Mpower

Mpower Innovation

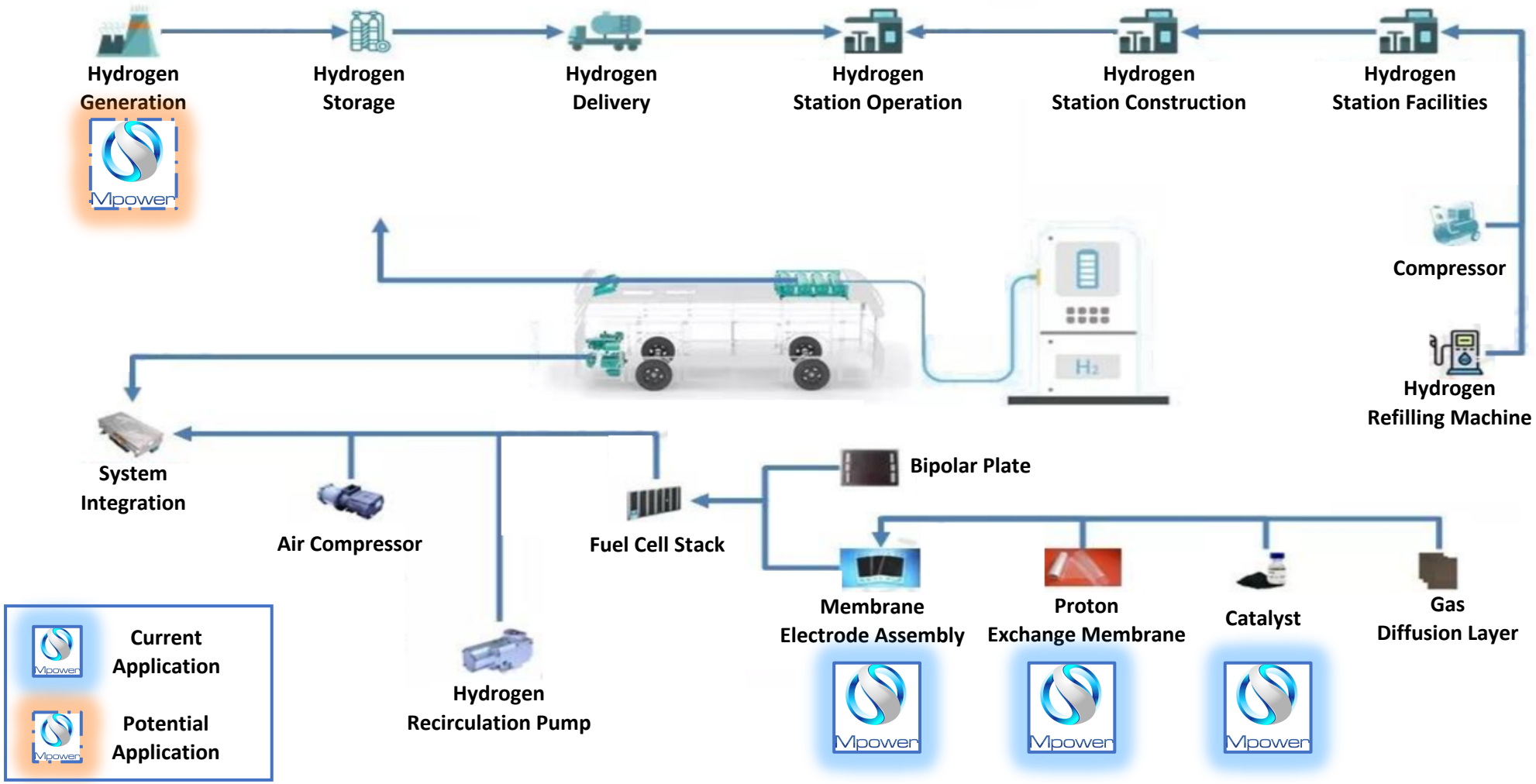
Solutions to Critical Hydrogen and Fuel Cell Challenges

