



Session #5: Hydrogen Applications for Transportation

June 28, 2023



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Upcoming Webinars

- **07/19 Telematics Use Case Applications and the Right Data to Accomplish Your Goals**
- **Others TDB/TBA**



Format

- Q&A at the end
- Submit questions and comments to “Panelists”
- Scheduled for 2:00p-3:15p
- Handout
- Recording





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Hydrogen Applications for Transportation June 28, 2023

2:00-2:05 **Rick Sapienza, NCCETC**--Introduction and Welcome

2:05-2:25 **Ophir Samson, HYDROTEC Fuel Cells/GM**—Overview of Hydrogen and Transportation Use Cases

2:25-2:35 **Robert Mount, Renewable Innovations**—Hydrogen as an Off-Grid Charging Solution

2:35-2:50 **Mark Finnicum, Stark Area Transit Authority (SARTA)**—Hydrogen Fuel Cell Tomorrow's Energy Powering SARTA Today

2:50-3:05 **Chris Cannon, Port of Los Angeles**—Port of LA's Hydrogen Deployments

3:05-3:15 **Q&A**





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Today's Speakers



Ophir Samson

HYDROTEC Fuel Cells/GM

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Robert Mount

Renewable Innovations

Founder/President & CEO

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Mark Finnicum

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Christopher Cannon

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General Motors' Hydrogen Fuel Cells

Presentation to the North American Fleet Managers' Association (NAFA)
Sustainable Fleet Technology Webinar Series: Hydrogen Applications for Transportation

June 28 2023

Ophir Samson
Director of Business Development, Hydrogen Fuel Cells
General Motors



zero crashes

general motors



zero emissions



zero congestion



Agenda

- Hydrogen as a fuel: why now?
- Hydrogen as a fuel: advantages and disadvantages
- GM Hydrotec



Hydrogen as a fuel: why now?

There are several reasons why hydrogen is gaining attention.

- **Global zero carbon emission goals**
 - Green hydrogen is a true zero-emission alternative to traditional fuels and a critical component in achieving net-zero climate goals
- **Technology advancements & declining costs**
 - Cost-competitive green hydrogen is finally on the horizon
 - Fuel cell technology is increasingly more efficient, reliable, and cost-effective
- **Growing government support to promote hydrogen innovation and adoption**
 - Governments are increasingly investing in hydrogen domestically (e.g., IRA and BIL with \$9.5B+) and abroad



Agenda

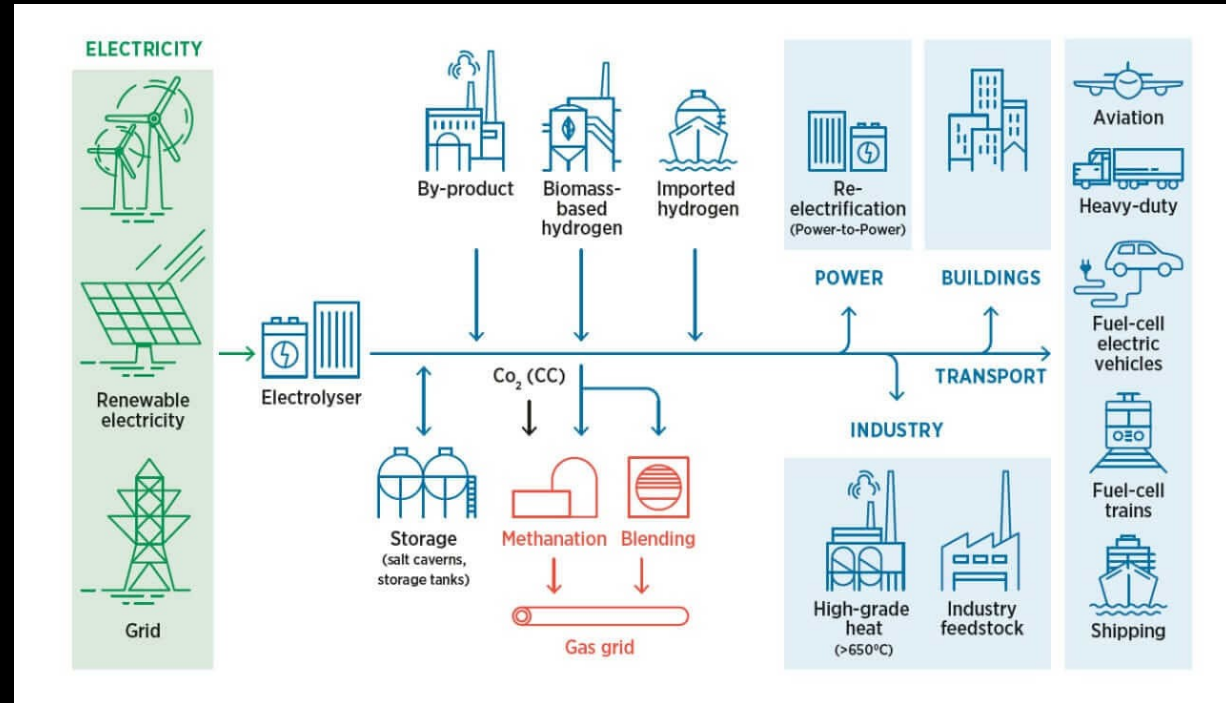
- Hydrogen as a fuel: why now?
- Hydrogen as a fuel: advantages and disadvantages
- GM Hydrotec

Why use hydrogen as a fuel?

