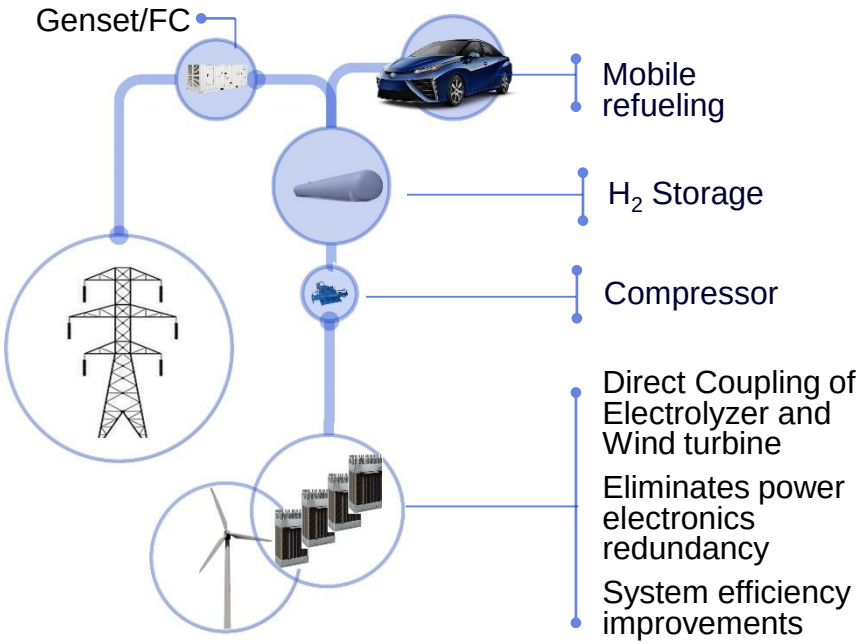
- Giner ELX 5MW Stack Platform
  - Active Area: 3,000+ cm²
  - Current Density: 5A/cm²
  - Operating temperature: 90 C
  - Operating Pressure: 600 psig (40 Bar)

1100 Nm³/hr Electrolyzer Stack

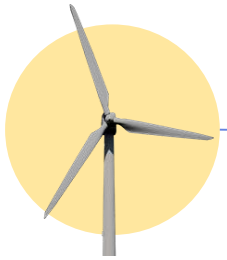
MW Applications/Systems

Wind to Hydrogen

- Netherlands
- Centralized hydrogen production
- Hydrogen used for transportation applications
- 4 Allagash stacks directly coupled to each windmill
  - Elimination of rectifier in electrolyzer
    - Eliminates equipment redundancy
    - Improves system efficiency
    - Capital cost improvements



Emerging Markets & Drivers



Kennebec 5MW Platform

- Power to Gas (P2G): Biogas
- Power to Mobility (P2M)
- Power to Hydrogen (P2H): Integration of Renewable Energy Sources
- Grid load shedding

ELX Recent Activities

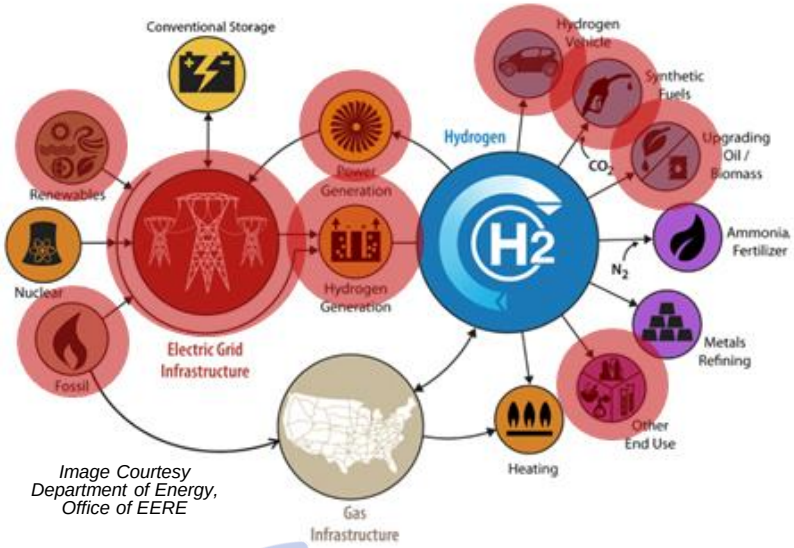


Image Courtesy Department of Energy, Office of EERE

Giner ELX PEM Electrolyzers have penetrated many of the hydrogen production utilization activities mentioned in H2@Scale

Netherlands- Wind to Hydrogen/Mobility (Multi-MW)

UK- Lab Hydrogen (30,000 units)

Finland- Synthetic Fuel w/CO_2

Portugal- Emission Control

Belarus – Industrial (200kg/day)

Spain- Hydrogen Refueling Station (65 kg/d) Follow up Projects Multi-MW

France-Major Utility company H_2 Generator Subsystem (200 kg/day)