July 2020

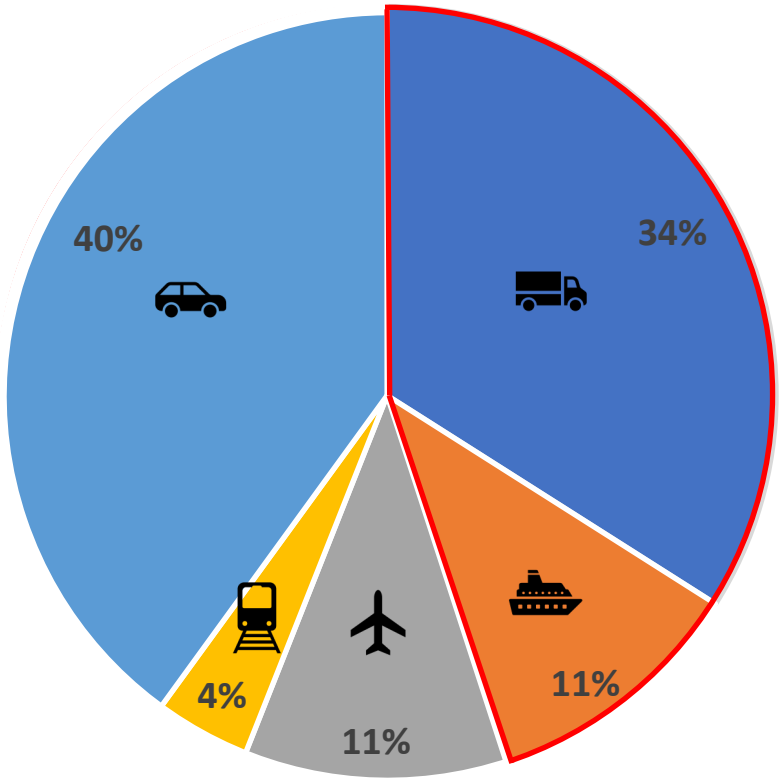
Mpower Innovation Overview

- Mpower uses disruptive nano porous material to solve critical technical problems in hydrogen generation and fuel cell, providing high performance, low cost and long durability proton exchange membrane (PEM) product.
- Located in Silicon Valley, California.
- Team has extensive entrepreneurial experience, including filing IPO in U.S. Team's prior startup was funded by Khosla Ventures, 3i and Softbank.
- Technical team were core engineers and scientists at industry leading companies and research institutes.
- Mpower has raised seed round from Corp VC and Angel investors
- Exclusive technology licensing and co-development with distinguished professors from top universities.

Mpower's Position in the Value Chain



Hydrogen is the ultimate transportation fuel



Source: IEA and IPCC Summary for Policymakers

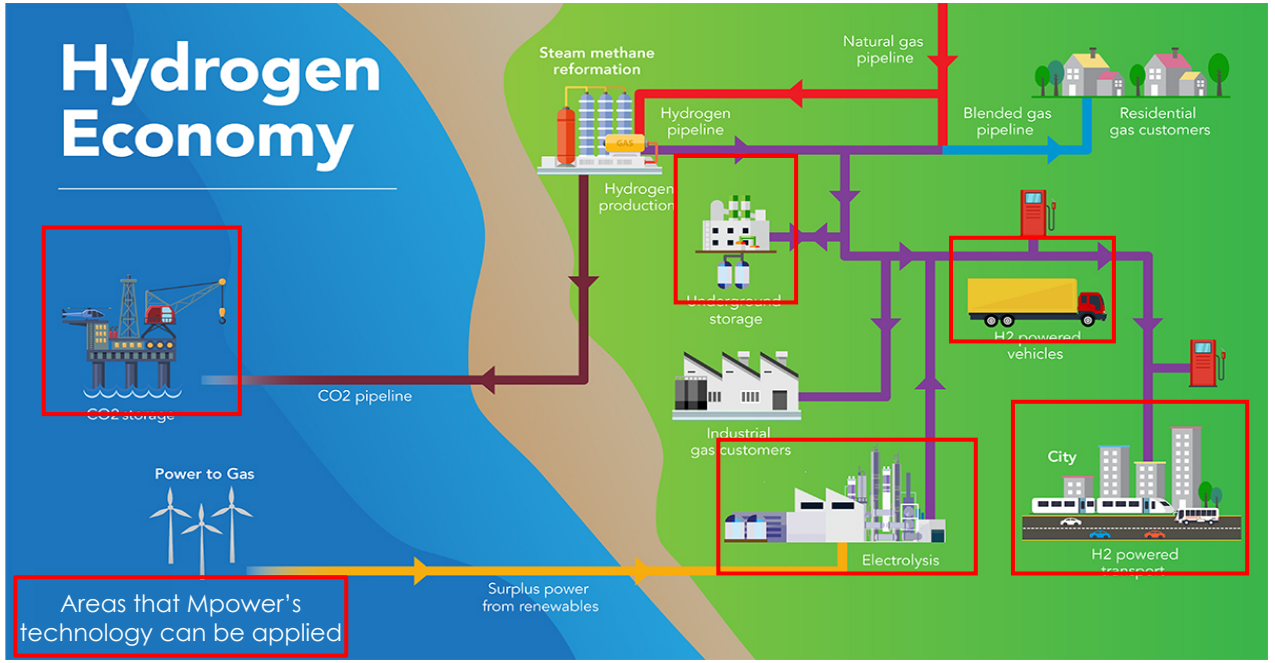
Global CO_2 Emissions by the Transport Sector

Benefit of adopting hydrogen fuel cell

- Power to pull heavy loads
- Long driving range
- Short refilling time
- High energy density leaves more load space
- No impact to utility stability
- Emit no harmful substance

Ideal solution to zero emission truck and marine in the near term

Hydrogen is the future of energy, market size $152 billion this year and $2.5 trillion by 2050

