# Water Electrolyzer Technology: Status and Challenges


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# Outline

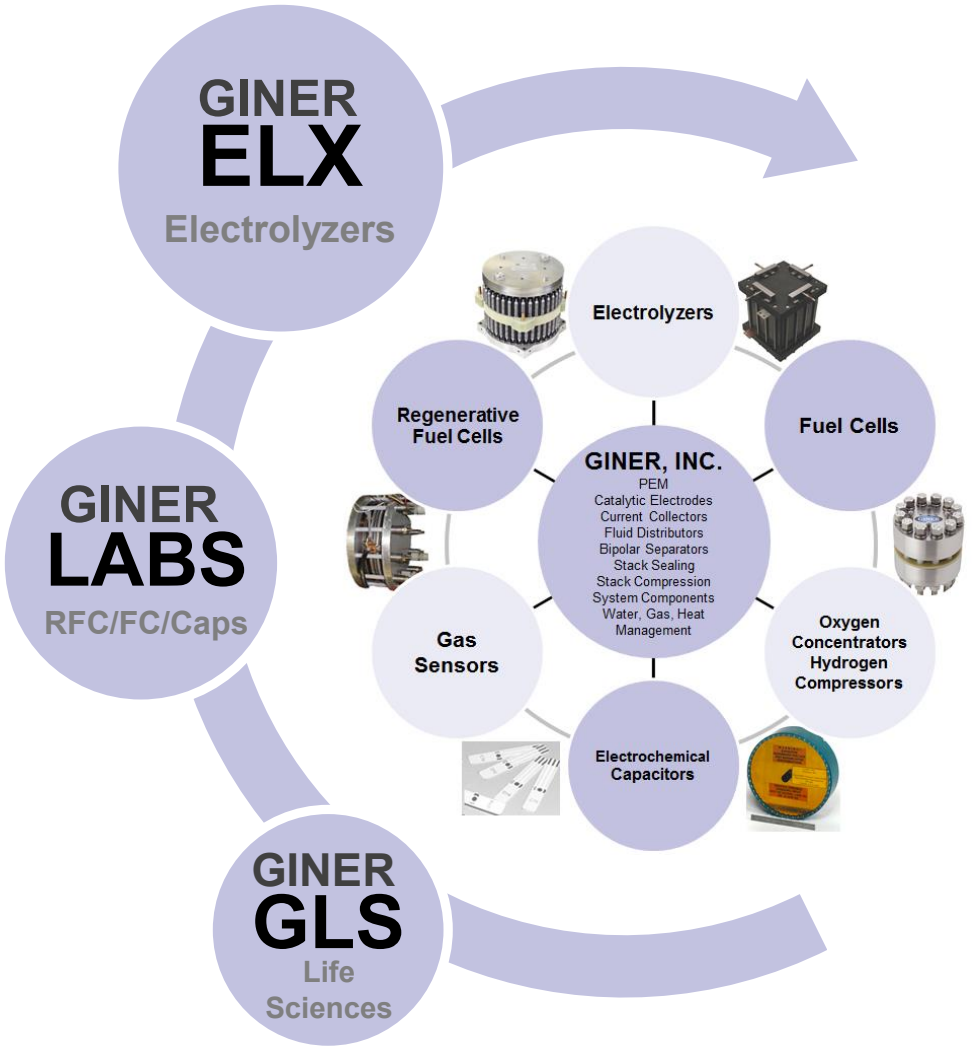
- Giner, Inc./Giner ELX, Inc. Intro

- Status of current electrolyzer technologies
- 'Giner' PEM electrolyzer technology
  - Product road map & projects

- Electrolyzer Technology - Challenges & Needs
  - Manufacturing
  - Scalability
  - Testing Equipment & Validation
  - R&D needs for emerging electrolyzer technologies
  - Grid Integration
  - Collaboration

# GINER, Inc. / GINER ELX, Inc.

- Giner, Inc. Founded in 1973
- Specializing in research & development of PEM based electrochemical technology and systems
- Since 2005 Giner has accelerated growth
  - Key driver has been the manufacturing of PEM electrolyzers to OEMs
  - Global leader in Polymer Electrolyte Membrane (PEM)-based electrolyzers
  - Highest efficiency technology for commercial applications
- Core Mission: Provide Innovative PEM Technologies with the Highest Efficiencies at the Lowest Costs to Developing Hydrogen Markets
- In April 2017, GINER **ELX**, Inc. was created to focus on commercial development and manufacturing of large scale electrolyzer stacks & systems