USA-Onsite Hydrogen Generation HRS, CA (3x200 kg/d)

Germany-Bio-Methanization (240 kg/d)

Germany-Supplying stacks to integrators - Industrial use. Follow up orders for 300 kg/day

India -Mobile Refueling Unit, Follow up order 200 kg/day

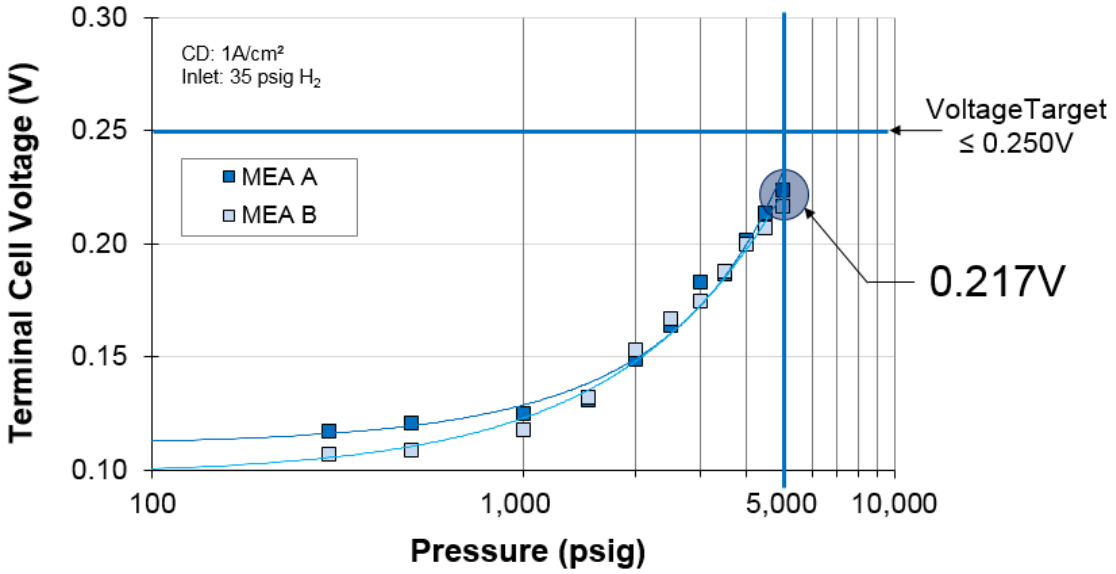
Brazil- Industrial (200-kg/day)

Advanced Electrochemical Hydrogen Compression (EHC)

"Mechanical compressor reliability is a major concern in high pressure hydrogen systems and threatens the deployment of a hydrogen infrastructure"

- Giner ELX developing NEW solid state Electrochemical Hydrogen Compressor (EHC) technology to support FCEV penetration
- 900 bar hydrogen compression
- Reduce cost, improve reliability, and increase in efficiency of EHCs

EHC Cell Performance @ 350 bar (5,000 psi)



- Successful EHC Operation @ 5,000 psi (350 bar) , ≤ 0.250V @ ≥ 1,000 mA/cm²
  - Single stage compression
  - Compression ratio 140:1
  - Performance: 0.217V @ 1000 mA/cm², 5,000 psi
- Back diffusion reduced by > 50% to < 3%
- Stack Efficiencies to 2.7 $kWh_e/kg\text{-}H_2$
- **Highest Efficiency for EHC operating at 5,000 psi**

EHC Stack Design & Development

12,688 psi
(875 bar)

5,000 psi
(350 bar)

5,000 psi operation,
Multi-cell Stack design,
Increase in active area

Evaluation of high pressure components, Flow distributors & internal cell components, membrane strength

1,000-5000 psi
(70-350 bar)

300 psi
(20 bar)

Optimization: Catalyst, Membrane & Cell-Component, Testing & Validation

875 bar Stack Design Features

- Proof pressure : 20,000 psi (1,400 bar)
- Active Area Scale-up: 50 to 300 cm²
- Utilizes low-cost materials: SS
- Enhanced bipolar plated design for reduced part count and dead-ended flow
- CE/UL Certification
  - Intertek review of 'NEW' H_2 compression technology

System Features

- System designed to be located in hazardous areas, zoned for Class 1, Div2, Grp B
  - UL Certified

Future Plans

Membrane/Stack/System

- Scale-up, Scale-up, Scale-up…
- Increase stack active-area to 300 cm^2, and then 1200 cm^2 +
  - Also requires scale-up of membranes
- Increased operating pressure
  - Currently operating at 5,000 psi. Increase to 12,688 psi
  - Maintaining seals of stacks at operating pressure of >12,688 psi
- Complete review of EHC System with Intertek
    - Established appropriated standards, component classifications, and operating requirements for certification
- Reduce Stack Costs
  - Unitize cell components (reducing parts/cell)
    - Combine cell components at the production level
    - Investigate techniques to reduce fabrication costs

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