HYDROGEN ONE

Low Energy Water Desalination and Green Hydrogen Systems

Hydrogen One Intro Video

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THE H1 TEAM

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CEO, CTO, Chairman

BS Chemical Engineering
Drexel University
23 years wastewater experience
32 years of engineering & management
5th startup

Anthony Helou
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BS Biology, American University of Beirut
BS Software Engineering, McMaster University
MBA, London Business School
CEO Synergy Petroleum
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Board Member - Disruptor

PhD, Prognostics
University of Cincinnati
8 years water treatment

Data Science Manager, Abbott
Data Analytics Manager, Eaton

WHAT IS GREEN HYDROGEN?

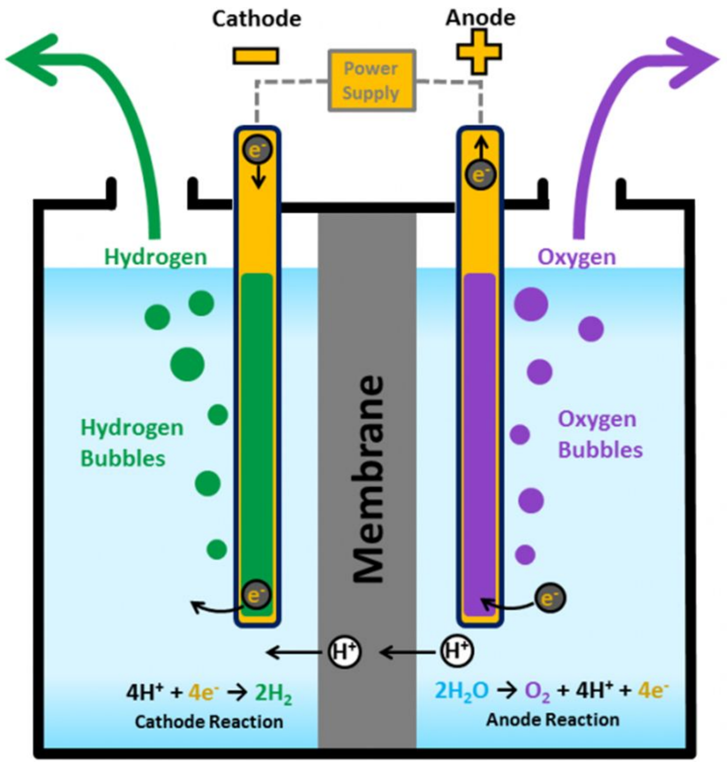
99% of hydrogen produced today is “grey/black hydrogen”, made from fossil fuels, no carbon capture, and sells for approximately $4.75/kg.

Carbon footprint of this is equal to or worse than simply using natural gas.

Green hydrogen is made from renewable energy sources with ZERO carbon footprint.

Green hydrogen pricing, using alkaline electrolyzers like those from H1, costs $2.62 - $4.51/kr in many parts of the world depending on the cost of renewable energy.

WHAT IS GREEN HYDROGEN?



MARKET OPPORTUNITIES

- Green hydrogen expected to grow 57%/yr over next 10 years.
- Green hydrogen will become the largest source of hydrogen by 2030
- Large petrostates are actively transitioning to produce of green hydrogen (Saudi Arabia)
- This will allow for renewable energy to be shipped around the world in the form of hydrogen
- ~ 3.0 billion of water and electrolyzer equipment to be purchased and installed over next 5 years.

ADVANTAGES OF HYDROGEN ONE EQUIPMENT

56% of the cost of green hydrogen is energy.

- H1 design will lower this by 10 – 30%

33% of the cost of green hydrogen is capital equipment depreciation.

- H1 equipment designs will lower this by 50%.

H1 will be able to reduce the cost of green hydrogen by up to 27%.

- When done, green hydrogen will be $3.00 - $3.50/kg, equivalent to blue hydrogen.

MISSION

1. Deploy low cost, high efficiency demin water systems that can operate directly from solar.
2. Develop low cost, high efficiency hydrogen electrolyzer based on CapDI module.
3. Develop integrated desalination/hydrolyzer modules based on CapDI module design.