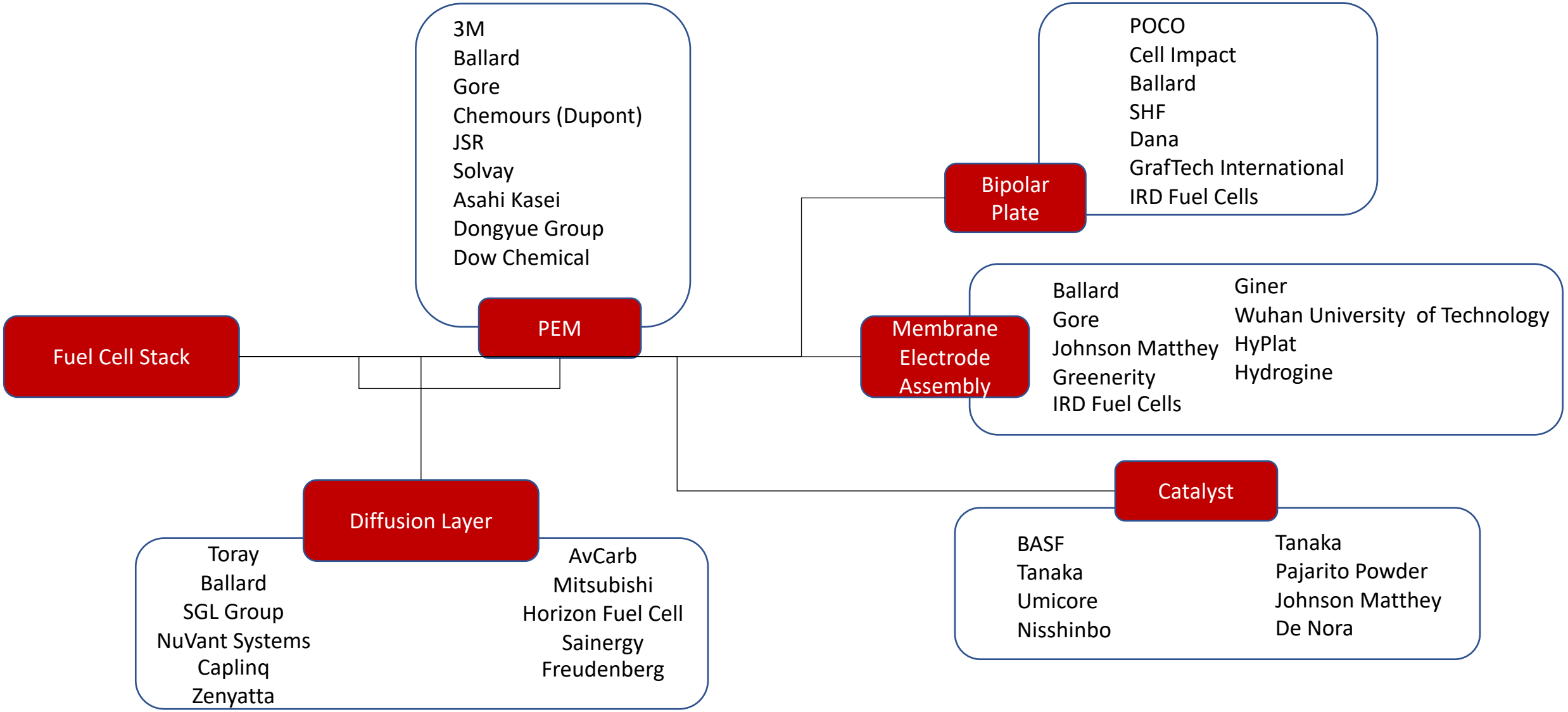


Continental and National FCV Target

Mpower

		Passenger vehicles	Buses and coaches	Trucks**	Forklifts	Refueling stations
US	Current	7,271 [44]	35 active, 39 in development	prototype test	>30,000 [335]	~42 online [37]
	Target		5,300,000 FCEVs on US roads by 2030 [337]		300,000 by 2030 [337]	7,100 by 2030 [337]
China	Current	0	2,000+ [64 83 84 85]	1,500+ [94]	2	23 [89]
	Target	3,000 by 2020 [87] 1,000,000 by 2030 [336]	11,600 commercial vehicles by 2020 [87]			100 by 2020 500 by 2030
Europe	Current	~1000+ [42]	~76 [42 73 86]	~100 [88]	~300 [42]	~152 [71]
	Target	3,700,000 by 2030 [34]	45,000 fuel cell trucks and buses by 2030 [34]			~3,700 by 2030[34]
Japan	Current	3,219 [44]	18	N/A	160	127; 10 in progress
	Target	40,000 by 2020 200,000 by 2025 800,000 by 2030 [24]	100 by 2020 1,200 by 2030 [24]		500 by 2020 10,000 by 2030 [24]	160 by 2020 900 by 2030 [24]

Fuel Cell Supply Chain



Project Overview

Objectives

- Develop thin and high conductivity fuel cell PEM to solve fuel crossover issue;
- Duplicate and validate technology at pilot plant and scale up for mass production.