Advantages

- Hydrogen has the **highest energy content by weight** of any chemical fuel
- Optimal for many weight-constrained environments
- Fuel cells have **no CO2 emissions; they only emit water**
- Hydrogen is **critical to decarbonizing our economy** and reach net-zero targets
- Refueling with hydrogen is **much faster than EV charging** (e.g., ~5 minutes for a truck, vs. 45 minutes of EV charging)
- Not reliant on connections to the electricity grid
- **Quiet**, has no moving parts, and operable in a wide range of temperatures

The (green) hydrogen value chain

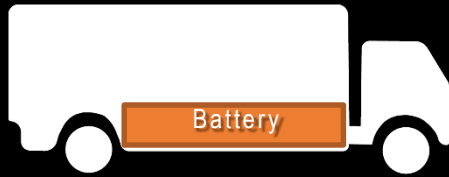


GM Fuel cells complement BEVs



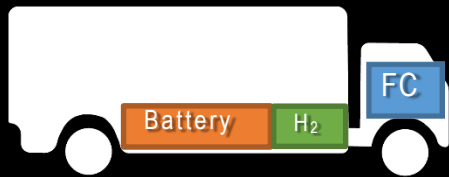
BEV

Charge battery from external power



Fuel Cell

Produce electricity on board from hydrogen



Energy Storage
Mass Energy
Density / Cost

LOW



MED



Refueling
Time

MED



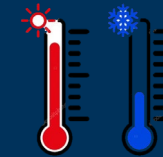
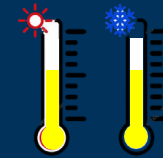
FAST



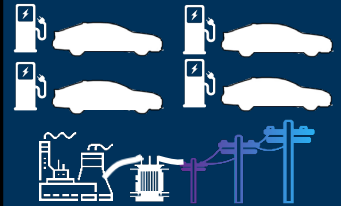
Fuel Cost



Operating
Temperature



Infrastructure
&
Scale



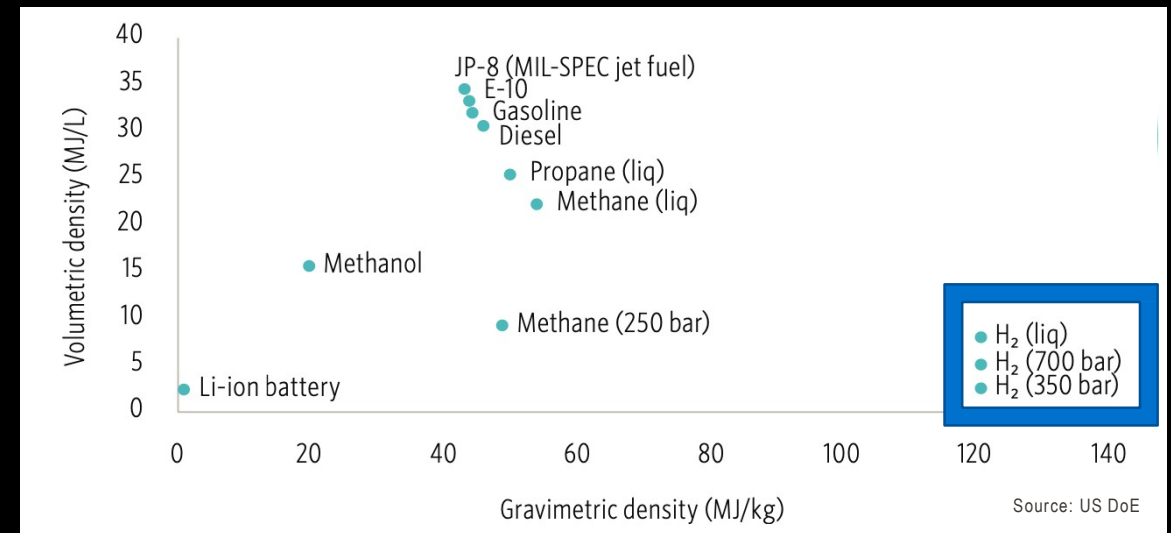
1 to many



Hydrogen as a fuel: challenges

- Despite having a very high energy density by weight, it has a low density by volume. This makes transportation and storage very challenging:
 - Gaseous form: requires much higher storage volumes than diesel
 - Liquid form: must be kept at -253F
 - Material form (e.g., ammonia): hazardous and ~20% end-to-end efficiency from solar to output
- Well to wheel efficiency is low for a fuel cell vehicle vs. BEV
- Currently green hydrogen is significantly more expensive than diesel
- Certain applications (e.g., mobility) require **major infrastructure upgrades**

Hydrogen has high gravimetric, but low volumetric density





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GM Hydrotec fuel cells in mobility



Extensive experience in automotive-grade Fuel Cell Systems (passenger through Class 7/8 applications)



NASA
1961 - 1972 APOLLO



1966 ELECTROVAN



2000 PRECEPT



2000 HYDROGEN1



2001 S10



2002 AUTONOMY



2002 HYWIRE



2004 HYDROGEN3



2005 SEQUEL

OVER 50 YEARS EXPERIENCE IN FUEL CELL TECHNOLOGY

3.2MILLION+ REAL WORLD MILES (PROJECT DRIVEWAY)

ELECTRIC, SCALABLE, CAPABLE, & SUSTAINABLE



WABTEC LOCOMOTIVE PROPULSION



2024 INTERNATIONAL® RH™ SERIES



2019 ZH₂ SILVERADO



2018 ZH₂ COLORADO



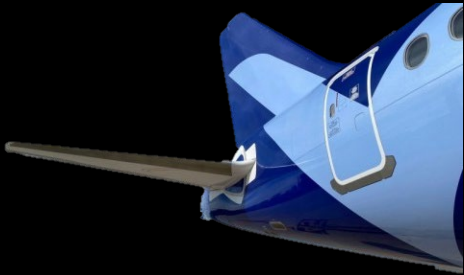
2007 EQUINOX - PRESENT
(PROJECT DRIVEWAY)



2005 SILVERADO (MILITARY)



GM Hydrotec fuel cells in other power applications



Auxiliary power units for commercial aviation



Stationary power units (large)



Stationary (small) and mobile power units



Gen2 Powercubes



GM Hydrotec fuel cells in other power applications



How We Charged 13 EVs at SUV of the Year Without Losing Our Minds

A pair of portable, hydrogen fuel cell DC fast chargers from GM's Hydrotec powered the electric vehicles at MotorTrend's 2023 SUV of the Year competition.

