NREL
NATIONAL RENEWABLE ENERGY LABORATORY

MW-Scale PEM-Based Electrolyzers for RES Applications

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DOE Hydrogen and Fuel Cells Program
2019 Annual Merit Review and Peer Evaluation Meeting

Project ID #: h2007

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Overview

Timeline and Budget

- Project start date: 3/1/18
- Project end date: 1/16/20
- Total project budget: $300k
  - Total recipient share: $30k
  - Total shared resources: $240k
  - Total federal share: $30k
  - Total funds spent*: $23k

Barriers

- Cost of Hydrogen production

Partners

- Giner ELX (CRD-18-742)
  - PI: Monjid Hamdan
- NREL ESIF Operations Team
  - Danny Terlip, Owen Smith and Sam Jimenez and Kevin Harrison

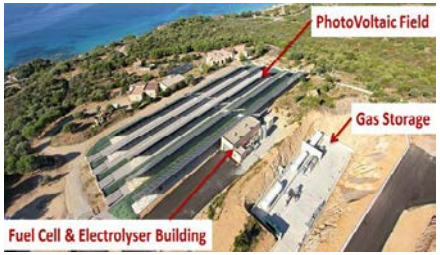
* As of 3/1/19

Relevance - Electrolyzer Stacks

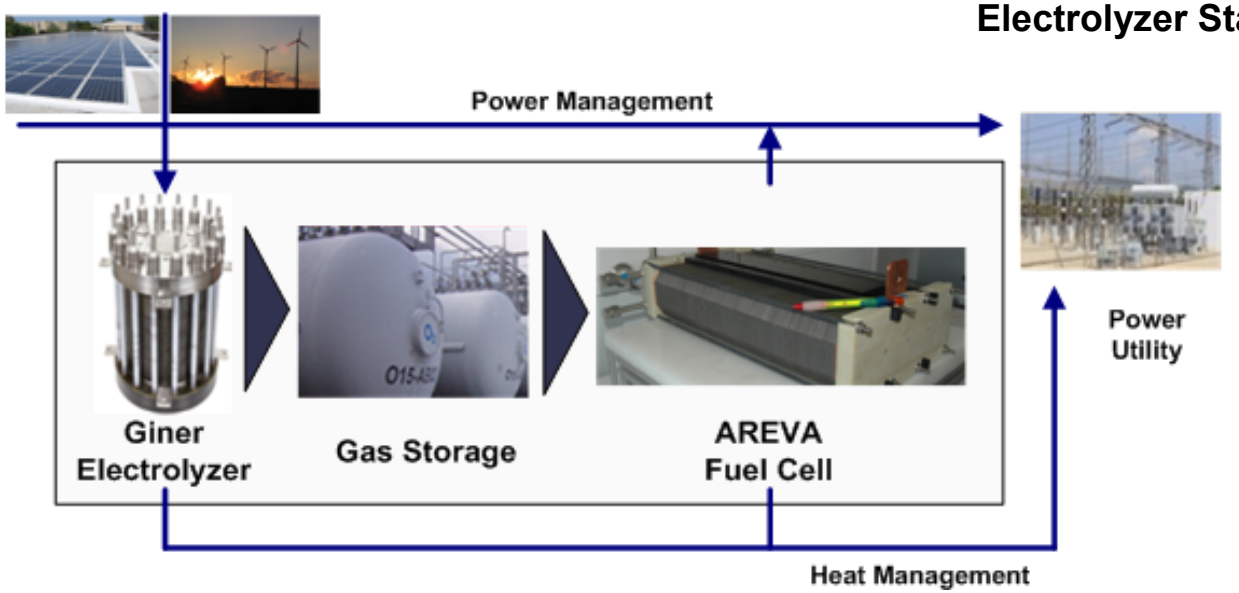
Regenerative Fuel Cell Systems

Target markets

- Intermittent Renewable Energy Source (RES) integration
  - Backup power for grid outages and load shedding
  - Increase RES ratio and ensure grid stabilization