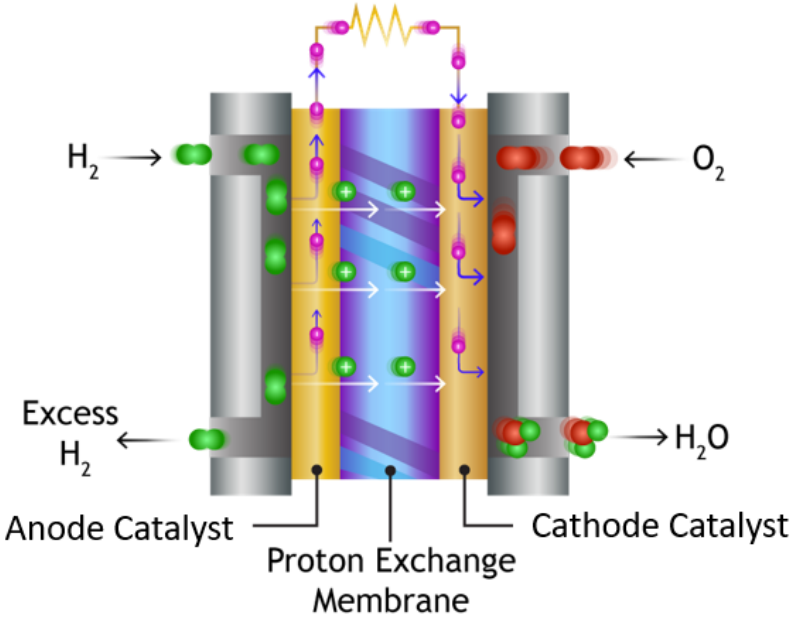
Targets

- Deliver high performance and competitive cost product to disrupt current PEM market;
- Capture significant market share and becomes market leader within 5 years.

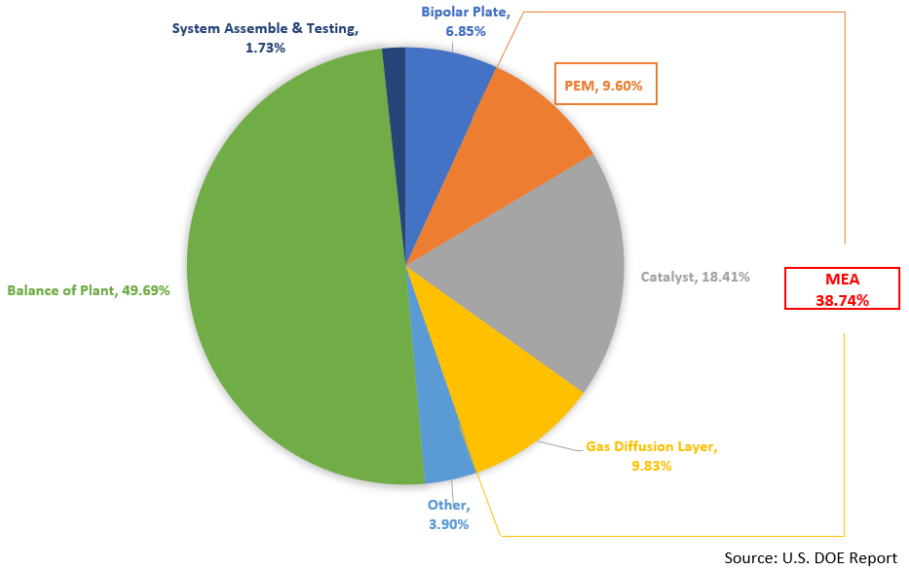
Tasks

- Complete product design at lab in Silicon Valley;
- Build and set up pilot line to deliver alpha and beta prototypes within 1 year;
- Build and set up mass production line and deliver product in 2 years.