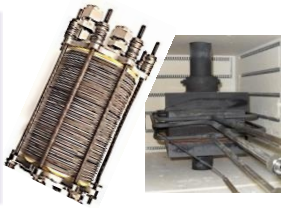

**Synergy of Giner, Inc. Technologies**

# Status of Current Electrolyzer Technologies

**Electrolysis Technology**

Maturity

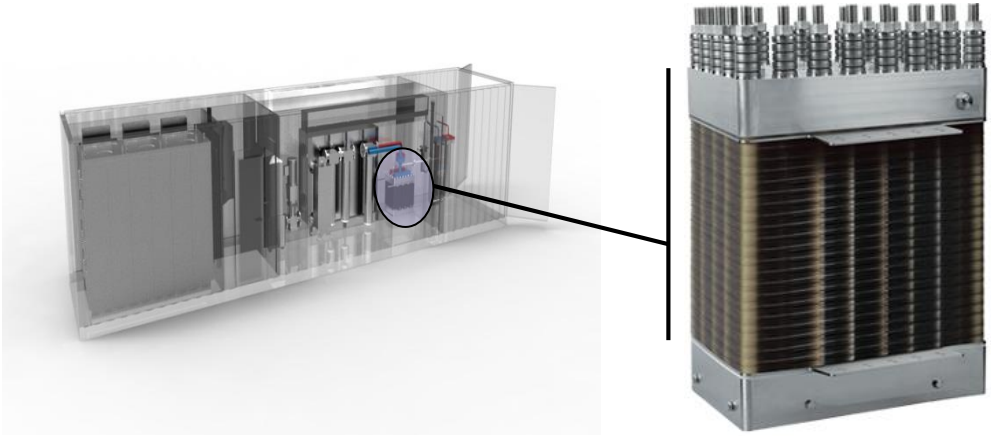
| | Production Rate (kg/day) | Production Rate ($Nm^3/hr$) | Pressure (bar) | Temp (°C) | Eff (%HHV) |
|---|---|---|---|---|---|
| Alkaline | 1500+ | 700+ | 30 | 40-90 | 52-69 |
| PEM | 475 ↑ | 220 ↑ | 40- 100 | 20-90 | 75-90 |
| Solid Oxide<br>HT-Alkaline | ~2 | 1+ | Atm | 600-1000<br>350-600 | >90 |
| AEM<br>(Alkaline Membrane) | ~2 | 1+ | 30+ | 50-80 | 40-70 |

# Status of Giner Commercial PEM Technology

## Emerging Markets & Drivers

- Power to Gas (P2G): Vast opportunities in Biogas
- Power to Mobility (P2M)
- Power to Hydrogen (P2H) Integration of Renewable Energy Sources
  - Large reserves of stranded energy (need to store/shift)
    - Ongoing broad developing **wind energy** sector
- Backup power for grid outages and load shedding



**220+ Nm³/hr**
(MW Scale)

30 Nm³/hr

3 Nm³/hr

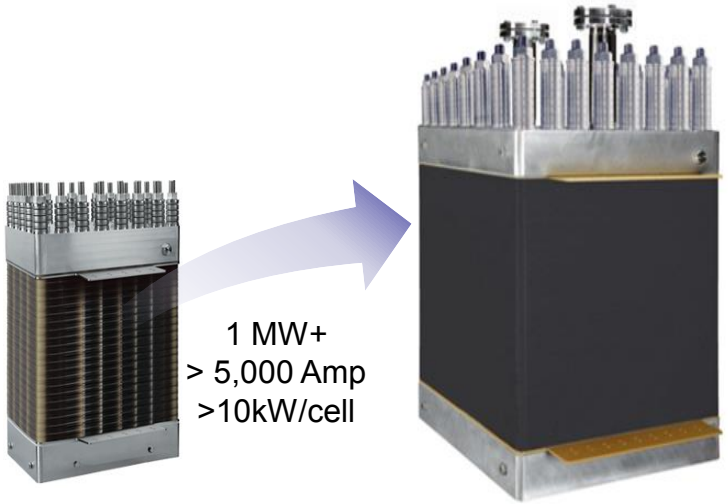
0.05 Nm³/hr

Aerospace/Military Applications

Commercial/Industrial Applications

# New Designs for Future Applications

## New Market Trends Require Larger Stacks




- 5MW Stack Platform
  - Operating Pressure: 600 psig
  - Active Area: 3,000+ cm²
  - Current Density: 3,000+ mA/cm²
- Development 2018/19
- Economics
  - Accelerates market opportunities