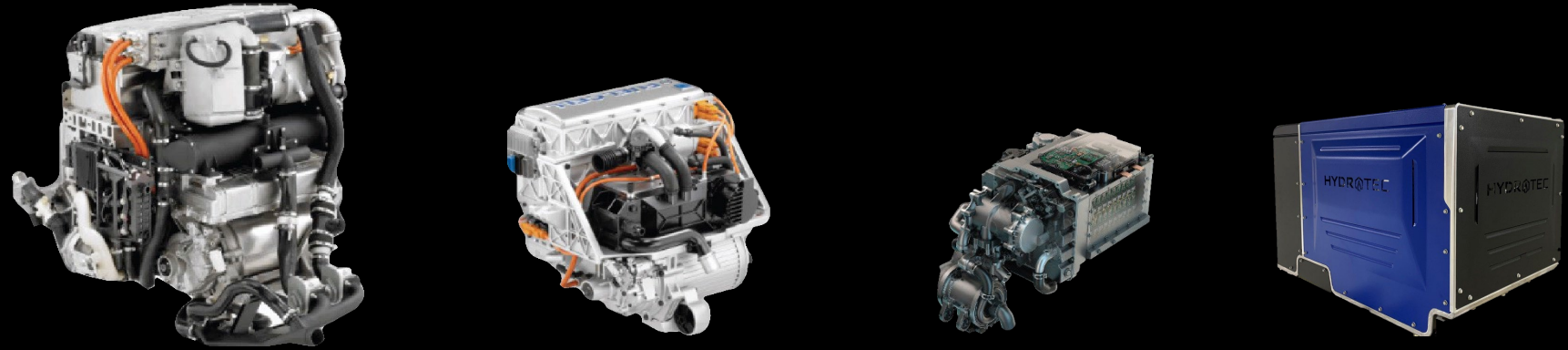


Green hydrogen future? Geopura secures millions in funding from GM, Barclays and Siemens





GM Hydrotec fuel cells: product evolution



SPECIFICATIONS	GEN0 FUEL CELL EQUINOX	GEN1	GEN2	GEN2 POWERCUBE
NET POWER	93 kW	85 kW	80 kW	77 kW
BIPOlar PLATE	MOLDED COMPOSITE	STAMPED STAINLESS STEEL	STAMPED STAINLESS STEEL	➔
PRECIOUS METAL	80 G Pt	30 G Pt	LESS THAN 15 G Pt	➔
SIMPLIFICATION	> 30 SENSORS	~15 SENSORS	~15 SENSORS	FULLY VALIDATED SINGLE PACKAGE SOLUTION
COST PER UNIT	BASELINE	↓	↓↓	↓↓



GM Hydrotec fuel cells: joint venture with Honda

High volume manufacturing facility established in Brownstown, MI

Leverages proprietary strengths in membrane electrode assembly manufacturing and stack assembly

All equipment and tooling installed





Hydrogen Applications for Transportation Solutions

June 2023



Imagine A Clean, Green Energy Future
———— We're Doing It Now ————

Why the U.S. Electric Grid Isn't Ready for the Energy Transition

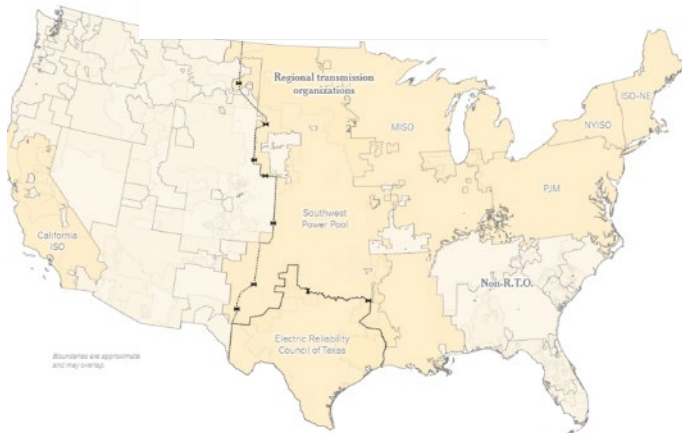
To start with there is no single U.S. electric grid.
By Nadja Popovich and Brad Plumer June 12, 2023

The U.S. electric grid is often described as a **vast, synchronized machine** – a network of wires carrying electricity from power plants across the country into our homes

- **Grid Ability**
- **Grid Availability**
- **Grid Reliability**

But, in reality, **there is no single U.S. grid.** There are three – one in the West, one in the East, and one in Texas – that only connect at a few points and share little power between them.

Those grids are further divided into a **patchwork of operators with competing interest.** That makes it hard to build the long-distance power lines needed to transport wind and solar nationwide



SOME OF OUR PRODUCTS / SOLUTIONS

EMPOWER EV RAPID CHARGER

- Recharge electric vehicles or fleet trucks in minutes
- No utility needed
- Transportable
- Scalable
- Utilizes GM Hydrotec, fuel cell power cubes
- Can be co-located at convenience stores and gas stations without a utility grid
- Can deliver building back up power
- 500kW up to 700kW Power
- (4) Dual Port DC Fast Chargers
- Utility Interface for Backup or Bi-Directions Utility Connection
- Optional Canopy
- Optional Lighting Package



Portable Drop and Go – Grid Independent

MOBILE POWER GENERATOR

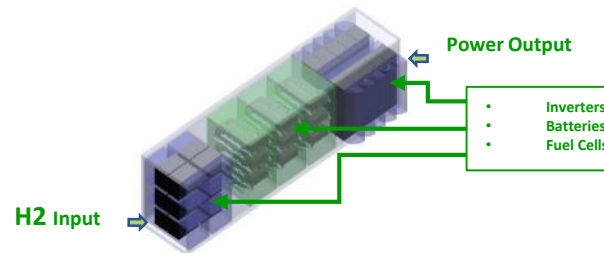
60 kw AC/180 kW DC Trailer System

- Power buildings
- Towable using a standard pickup
- Holds up to 70 kg hydrogen – 3 to 5 days of operation
- Provide fast-charge capability for EVs without installing permanent charge points
- 60kW Fuel Cell Continuous Power
- 200kW Inverter
- 180kWh Li Battery array
- 180 kW DC Fast Charger



EMPOWER 1.5 MW FUEL CELL BACK UP POWER

- Intended for data centers, Fleet Charging, and large infrastructure projects
- Up to 600 kW lithium-ion batteries
- Packaged in a 40-foot ISO container
- Low maintenance expense
- Reduced permitting times