AREVA's energy storage platform 'GREENERGY BOX' in Corsica, France Utilizing Giner Low-Cost Electrolyzer Stack



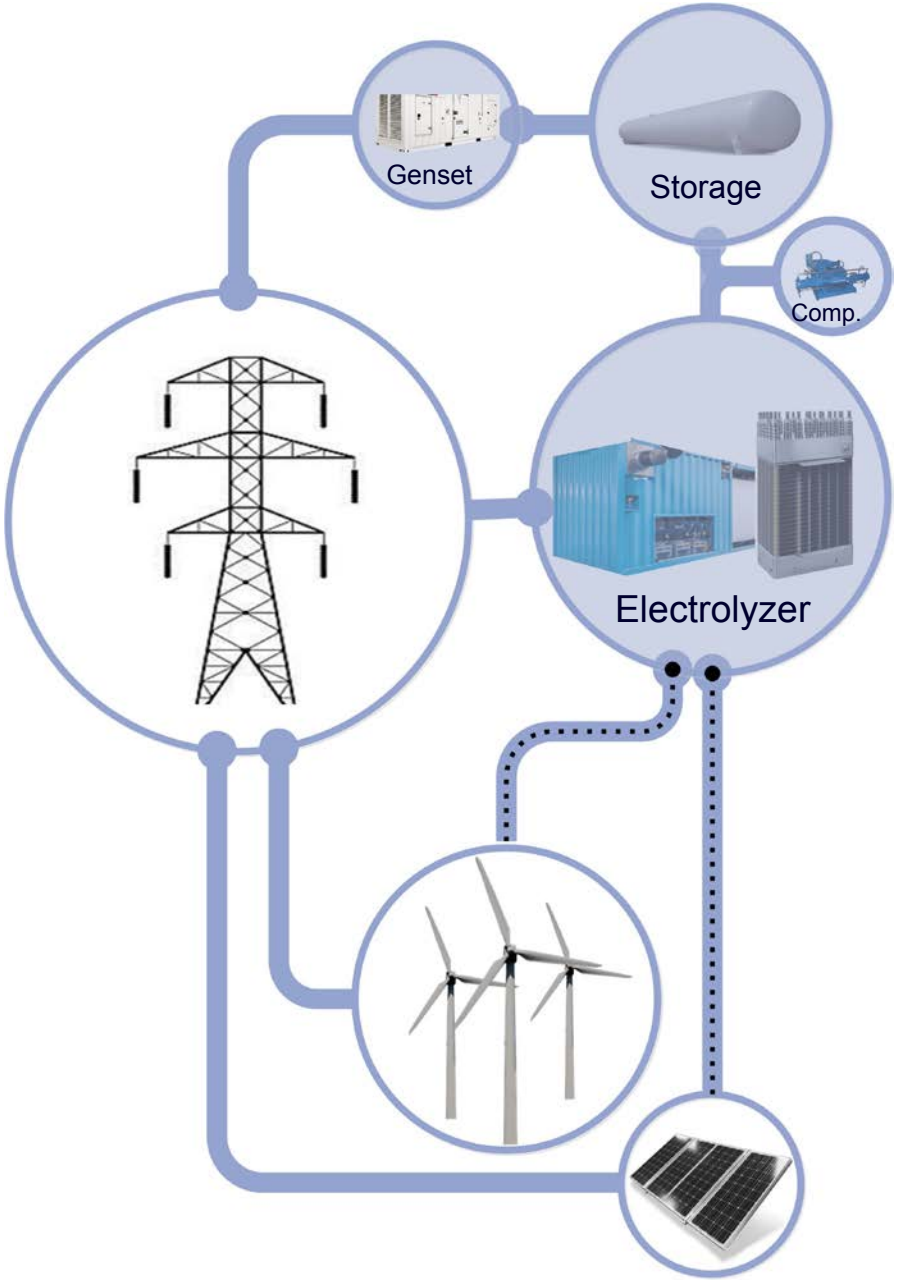
Modular RFC systems with energy storage from 0.2 to 2 MWh