1100 $Nm^3/hr$ Electrolyzer Stack

# Large Scale Systems for Mobility

BOP

Understanding Standards/Codes
System simplification
Component availability & cost


Giner 500 kW HRS System - Mobile Refueling

**Cost Contributors**

& Needs

Electrical

Rectifier cost
Redundancy
Rapid power switching for RES

Stacks

Scale up

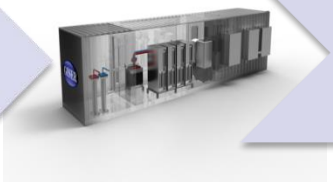
# Product Roadmap

**2013 - 2014 - 2015 - 2016 - 2017 - 2018+**

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

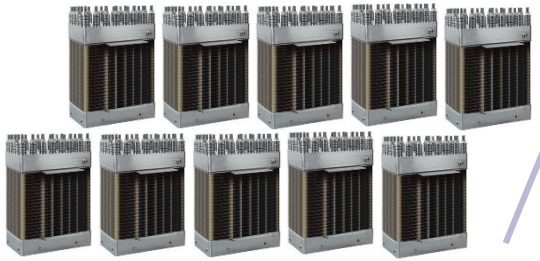
130 – 260 kg/d Systems
CA $H_2$ Refueling Stations


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



MW Stack (480 kg/d) & MW System Sales "P2G"

MW System Demonstrations



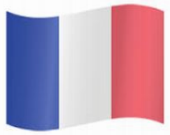
Multi-MW to GW Demo's
(4,800 kg/d to 480,000 kg/d)
Systems Integration

# Recent Projects

On-site Hydrogen Generation HRS in CA (3x200 kg/d)

Bio-Methane (240 kg/d)  Phase I finished 2014 & P-II 2016

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



200 kg/day $H_2$ Generator Subsystem 2017 France-Major Utility company

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

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

# Electrolyzer Technology Challenges & Needs

- Manufacturing
- Scalability
- Testing Equipment & Validation
- R&D needs for emerging electrolyzer technologies
- Grid Integration
- Collaboration

# Challenges: Manufacturing

## Manufacturing Innovations Required

- MEAs
  - Lack quality inspection - leaks, pinholes, and shorts
  - Lack of MEA assembly processes (alignment of electrodes)
  - Lack of high rate pressing/lamination processes
  - Lack of high quality cutting processes
  - Electrodes
    - Lack of uniformity and quality of coatings
    - High scrap rates associated with decal transfer coating
    - Lack of manufacturing processes for scaling catalysts batches
    - Lack of performance-based tolerances
    - Lack of continuous catalyst ink processing
    - Lack of high throughput heat processing

- Cell Components
  - High cost of production equipment
  - Lack of plate joining processes

- Stack Assembly
  - Lack of methods to ensure alignment of cells during assembly
  - Lack of high rate stack sealing processes
  - Lack of methods to handle soft, flexible components during automated stack assembly

# Challenge: Scalability

**Stack Design(s)**

- Cell materials not available for larger active areas
  - Alternative support materials
- New tooling to develop components for scaled-up cell areas
  - Injection molds, membrane support materials

**Production Line(s)**

- Need to align MW design(s) across company product lines
  - Simplifies supply chain and inventory management
  - Improves production efficiency
    - Reduces scrap
    - Reduces labor content
    - Eases training and QC/QA
    - Improves internal supply chain
- MW Scale Stacks require implementation of new manufacturing processes or process improvements
  - Automated catalyst decal preparation
  - Cell component unitization
  - MEA Automation/Roll-to-Roll
  - Stack assembly automation

**Regulation**

- Certification requirements: MW stacks need to be compliant with pressure directives, CE, UL…