TRANSPORT REFUELER

Minimum 1000kg H2 transport and Refueling

- Min 1000kg H2
- Fuel Cell Powered
- Onboard Compression
- Onboard Chiller
- Refueling Pressure
 - 200 BAR
 - 350 BAR
 - 500 BAR
 - 700 BAR



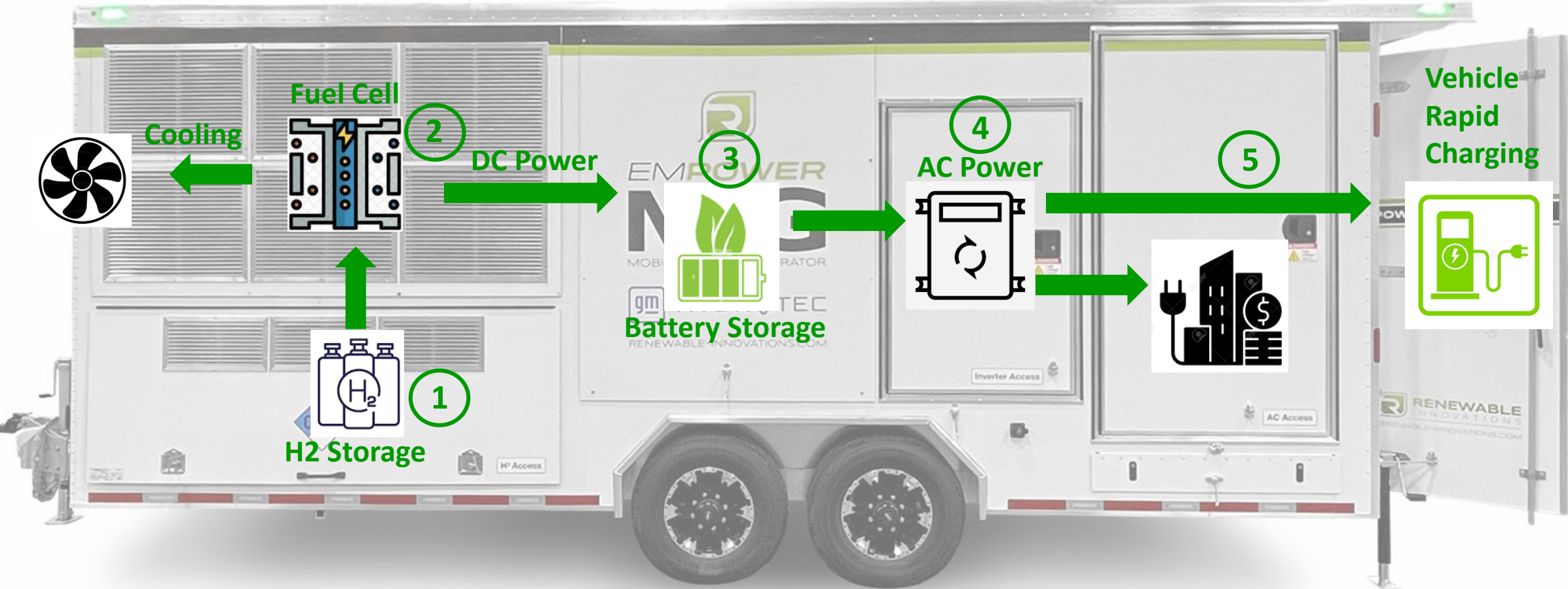
Traveling TO DEMONSTRATE & VALIDATE



Traveling TO DEMONSTRATE & VALIDATE



How RENEWABLE INNOVATION'S SYSTEMS WORK





H₂ • 40 kg Onboard Hydrogen • Commercial Refill

40+ kgs H2



80 to 160 kW FC Power



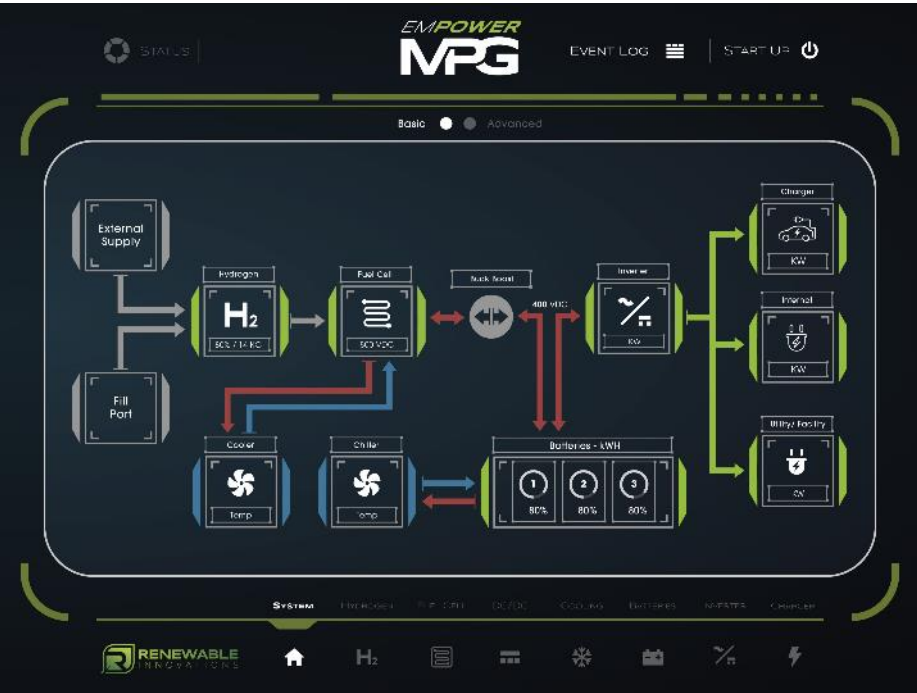
• 60-200 kWh Energy Storage

60 to 200 kWh battery

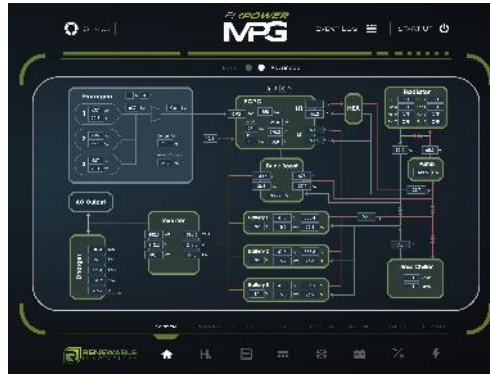


200 kW AC Power