Challenges & Needs

MW Large Scale Projects

Wind-to-Hydrogen gaining momentum
Microgrid Applications

- Microgrid & hydrogen storage application on isolated island
  - Centralized hydrogen production adjacent wind farm
- Primary source used to generate electricity: fossil fuels
- Renewable energy sources provide 33% of total energy
  - 25% from wind turbines
  - 8% from solar panels
- Target-100% energy from renewable power sources by 2020
- Driver: Regulatory support



Markets for Electrolyzer Systems

- Power to Mobility
- Power to Gas
- Power to Hydrogen

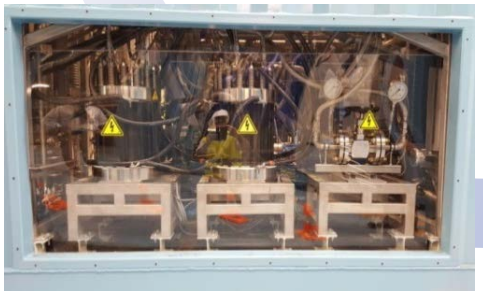
System & BOP

Built to NEC/IEC standards
NFPA2/ATEX Compliant

Giner 500kW-1MW
HRS System -
Mobile Refueling

Electrical

Rectifier Controls w/
Load Following for RES

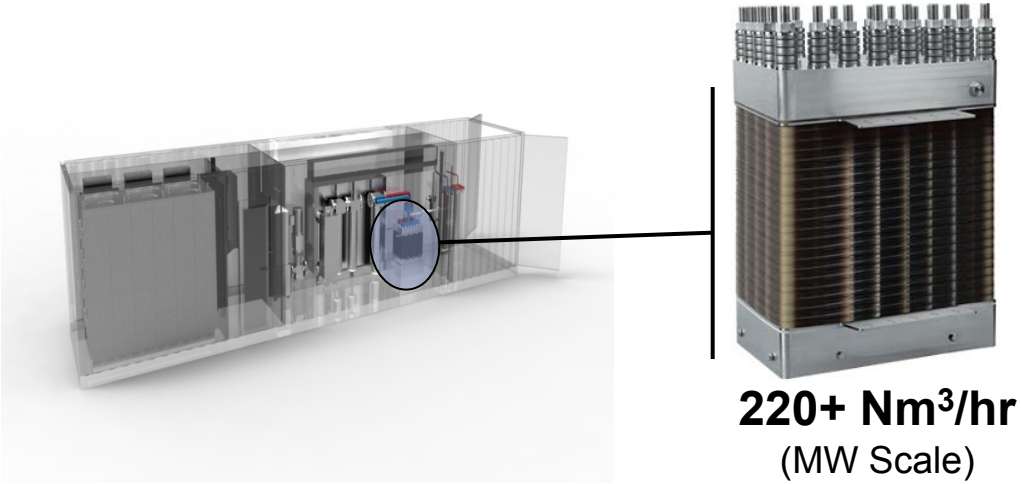


Modular Systems

30,60,90,200 Nm^3/hr

Objectives & Goals

- Address critical aspects for the successful commercialization of Giner ELX's 'Allagash' MW PEM-based electrolyzer platform
  - Perform long-duration testing at Giner ELX and NREL to inform next-generation MW-scale electrolyzer system development.
- Develop, assemble and test electrolyzer for use in Large-Scale Renewable Energy applications
  - Scale-up of PEM-based Electrolyzer Stack
    - Current 150kW platforms to 1-5 MW platforms
  - Validate Performance at high current density ($3A/cm^2$) at 30 bar
    - Stack decay rate, Fluoride release rates and H_2 in O_2
- Cost reduction of Stack and improved manufacturability to reduce the cost of hydrogen production