1100 $Nm^3/hr$

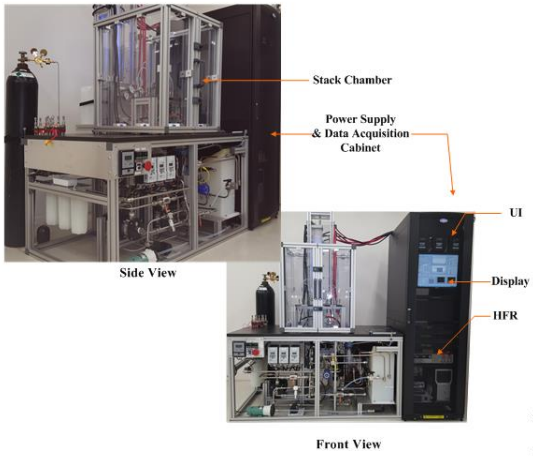
0.05 $Nm^3/hr$

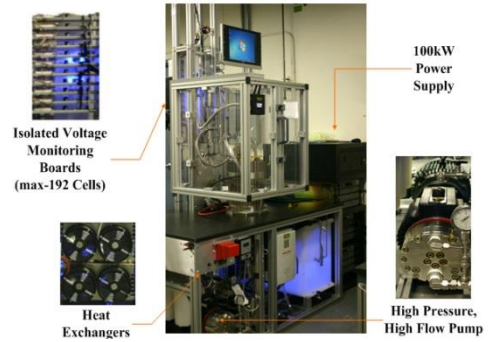
# Challenge: Testing Equipment

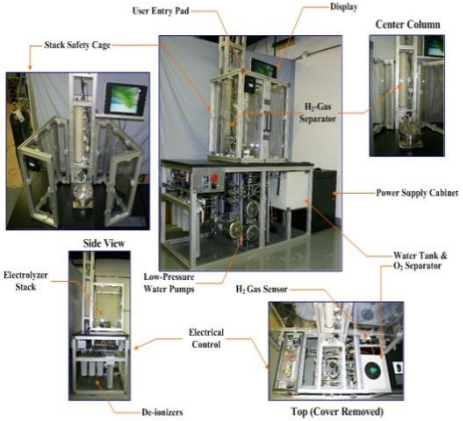
**Scale-up to MW Stack also requires scale-up of testing equipment!**

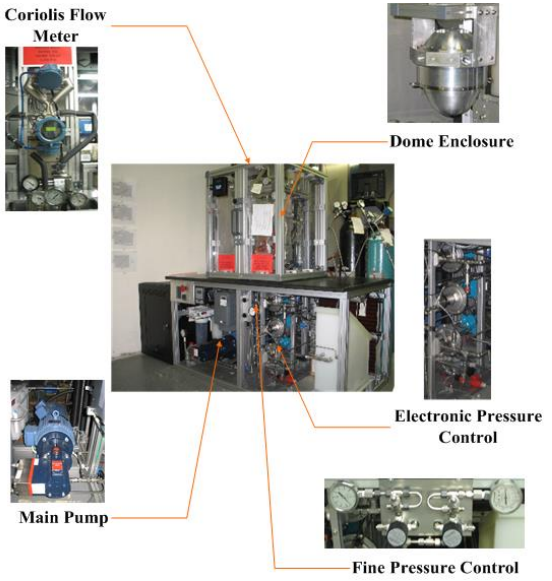
Test equipment requirements:

- High differential pressure capabilities
  - $H_2$: 0 - **100 bar**
- Large power requirements
  - Stack sizes to **5 MW+**
- New Evaluation methods:
  - Membrane performance
  - Durability
  - Lifetime
- Safety!
  - Availability of High Voltage, High Pressure Equipment
  - Employee Training



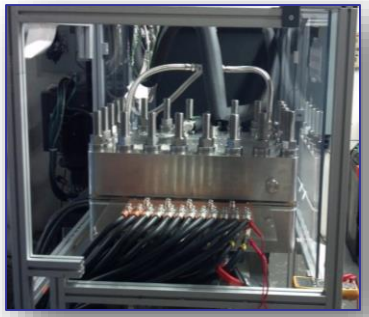



# Challenge: Validation of Large Scale Electrolyzers

**New Test Facilities required as larger stacks come online…**

- MW stack testing limited to facility power
  - Limits stack size (or number of cells) that can be tested
- Large cost to increase power into a facility
- Heavy lifting equipment required