System Overview



System Details



Cooling Network



Standby Status



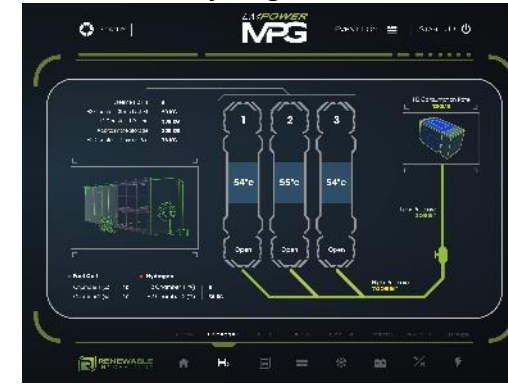
BOP DC Status



Charger Status



Hydrogen Status



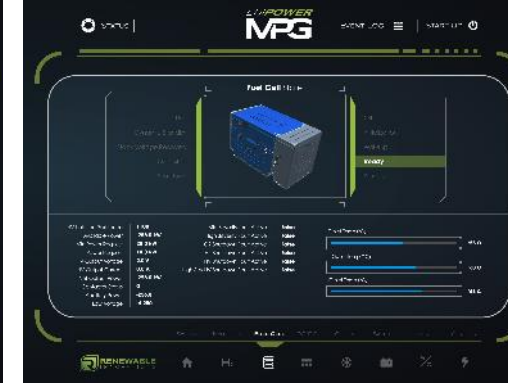
Power Status



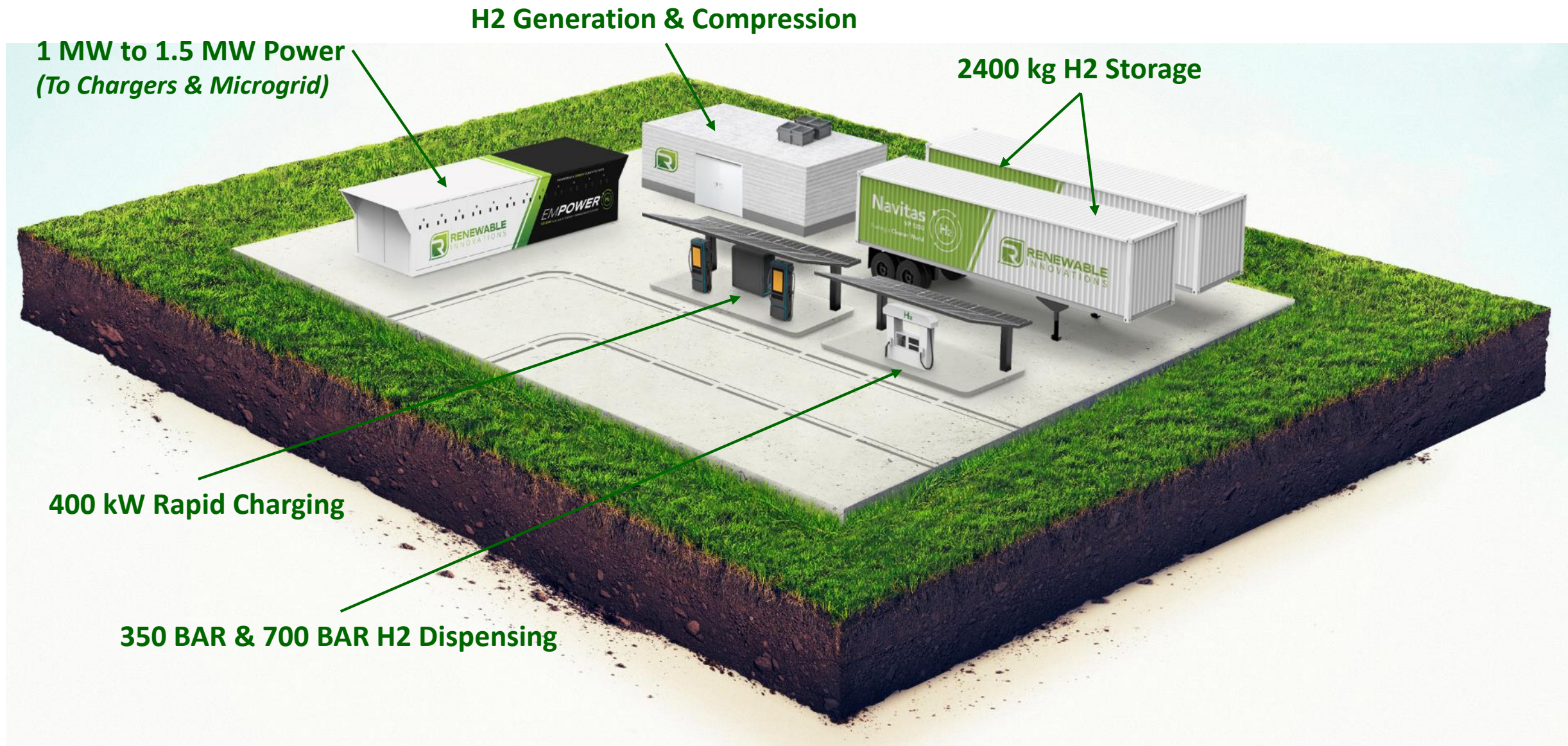
Battery Status



Fuel Cell Status



Renewable Innovations bringing you the Complete Green H2 ECO System. Site Selected and being built!



U.S. National Clean Hydrogen Strategy and Roadmap

The U.S. National Clean Hydrogen Strategy and Roadmap explores opportunities for clean hydrogen to contribute to national decarbonization goals in various sectors.