PEM and MEA are the Most Important Components in Fuel Cell



PEMFC Electric Power Generation



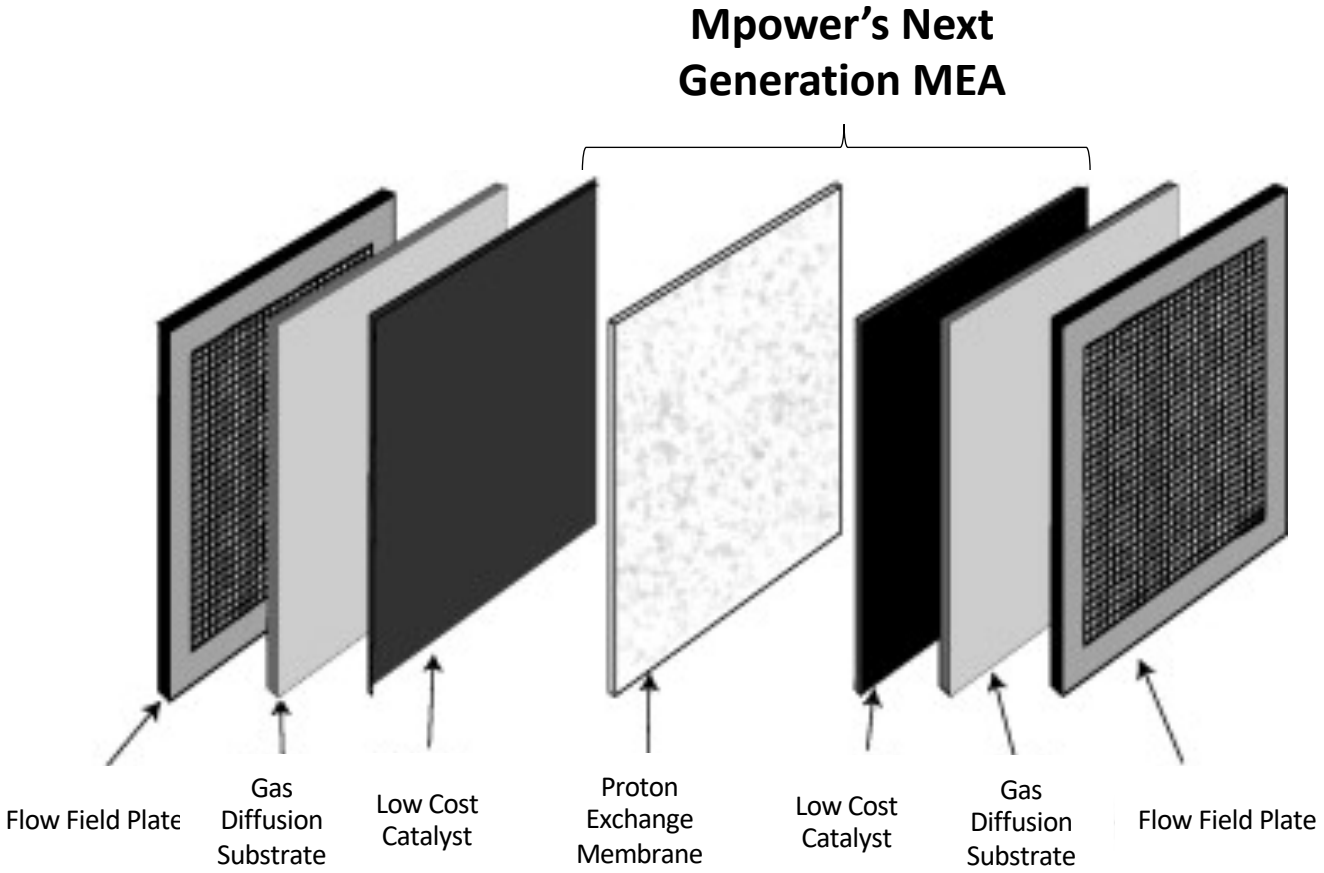
Source: U.S. DOE Report

Current Vehicle Fuel Cell System Cost Breakdown

Year	Fuel Cell Mkt Size (Billion USD)	PEM Mkt (Billion USD)	Catalyst Mkt (Billion USD)	MEA Mkt (Billion USD)
2018	$ 2.0	$ 0.09	$ 0.17	$ 0.34
2025	$ 9.0	$ 0.24	$ 0.72	$ 1.16
2030	$ 44.4	$ 0.85	$ 3.54	$ 5.21

Calculated based on Fuji-Keizai report and U.S. DOE data

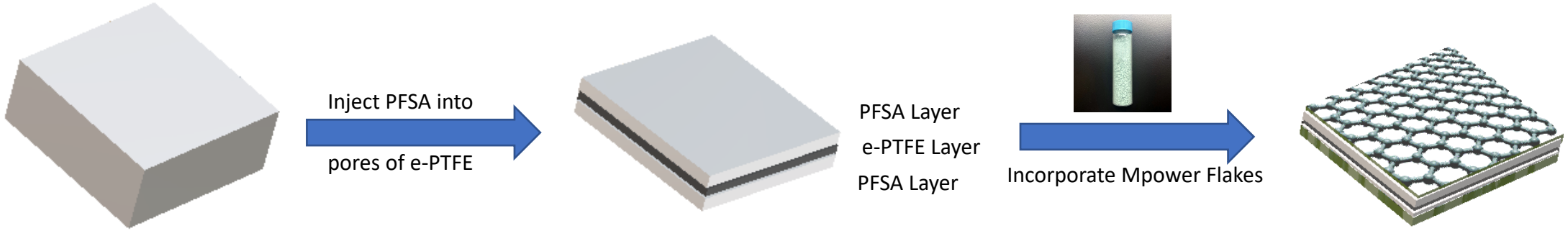
Product Description



Mpower's Next Generation Products

- **PEM:** solve fuel (H_2 and O_2) crossover issue and improve ion conductivity, meanwhile reduce thickness
- **MEA:** significantly improve the performance and lifecycle, while reduce current high cost.