*Short-stack testing of Giner's MW platform, 100 kW required for 6 cells, weight 2500 kg*

**1100 $Nm^3/hr$ Electrolyzer Stack**

# Challenges: Emerging Electrolyzer Technologies

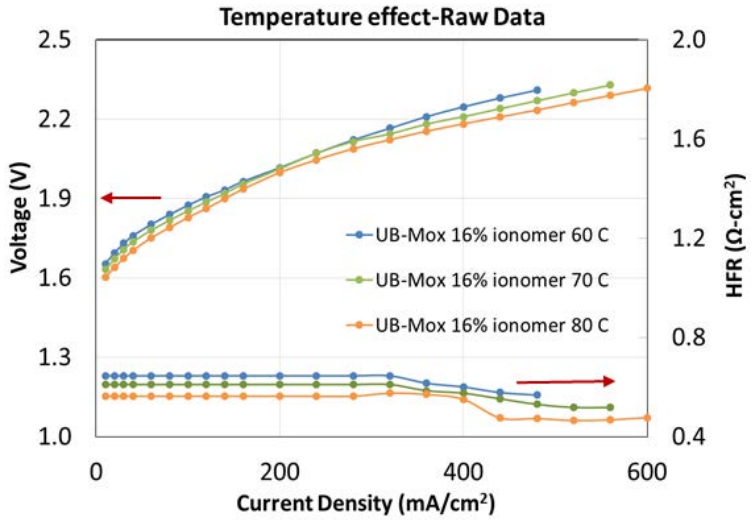
## Low Temperature Electrolysis (AEM)

**Advantage**

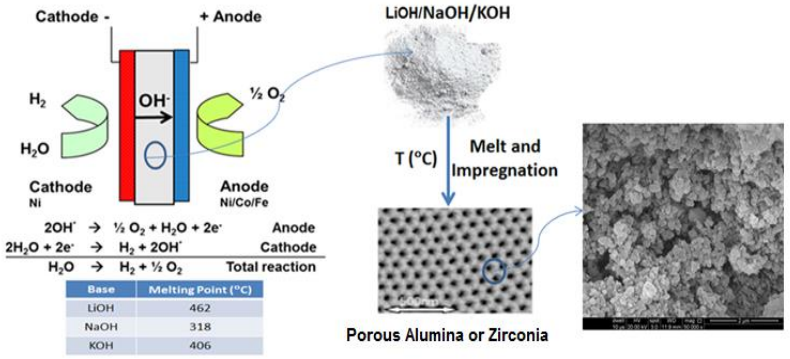
- Low CapEx: Use of non-noble metal catalyst

**Needs:**

- **Efficiency improvement**: development of catalyst & alkaline membranes
  - Performance target: 2.0 V @ 600 mA/cm$^2$




## High Temperature Electrolysis (HT Alkaline)




**Advantage**

- Low OpEx: Use of high temperature sources - Improved efficiency

**Needs:**

- **Life time improvement**: Development of new electrolyte matrices resistant to molten hydroxides (*$\alpha$-$Al_2O_3$ typically used*)
- **Performance improvements**:
  - Area-specific resistance (ASR) of ≤ 0.2 Ohm-cm$^2$ at 350 to 550 °C.
  - Increase Stack electrical efficiency & CD: > 90% LHV $H_2$ at 1.2 A/cm$^2$
- **Heat Sources:** Renewable/Nuclear/Industrial

Need to identify degradation mechanisms *(see 2017 AMR presentations: PD143 & FC 129)*

# Challenge: R&D Needs for emerging technologies…

**…will shadow methods used in PEM electrolysis**

- Low Temp AEM- Needs:
  - Efficiency improvements
    - Continued development in non-PGM catalysts & alkaline membranes
- Hi-Temp Alkaline/SO Needs:
  - Durability improvements (matrix)
  - Designs that operate at higher pressure
    - Sealing