STATUS OF DEVELOPMENT

Efficient demin water systems:

- Complete, in production. Operates on AC or DC power. See slide 5.

High efficiency electrolyzer:

- 2 patents pending, prototypes built, being tested by US Department of Energy

Integrated desalination/electrolyzer:

- 1 patent pending, prototype under design

HYDROGEN ONE OBJECTIVES FOR 2022

Sell desalination systems into the green hydrogen market.

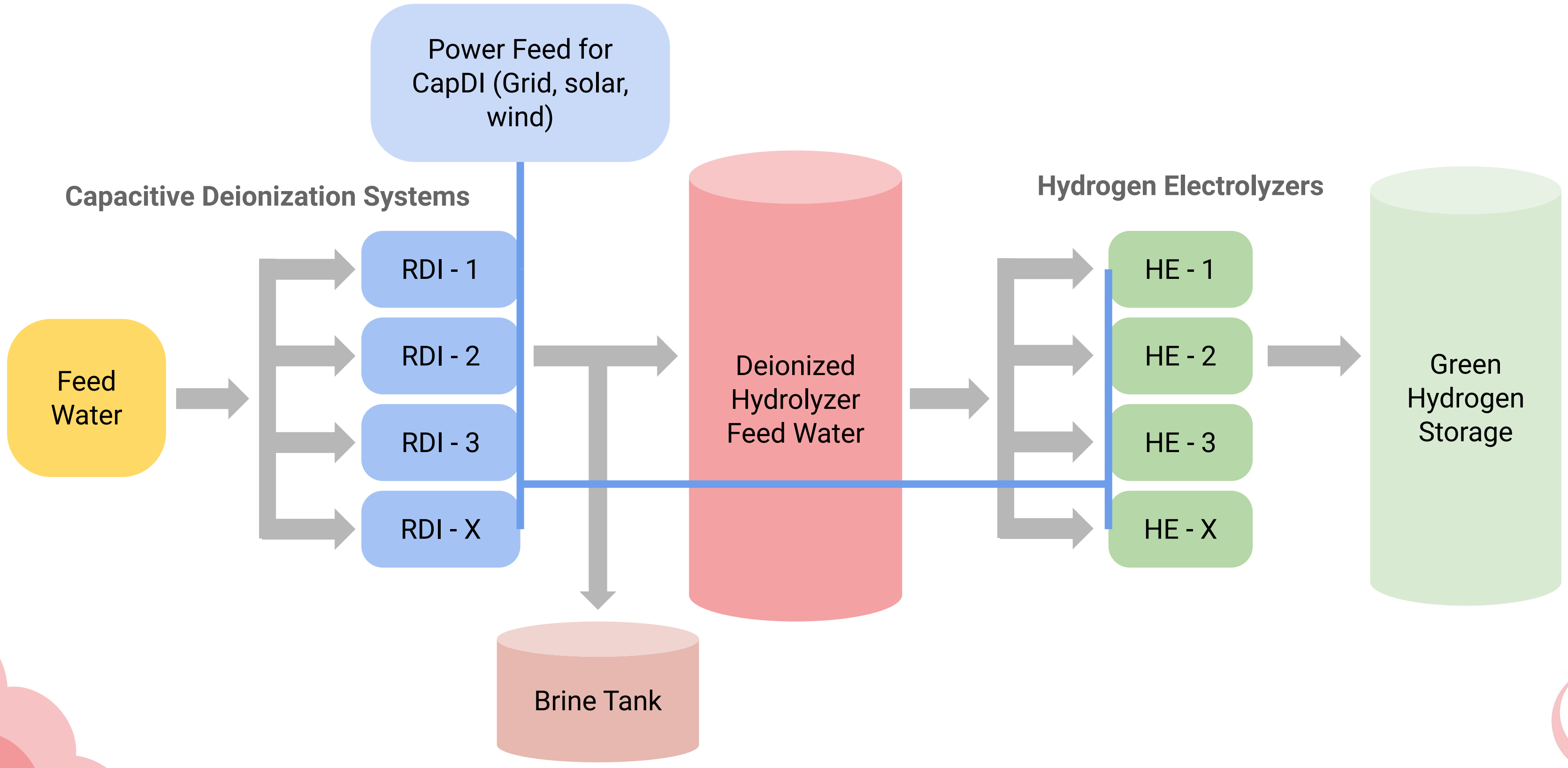
Finish development of the H1 electrolyzer