Comparison with Existing PEM Products



PFSA Membrane (Nafion)

- Relatively high stability
- Good mechanical strength in harsh chemical environments
- Very thick membrane
- Chemical degradation happens
- Repeated swelling and shrinking causes strength decrease
- Severe fuel crossover
- High cost

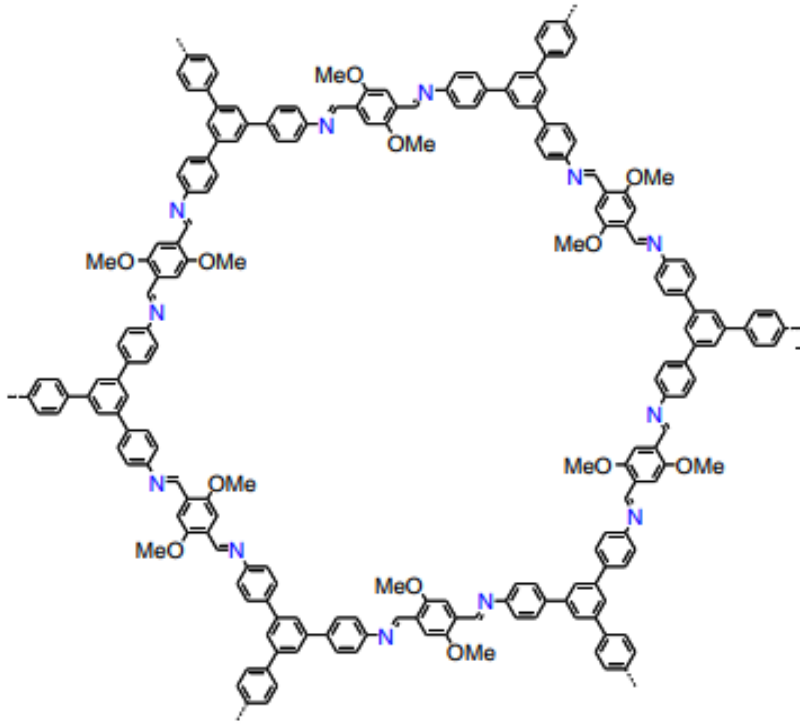
Composite Membrane

- Thinner membrane
- Less shrinkage
- Improved mechanical property
- Severe fuel crossover for 5 µm membrane
- Higher cost

Mpower ultra-thin membrane

- Even thinner membrane
- Minimum shrinkage
- **Replace Nafion with COF**
- Improved mechanical property
- Little or no fuel crossover for 5-12 µm membrane
- Competitive cost

Innovation Based on Breakthrough Nano Porous Material



- Staggered stacking has shown to inhibit gas transport
  - Desirable for H_2 and O_2 crossover inhibition
- Functionalization has shown to achieve great acid resistivity.
- Functionalization and/or impregnation has shown to promote great proton conduction.
- What is left is membrane fabrication.
- We have fabricated a dense COF membrane with characteristics not found in Academia or Industry

Target PEM Performance

Membrane	Thickness (µm)	Ion Conductivity* (S/cm)	Conductance* (S/cm^2)
Nafion 117	200	0.14[a], 0.10[b]	5 - 7
Nafion 112	60	0.10b	17
Dev. Dow	100	0.15[b]	15
Gore-Select	20	0.052[a], 0.053[b]	26
Gore-Select	5	0.028[a]	56
Gore-Select	12	0.096[b]	80
Mpower	5	0.1	200