**Fluid End Plate**

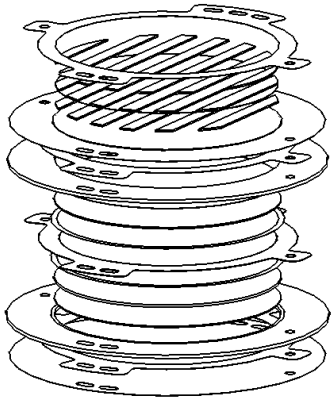
**Negative Terminal**

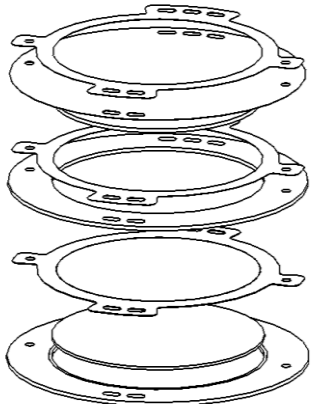
**Repeating Cell Unit >90% of Cost**

- **Cell Separator**
- **Anode Support Mat'l**
- **Cell Frame ($O_2$)**
- **MEA**
- **Cathode Support Mat'l**
- **Cell Frame ($H_2$)**

**Positive Terminal**

**End Plate**





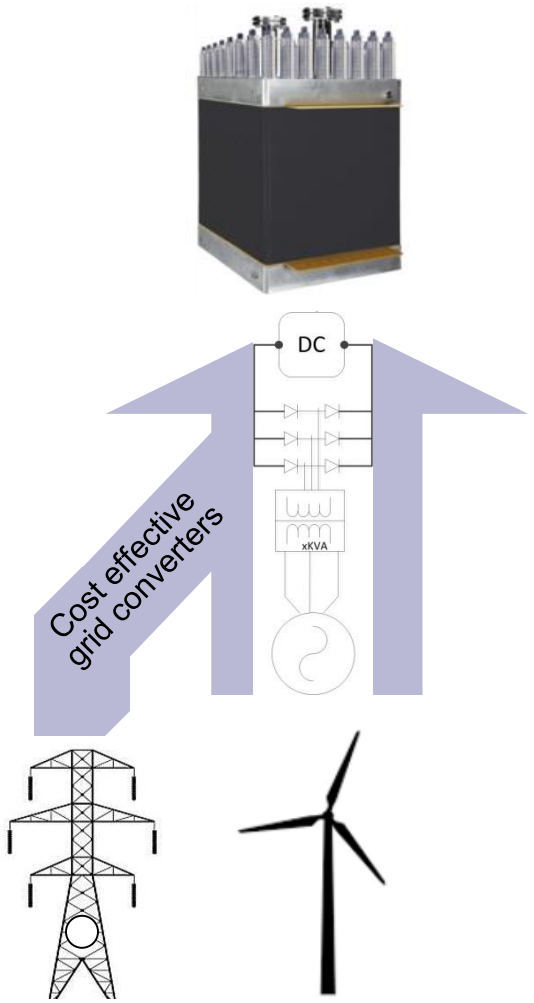
Stacks need to be designed with fewer components to reduced cost and ensure competitiveness on a larger scale

There is a need to Reduce Part Counts to decreases labor/fabrication costs and enable **Automation**

Addition info: *https://www.hydrogen.energy.gov/pdfs/review13/pd030_hamdan_2013_o.pdf*

# Challenges: Grid Integration (w/RES)

- Wind-to-Hydrogen gaining momentum
  - Systems & demos that address
    - Costs
    - Capacity factors
    - Optimization
    - Integration of wind turbine and electrolyzer control systems
- Optimized placement of plant
  - Centralized hydrogen production
  - Adjacent wind farm
    - Future pipeline network?
- Cost performance models




Power electronics to improve controllability and operating range

Power electronics that reduce redundancy and costs in interfacing RES to electrolyzers

Semiconductor switches for rapid switching and handling of high power

# Challenges: Coordination

**Develop roadmap for renewable electrolysis • Coordination, Planning, and Stakeholder Development**

- Ideal Location site
- Wind / Solar Farm

Work with industry on developing hardware and control strategies to couple RES to electrolyzers

- Equipment & Labor

Install equipment, characterize performance, and develop standard test procedures for renewable electrolysis systems

Utility Co.

Electrolysis Manufacturers + Engineering Construction Firms

**$H_2$@Scale Coordinator**

Legislative Bodies

Auto Manf.

- Tax Incentives & regulatory support

- Funding to enable Infrastructure Acceleration


# Thank You!