Build combination desalination/electrolyzer prototype

Develop strategic partnerships with

1. Traditional energy companies (Saudi Aramco, Petrobras, PDO, Exxon-Mobil)
2. Renewable energy companies (solar and wind)
3. Current hydrogen equipment builders (Thyssen-Krupp)

CAPACITIVE DEIONIZATION SYSTEM DESIGN
FOR DESALINATION AND/OR ENERGY STORAGE



Appendix of Background Information

External Analysis

Figure 1 shows published costs of hydrogen production from currently-available PEM electrolyzers, collected from several external sources. Overall, this data shows that hydrogen can be produced today within a cost range of ~$2.50 – $6.80/kg from a mix of renewable and grid feedstocks. This is in good alignment with the DOE analysis, which shows that hydrogen can be produced via PEM electrolysis at a cost of ~$4 to $6/kg for specific conditions. Table 2 elucidates some of the parameters used to obtain these costs including electricity cost, associated capacity factor, stack efficiency, and system capital cost. Each of these sources comprises a range of scenarios for hydrogen production including solar, wind, grid, or a combination along with optimistic and conservative cost assumptions.

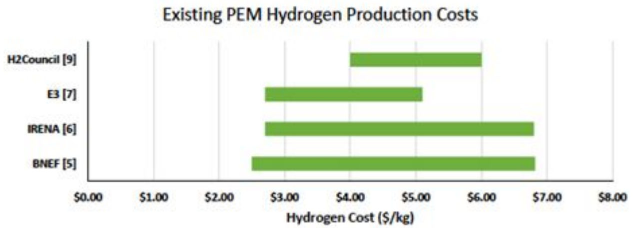
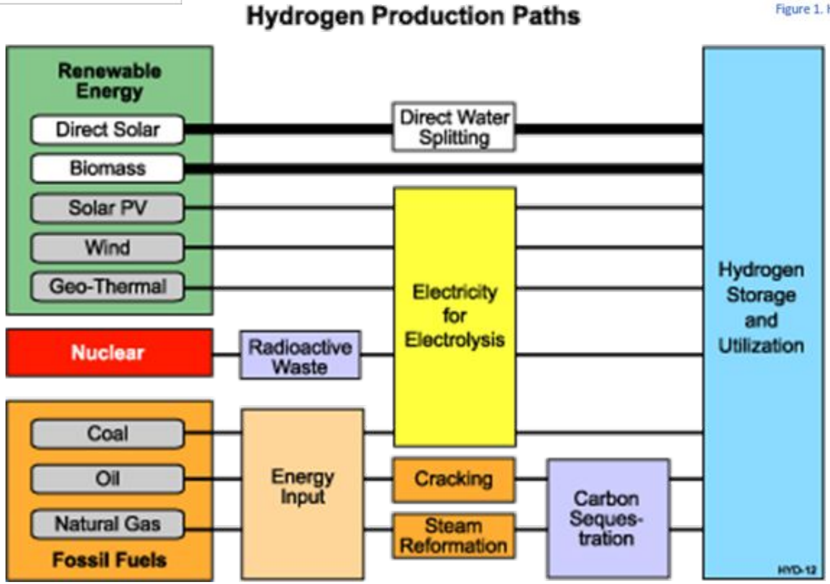
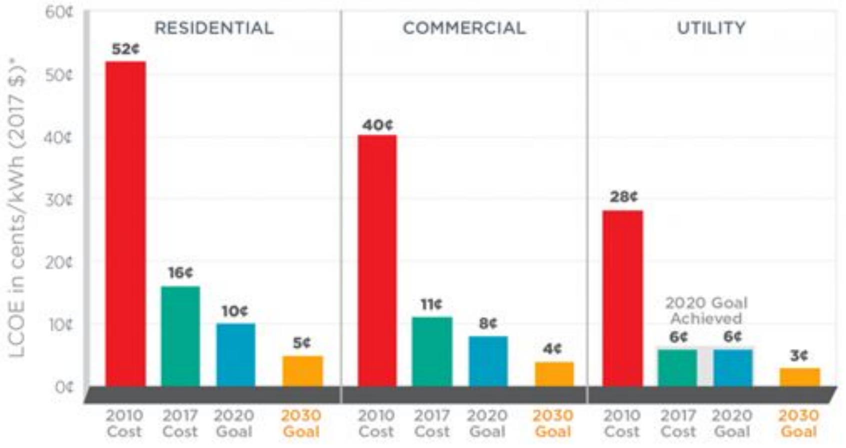