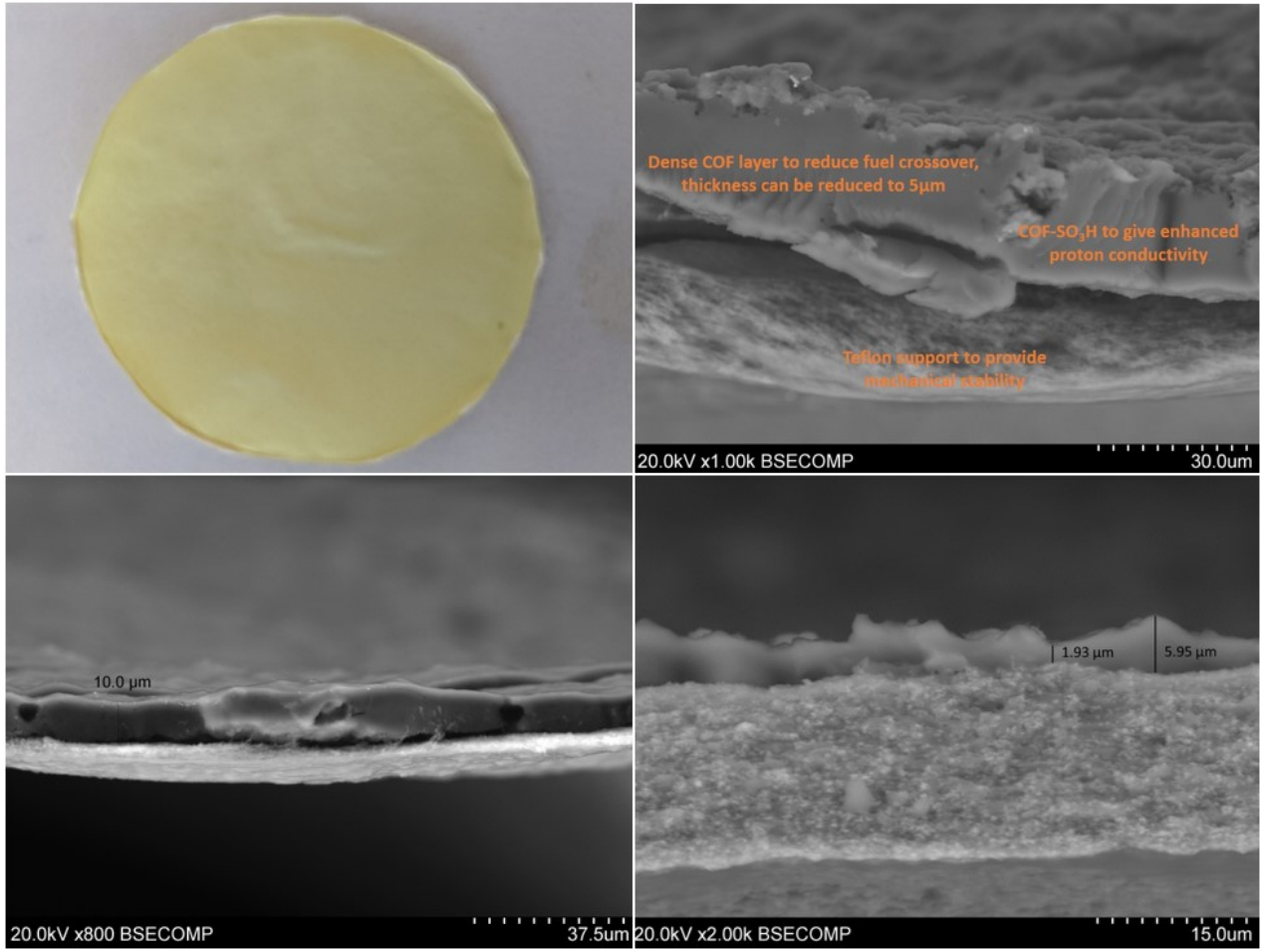
a. z-direction, sulfuric acid immersed sample measured with four-point probe
b. X-y direction, high-frequency measurement for membrane immersed in deionized water.
* Ion conductivity and conductance tests are performed at 70°C

Mpower's PEM Product Target

Key Technical Parameters				
Parameter	Thickness	Ion Conductivity*	Conductance*	Hydrogen Permeability
Unit	µm	S/cm	S/cm^2	Barrer
Value	5	0.1	Gen 1: 120 - 160 Gen 2: 160 - 200	Gen 1: 4 Gen 2: 3

* Ion conductivity and conductance tests are performed at 70°C

Mpower's 5 µm Membrane



First of its kind dense COF layer fabrication

US Patent Pending

Target PEM Cost and Price

Product	Cost	Price
Gore-Select	$5.59/kW [a]	$14/kW [b]
Mpower Membrane	$5.48/kW [c]	$8.77/kW [d]