The report consists of the three parts



Setting National Decarbonization Goals

- 100% carbon pollution-free electricity by 2035
- Net-zero greenhouse gas emissions by 2050
- Increasing clean hydrogen production from nearly zero today to **50 MMT per year by 2050** could result in a **greenhouse gas emissions reduction of 10%** relative to 2005 levels



Identifying Three Strategies to Enable the Benefits of Clean Hydrogen

- Target strategic, high-impact uses of clean hydrogen
- Reduce the cost of clean hydrogen
- Focus on developing regional networks



Developing Guiding Principles and National Actions

The report establishes eight principles for federal agencies to ensure a sustainable, resilient, and equitable clean hydrogen economy:

- Enable deep decarbonization
- Catalyze innovation and investment by fostering partnerships
- Promote diversity, equity, inclusion, and accessibility
- Advance energy and environmental justice
- Spur domestic manufacturing and robust supply chains
- Grow quality jobs
- Enable affordability and versatility
- Approach clean hydrogen development and deployment holistically

Clean Hydrogen in the US could ...



Support economy-wide decarbonization



Create quality jobs to support the energy transition

~10%

economy-wide emissions reductions by 2050

100,000

jobs created by 2030

450,000

Cumulative job-years through 2030

Three anticipated waves of clean hydrogen adoption

First Wave

Existing markets with few alternatives to clean hydrogen for decarbonization

- Forklifts
- Refineries
- Transit buses
- Long-haul heavy-duty trucks
- Heavy machinery in mining, construction, and agriculture
- Ammonia production

Second Wave

Industry investment and policy momentum converge

- Medium-duty trucks
- Regional ferries
- Plastics
- Steel production
- Energy storage and power generation
- Aviation

Third Wave

Scale and infrastructure increase while costs decline

- Backup and stationary power
- Methanol
- Container ships
- Cement production
- Blending with existing natural gas networks



Clean Energy for a Brighter Future

Renewable Innovations is Accelerating the Growth and Opportunities within the Renewable Economy.



Multiple Possibilities with Hydrogen



HYDROGEN FUEL CELL

The Energy of Tomorrow
Powering SARTA Today.

SARTA Operational Facts



- 2.2 million trips per year
- 212 employees
- \$22 million budget
- Extensive use of technology including Ford Transit Electric Cutaway with a Fuel Cell Range Extender Prototype.

SARTA Current Fleet

- 83 of the 102 buses operated use alternative fuel.
 - 62 CNG
 - 19 Hydrogen Fuel Cell Electric buses and vans. (9-150Kw Fuel Cell-50Kg)(5-85Kw Fuel Cell-60Kg)(5-40Kw Fuel Cell-13Kg)
 - 2 Diesel Electric Hybrid
 - 6 Diesel buses by end of 2022
- In 2010, 96 of the vehicles SARTA operated were diesel.





SARTA Mission Statement

SARTA is committed to enhancing the quality of life for our community by providing efficient, affordable and sustainable mobility options for Stark County.




SARTA Vision Statement

To enhance the **economic and environmental viability** of Stark County by providing mobility access for employment, education, medical care and recreational opportunities.

We will do this by:

- ~Operating within budget and in a financially responsible manner.
- ~Enhancing quality of life through personal independence.
- ~Offering mobility options to meet the diverse needs of the public.
- ~Creating an environment supporting professional development to ensure a dynamic workforce operating according to the highest ethical standards.
- ~Continuing our efforts to utilize alternative energy sources for our fleet and facilities.

A close-up photograph of a hydrogen fuel cell stack, showing several circular components and metallic housing. The image is partially visible on the left side of the slide.

So how did Hydrogen end up at SARTA in Canton, Ohio?

- SARTA applied to be part of the initial American Fuel Cell Bus Program in 2015 as part of a \$90 million Federal Transit Administration program.
- Now seven years later SARTA is the third largest hydrogen fleet operating the second largest hydrogen station in the United States and the largest fleet outside of the state of California.



Operational Needs vs Technology

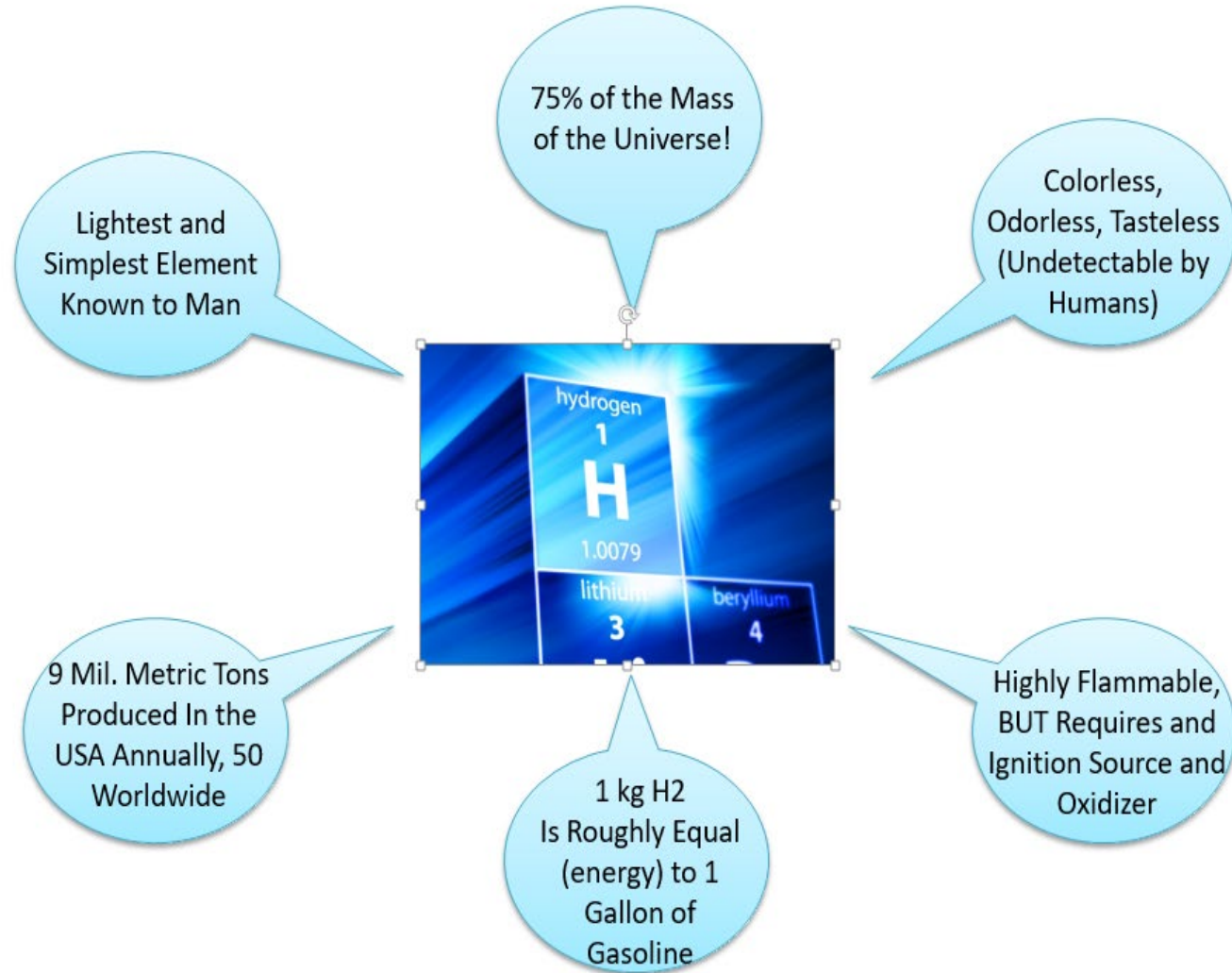
- Operationally, agencies need a Battery Electric or Hydrogen Fuel Cell Electric vehicle that can be used in the same way they use Diesel or CNG in their fleets today.
 - Our first Hydrogen buses have a range of 200 miles in ideal conditions. By working with the manufactures our newest model has a range of over 230 miles with a smaller fuel cell and an additional 10Kg of hydrogen.
 - The Cutaway Vans range is 100 miles on battery, but with the fuel cell it is extended to 250 to 300 miles.
 - Parasitic load factors determine the mileage of both electric and hydrogen vehicles.
 - SARTA has taken a leadership role in working with vendors and engineers to make the enhancements needed to help propel the technology even further.