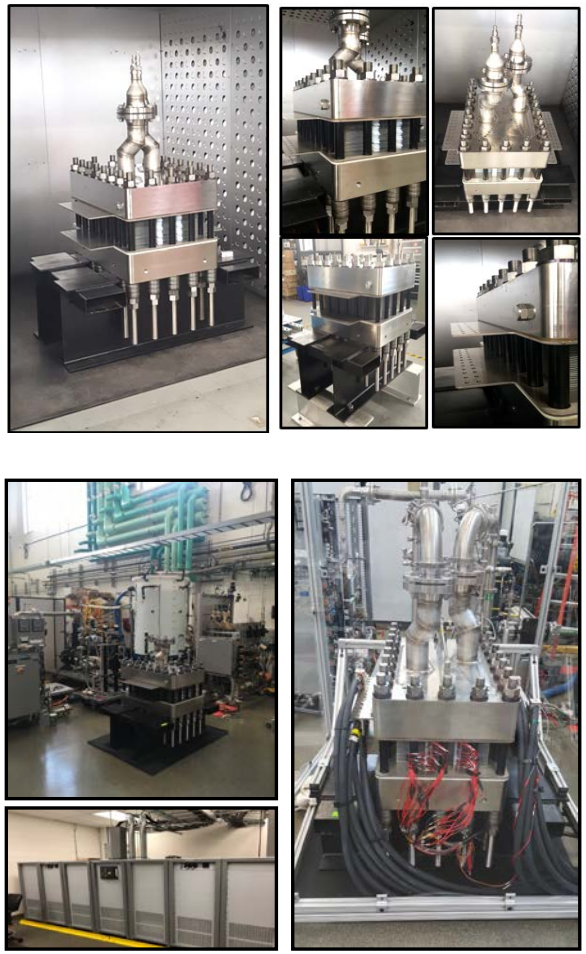


Approach

Three (3) primary tasks :

- **Task 1 (Giner ELX):**
  - Scale-up active area of the electrolyzer stack
    - 290 cm² (150 kW platform) to 1,250 cm² (1 MW platform).
  - Determine number of cells based on the power capabilities at NREL's Energy Systems Integration Facility (ESIF) test site
  - Manufacture & Assemble multi-cell stack based on 1 MW stack platform
- **Task 2 (NREL):**
  - Modify electrolyzer testbed at NREL's ESIF facility for large-scale electrolyzer stack testing
  - Integrate, operate, and monitor stack testing over 5,000-hour period
    - Operate cyclically between a current density of 0 to 3 A/cm²
- **Task 3 (Giner ELX/NREL):**
  - Performance analysis
    - Evaluate efficiency, durability, and lifetime of the stack
      - Analyze fluoride release rate to determine membrane degradation rates/stack lifetimes
      - Monitor voltage performance / stability at current densities of 3 A/cm²
      - Monitor cross-cell diffusion (%H_2 in O_2)
      - Tear down: Determine impact on cell components and catalyst utilized in the MW stack platform