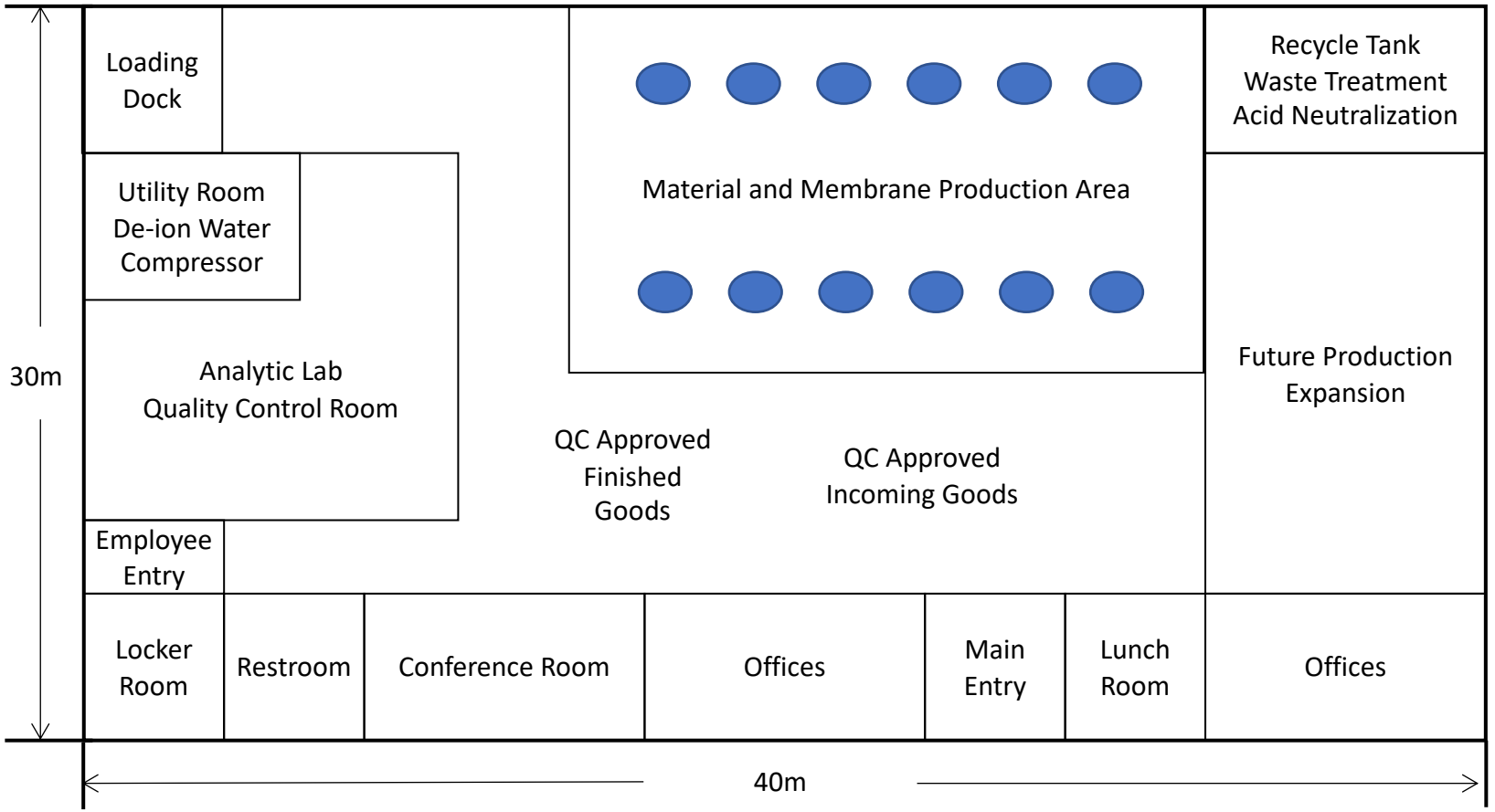
a. Gore's membrane cost is not publicly available. This estimation is from U.S. DOE report, production rate at 10,000 units 80kW vehicle per year.

b. Gore keeps its price confidential, this price is from one of Gore's customers.

c. Based on very conservative 120 S/cm^2 conductance compared to Gore's 80S/cm^2 conductance. This is our estimated cost for membrane from the pilot line, which can supply membrane to 3,250 units 80kW FCV. For the mass production line, the cost will be significantly lower.

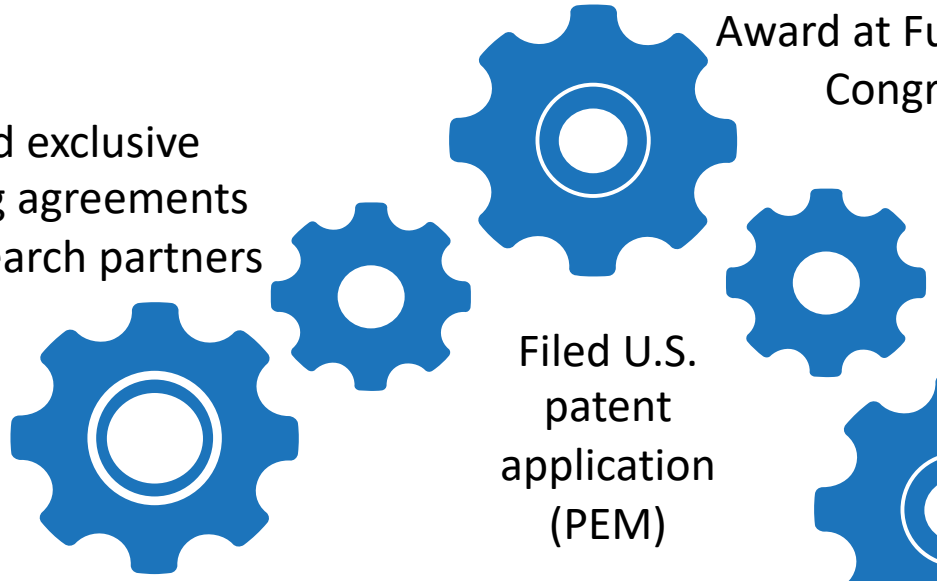
d. Based on 60% profit margin.

Membrane Pilot Plant Conceptual layout



Size: 1200m²
Production capacity: 26,000 m²/year

Milestones



Signed exclusive licensing agreements with research partners

Most Innovative Corporation Award at Fuel Cell Vehicle Congress 2019

Filed U.S. patent application (PEM)

Completed material design for Catalyst and PEM

Signed MoU with China Science Valley

Engaging with a leading fuel cell vehicle & fuel cell stack company

Set up 2nd R&D facility in Texas

Thank You

+1 (650) 666 – 6860

info@mpowerinnovation.com

1600 Adams Dr, Ste 103, Menlo Park, CA 94025

Mpower

Mpower can improve existing filter masks by capturing or kill virus, may be able to replace 3 layers with our membrane