Figure 1. Hydrogen production costs compiled from various external analysis.



SunShot Progress and Goals



*Levelized cost of energy (LCOE) progress and targets are calculated based on average U.S. climate and without the ITC or state/local incentives. The residential and commercial goals have been adjusted for inflation from 2010–17.

Hydrogen can be produced from polymer electrolyte membrane (PEM) electrolyzers at a cost of ~$5 to $6/kg-$H_2$, assuming existing technology, low volume electrolyzer capital costs as high as $1,500/kW, and grid electricity prices of $0.05/kWh to $0.07/kWh.

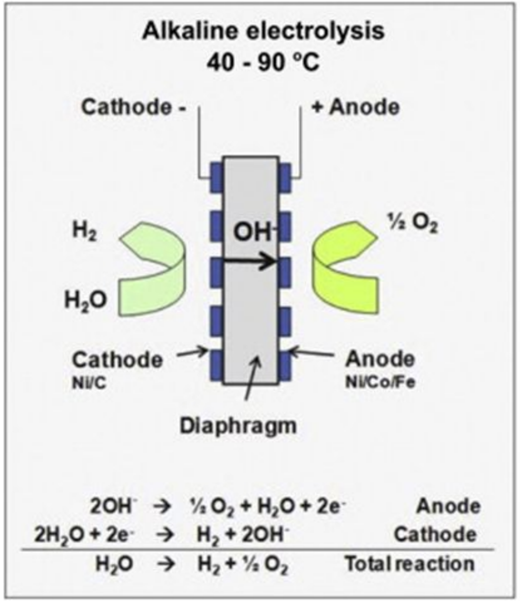
Table 1 shows the cost of hydrogen can range from ~$4 to $6/kg-$H_2$ with electrolyzer capital cost of $1,000/kW as an example and coupled to utility scale photovoltaic (PV) solar and utility scale onshore wind.[3]

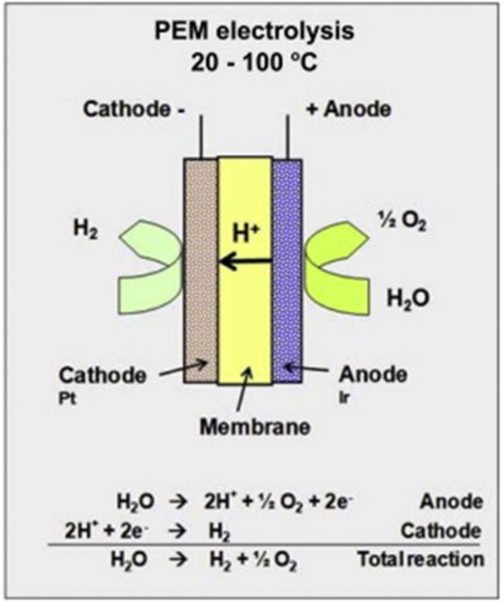
Table 1 – Hydrogen costs for PEM electrolysis from H2A with associated inputs of electricity cost, capacity factor, and uninstalled system capital cost.[4]