Accomplishments Stack Build, Integration into NREL ESIF Testbed



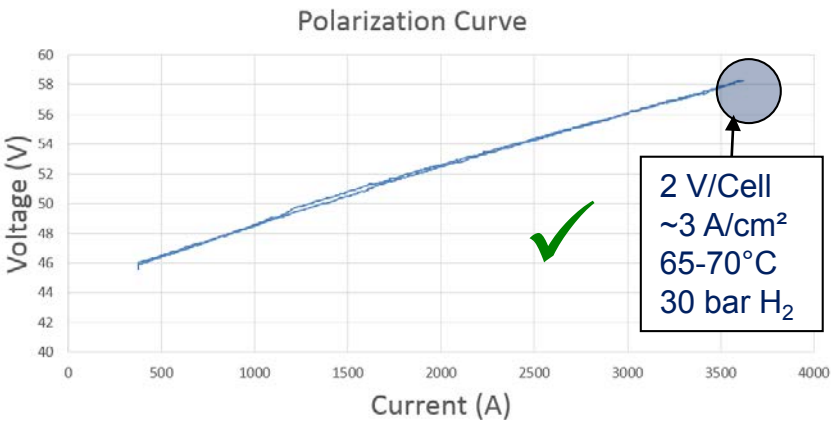
Giner ELX

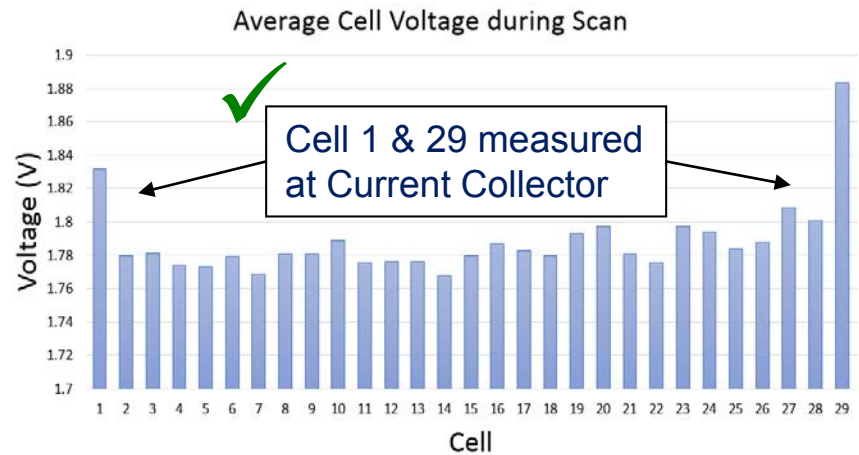
- ¼ MW stack build assembled -Feb 19th, 2018
- Stack Prechecks -Mar.-Jun., 2018
- Stack delivered to NREL -July 21st, 2018
- Installed into NREL testbed -Aug 23rd, 2018
- Stack Design Specifications
  - Active Area: 1,250 cm²
  - Build contains 29 Cells
  - Operating Pressure: 40 bar
  - Operating Temperature: 70C
  - Operating mode: Differential Pressure
  - Current (Nominal): 3,750 Amps (3 A/cm²)
  - Includes support-base for ease of transport
  - CE Compliant
- Design Iteration: 6th
  - Improvement in performance and/or lifetime achieved with each iteration
  - Advancements implemented in other platforms to reduce cost/improve lifetime