Community Reaction to Technology

- Our community leaders as well as employees have embraced the technology and the spotlight that SARTA has put on Stark County and Northeast Ohio.
 - Ohio is the 3rd largest producer of hydrogen fuel cell components and membranes.
 - Northeast Ohio is home to NASA Glenn, Rolls Royce and LG stationary fuel cell headquarters.
 - The vehicle needs to be accepted by the Operators, Maintenance and Community Stakeholders.



Hydrogen Facts



Where is Hydrogen Used?

Hydrogen is one of the most important building blocks in the chemical industry.

- Ammonia Production (Fertilizers)
- Methanol Production
- Polymer Production
- Food Processing
- Oil Refining oil (Sulfur Reduction),
- Metal Processing and Heat Treating
- Welding
- Powering Fuel Cells

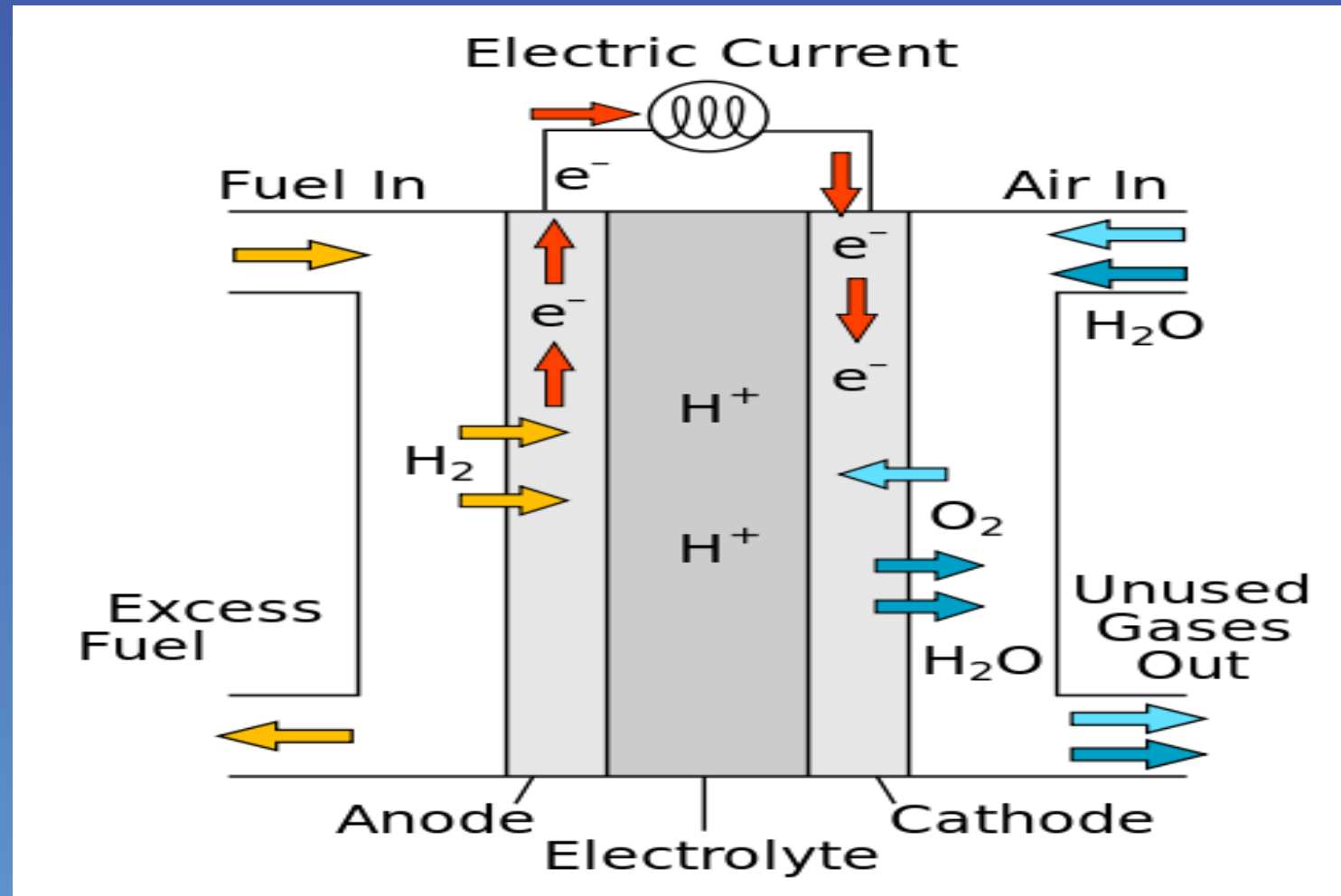


Fuel Cell Facts

- Fuel Cells are similar to a regular battery but it does not run down or need recharging and can produce electricity constantly.
- They are more efficient than the ICE (Internal Combustible Engine) only producing warm air and water vapor in its exhaust.
- A fuel cell consists of a anode, cathode plate separated by a proton exchange membrane that splits the hydrogen atom into a negative and positive electron. The negative electron is forced through a circuit to create electricity while the positive passes through the membrane and mixes with oxygen to create H₂O that is then released as water through the exhaust pipe.