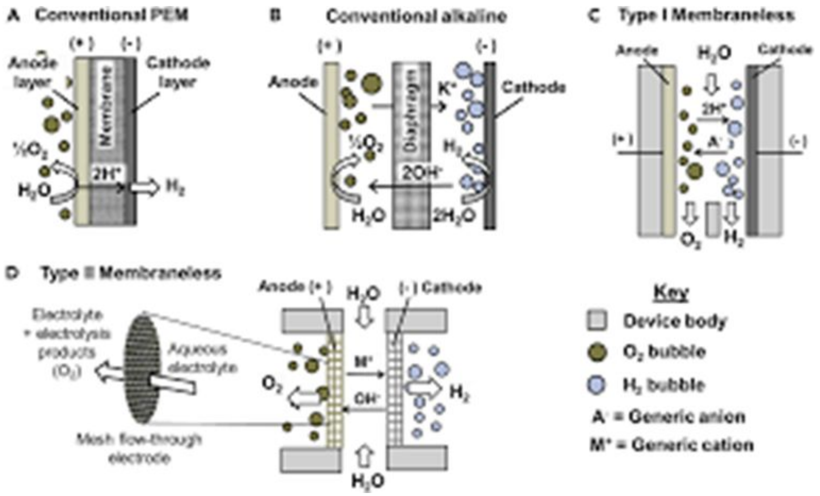
	Electricity Cost (¢/kWh)	Capacity Factor	System CapEx ($/kW)	H_2 Cost ($/kg)
Grid Low	5.0	90.0%	1,500	$5.13
			1,000	$4.37
Grid High	7.0	90.0%	1,500	$6.27
			1,000	$5.50
	NREL ATB 2020 [1]			
Solar PV Utility Los Angeles, CA	3.2	31.8%	1,000	$6.09
Solar PV Utility Daggett, CA	2.9	35.1%	1,000	$5.54
Wind Onshore Utility, Class 6	3.8	38.0%	1,000	$5.76
Wind Onshore Utility, Class 1	2.8	52.1%	1,000	$4.22

Table 2 – Hydrogen production costs from various external analysis and associated assumptions.

Low ($/kg- H_2)	High ($/kg- H_2)	Year	Electricity Cost (¢/kWh)	Capacity Factor (%)	System CapEx ($/kW)	System Efficiency (% LHV)	Reference
4.00	6.00	2020	4.0 – 10.0	20 – 30	750	65	H2Council [9]
3.75	5.10	2018	ATB	ATB	1,124	63	E3/UCI [7]
2.70	6.80	2018	2.3 – 8.5	26 – 48	840	65	IRENA [6]
2.50	6.80	2019	3.5 – 4.5	-	1,400	-	BNEF [5]


Alkaline electrolysis
40 - 90 °C
Cathode -
+ Anode
H_2
H_2O
OH^-
½ O_2
Cathode
Ni/C
Anode
Ni/Co/Fe
Diaphragm
$2OH^- \rightarrow ½ O_2 + H_2O + 2e^-$ Anode
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ Cathode
$H_2O \rightarrow H_2 + ½ O_2$ Total reaction


PEM electrolysis
20 - 100 °C
Cathode -
+ Anode
H_2
H^+
½ O_2
H_2O
Cathode
Pt
Anode
Ir
Membrane
$H_2O \rightarrow 2H^+ + ½ O_2 + 2e^-$ Anode
$2H^+ + 2e^- \rightarrow H_2$ Cathode
$H_2O \rightarrow H_2 + ½ O_2$ Total reaction


A Conventional PEM
(+)
(-)
Anode layer
Membrane
Cathode layer
½O_2
$2H^+$
H_2O
H_2
B Conventional alkaline
(+)
(-)
Anode
Diaphragm
K^+
Cathode
½O_2
H_2
$2OH^-$
H_2O
$2H_2O$
C Type I Membraneless
Anode
H_2O
Cathode
$2H^+$
(+)
A^-
(-)
O_2
H_2
D Type II Membraneless
Anode (+)
H_2O
(-) Cathode
Electrolyte + electrolysis products (O_2)
Aqueous electrolyte
Mesh flow-through electrode
M^+
O_2
OH^-
H_2
H_2O
Key
Device body
O_2 bubble
H_2 bubble
A^- = Generic anion
M^+ = Generic cation