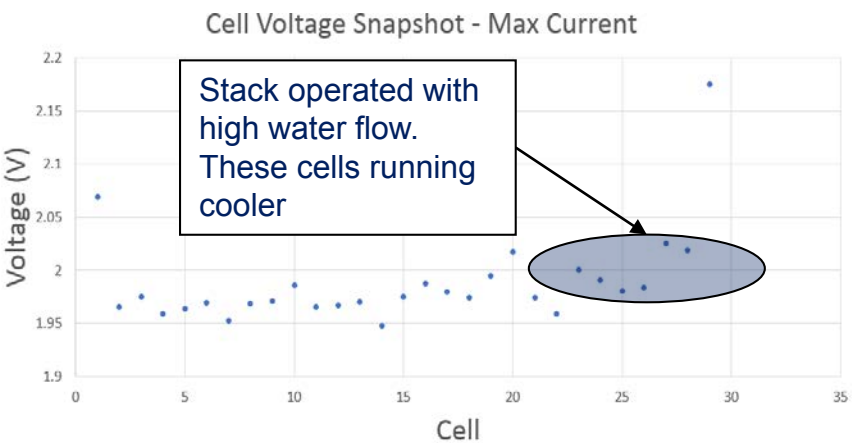
NREL-ESIF

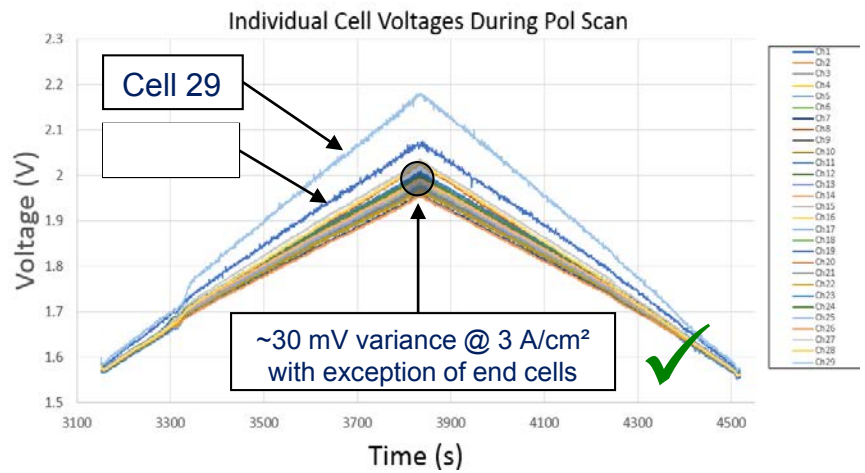
- Modified Electrolyzer Test Bed to accommodate 'Allagash' MW-platform stack
  - New sensors, power cables, pressure regulator, pumps, etc..
  - Purchased & installed 2 new (4 total) 250 kW power supplies (AC/DC)
    - In current sharing mode, all supplies will provide the required current (3800A) to the Giner ELX stack
    - Test stand is now capable of a1MW stack
- Stack integrated into testbed and operational
- All cell voltages stable and within range

Accomplishments - NREL Test Data









Data:

- **300 hours of operation on 29-cell stack at various current and daily start/stop cycles**
- ✓ **%H2 in O2:** <10% LFL (Water from H_2 Separator drains into O_2 Reservoir)
- ✓ **Fluoride Release Rate measured:** < 6 ppb (3 samples; control 5, 10, and 15 ppb)

Accomplishments - Parallel Testing at Giner ELX

7-Cell Allagash Testing & Performance

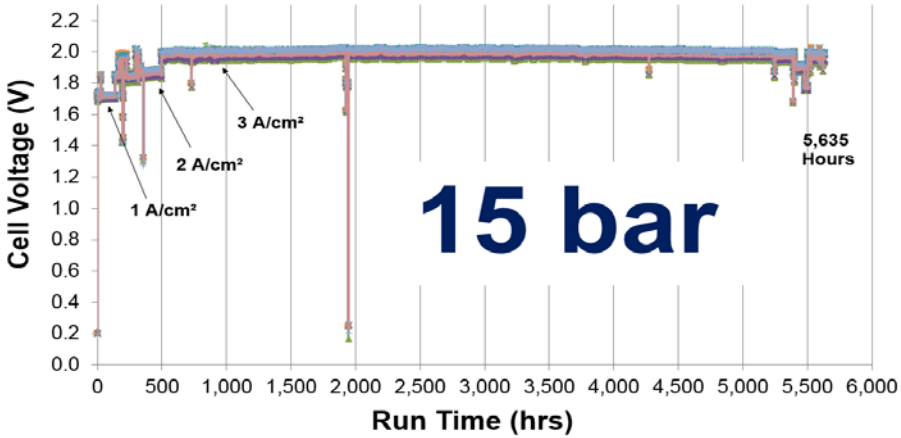
- ~5,000 hrs. at 3A/cm², 15 bar
- ~5,000 hrs. at 3A/cm², 40 Bar (*Ongoing*)

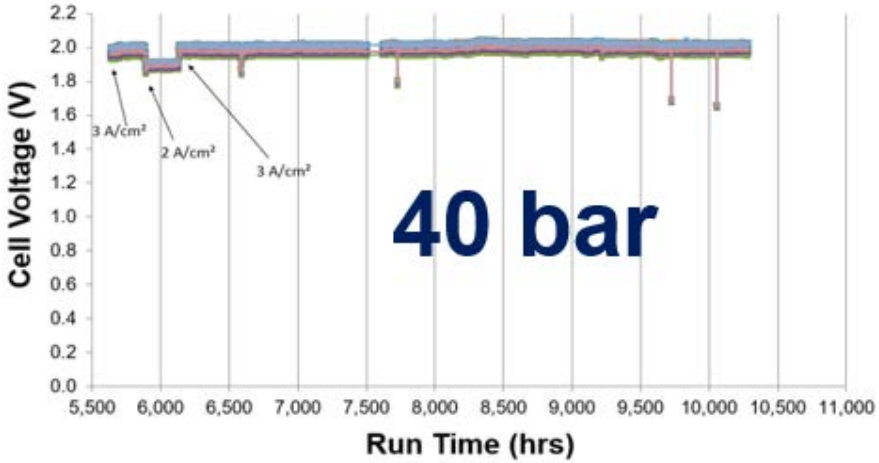
- Low Voltage Degradation rate
  - <1 μV/hr over 10,000-hour period