- <https://www.youtube.com/watch?v=a4pXAmljdUA>



How does a Fuel Cell Work?



The Engine Bay of a Hydrogen Bus



Growing Pains - Sufficient Space



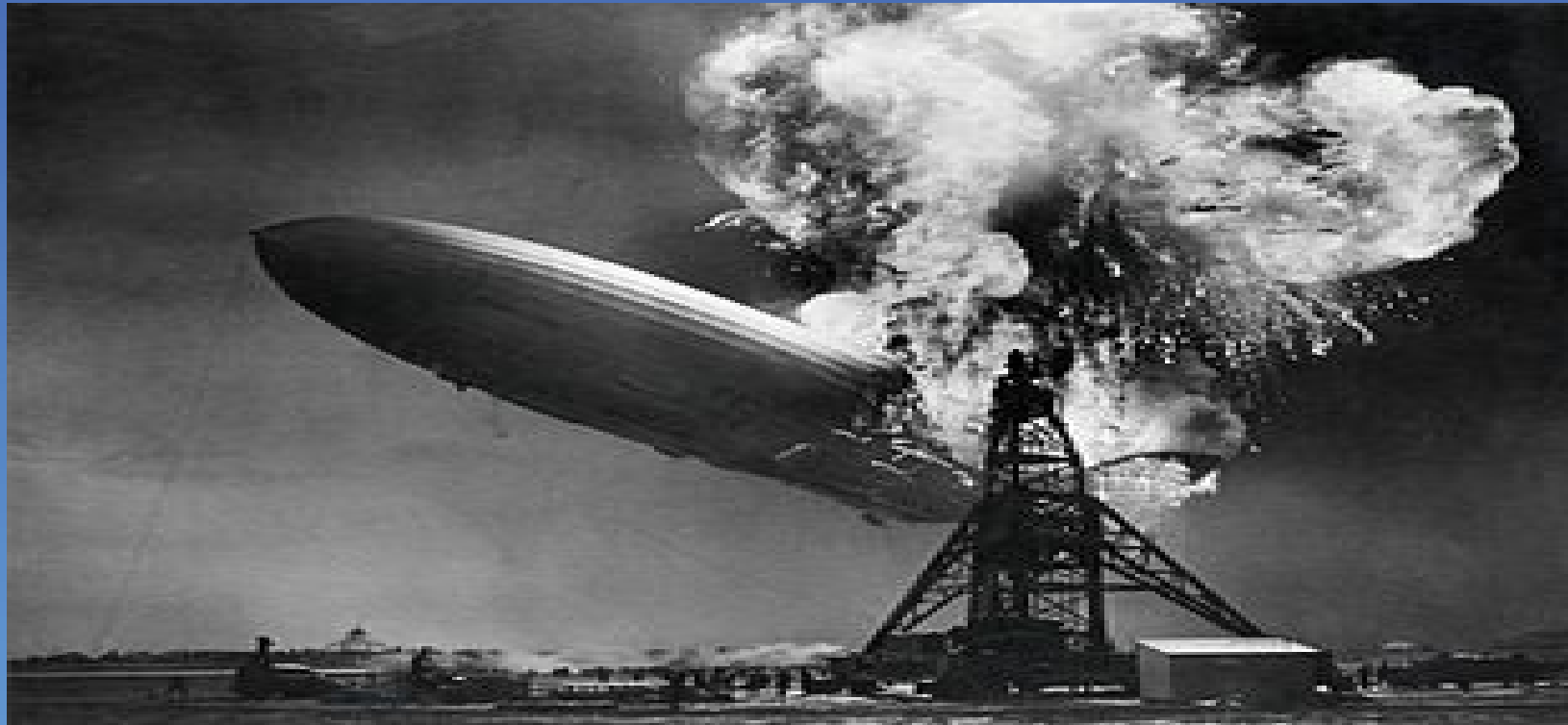
Growing Pains

- Educating your Employees, Community and First Responders on the technology.
- Educating Politicians and those in the decision making process at both the State and Federal levels.
- Advancing the Technology: Borrow a Bus Program. We have sent the bus to Florida, Texas, California, Oregon, Washington, District of Columbia, Virginia, South Carolina, Kentucky, Georgia, Maryland, New Jersey and Canada.
- In 2019 SARTA transported a hydrogen bus to Washington, DC to demonstrate the technology. Demonstrations were held at Capital Hill, U.S. Department of Transportation and U.S. Department of Energy.



Growing Pains and FEARS!

- Educating our staff and your community to remove their fears and changing their perception of using Hydrogen as a fuel. **"California is coming to a neighborhood near you!"**



H2 Education at Ohio Statehouse



SARTA seeks to build support for hydrogen hub in Ohio

Robert Wang The Repository

Published 5:35 a.m. ET Feb. 17, 2022

[View Comments](#)



To the Future





Port of Los Angeles
SFT Webinar Series
Presentation
Hydrogen Fuel Cell
Deployment
Chris Cannon
June 28, 2023







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