10,000+

Total Operating Hours

(as of March 2019)



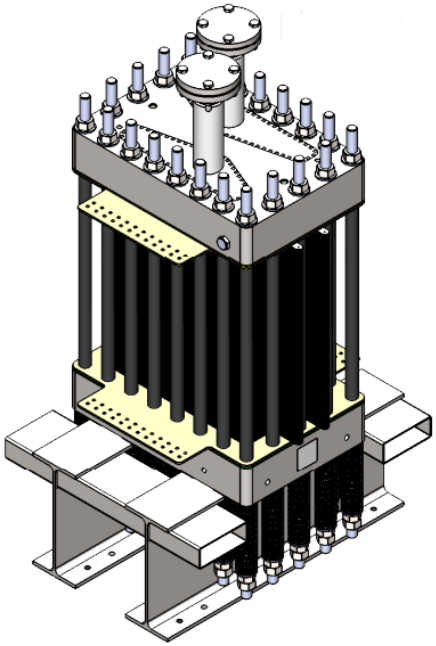


Future Plans

- Continue stack testing
  - 5,000-hour period
  - Operate stack cyclically between a current density of 0 to 3 A/cm²
  - Continue performance evaluations (efficiency, durability, lifetime) of the stack
    - Analyze fluoride samples to determine membrane degradation rates/stack lifetimes
    - Monitor voltage performance / stability at current densities of 3 A/cm²
    - Determine impact on cell components and catalyst utilized in the MW stack platform

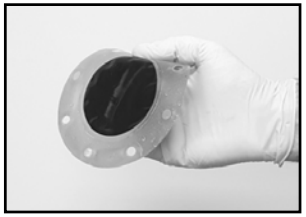
Any proposed future work is subject to change based on funding levels

Cost Reduction, Volume Production

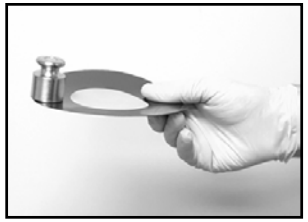


Key supply chain/production Solutions/Activities:

- **Cell Frames:** Lead time reduced with purchase of injection mold
- **Assembly & Sealing:** Designed/Purchased Bolt Tensioner to reduce labor and assembly time
- **MEAs:** Implemented R2R Catalyst for MW-Platform
- Capable of producing catalyst for 10-1MW stacks in one day
- **Single Cell Architecture:** Rapid production/Automation:

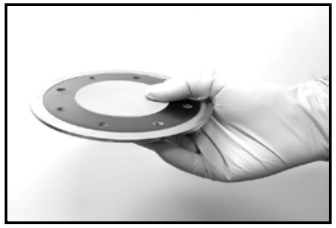


Traditional Supported Membranes



Latest Supported Membrane*

- Enables Dry build
- Hard surface seal

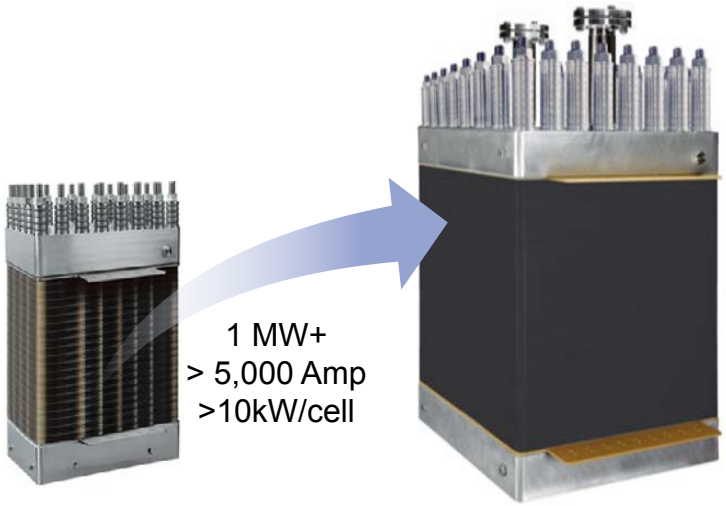


Single-piece Cell Architecture*

**Developed under separate DOE project, Scale-up required for MW-Platforms*

Emerging Designs for Future Applications

New Market Trends Require Larger Stacks



5 MW
12,500 Amp
25 kW/cell

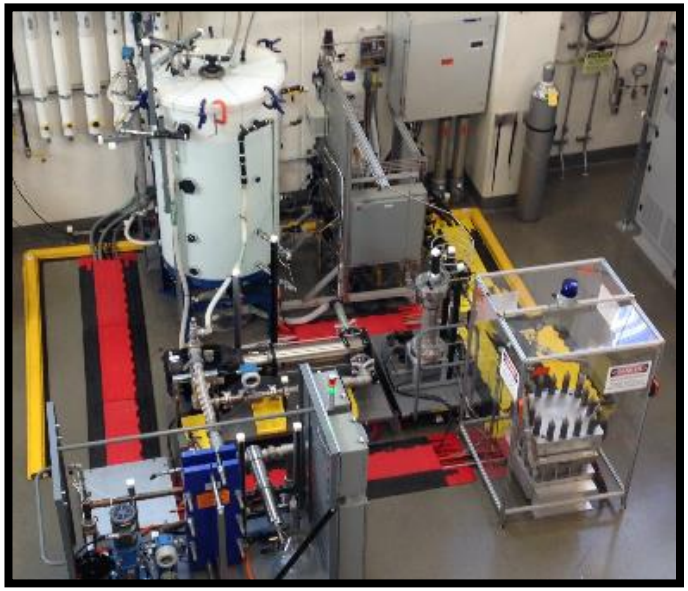
- 5MW Stack Platform
  - Operating Pressure: 600 psig
  - Active Area: 3,000+ cm²
  - Current Density: 3,000+ mA/cm²
- Development 2018 - 2020
- Economics
  - Accelerates market opportunities

1100 Nm³/hr Electrolyzer Stack

Collaborations & Partnerships

- **Giner ELX**
  - PI: Monjid Hamdan
  - CRADA 18-742
- **NREL**
  - ESIF Operations Team
  - Danny Terlip, Owen Smith and Sam Jimenez and Kevin Harrison

NREL Electrolyzer System



NREL Energy Systems Outdoor Test Facility

System Specifications

- 20 – 70 bar differential pressure
- 4000 A_{dc} at 250 V_{dc} (1 MW DC)
- H_2 Purity: < 5 ppm_v H_2O_v
- 250 kW PEM stack → 5 kg H_2 / hr
- Compression w/ ~300 kg H_2 storage
  - 200, 400 and 900 bar

Summary

Objective

- Develop, assemble and test electrolyzer for use in Large-Scale Renewable Energy applications

Accomplishments

- Over 300 hours of operation at NREL on 29-cell stack
  - < 2 V/cell at 3 A/cm^2, 60 – 70C and 30 bar cathode pressure
  - Daily on/off cycles
  - Varying current to the stack
  - < 10% H_2 in O_2
  - Water samples obtained and returned to Giner ELX for analysis
  - < 6 ppb Fluoride release rate
- Over 10,000 hours of operation at Giner ELX on 7-cell stack
  - < 1 uV/cell-hr over 10,000 hours of operation
  - 5000 hours at 15 bar cathode pressure
  - 5000 hours at 40 bar cathode pressure

Future Plans

- Continue stack operations at NREL and Giner ELX monitoring for;
  - Stack degradation rate, Fluoride release rate and H_2 in O_2

Thank You

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Publication Number

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