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Millennium Reign Energy Impact Profile

Alternative Fuel Industry
April 2019

Company Description

Millennium Reign Energy, LLC (MRE) is a hydrogen infrastructure manufacturer and distributor that has built a fully automatic hydrogen generating station and storage system. The AutoARK® technology uses electricity from any source to separate water (H2O) into hydrogen and oxygen.

Headquarters	Dayton, Ohio
Founded	2008
Business model	LLC
Employees	7
Financial status	\$6.7MM funded to date
Intellectual Property	9 patents issued USA/EU/Canada
Website	http://www.mreh2.com/

Alignment with SDGs

	Good Health & Well-Being
	Clean Water & Sanitation
	Affordable & Clean Energy
	Responsible Consumption & Production
	Climate Action

Climate Impact Score: 9/10



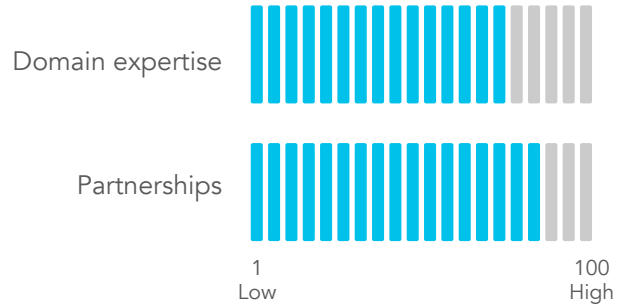
Boundless Analysis

- ▶ This profile compares MRE’s electrolysis technology against other hydrogen production technologies and fuels used in the transportation industry.
- ▶ The Climate Impact Score is based on per product impact and it is based on GHG emissions, air quality, use of water and energy.
- ▶ Boundless scores MRE 9/10 on per unit impact. The score rationale can be found in Appendix F.
- ▶ Scaled operations could eventually replace 18% of the domestic road fuels market and save 17 billion metric tons of CO2.
- ▶ The outlook for MRE to successfully commercialize their technology and products is positive. Key factors in the assessment:
 - Positive revenue stream of \$1.9 MM from inception and 2019 YTD at \$700K.
 - Three trademarks have potential to drive revenue and brand recognition.
 - Certificate of Attestation from CSA Group for their products reduces overall installation costs.
 - In discussions with a major retailer on installing fueling stations.
 - Plans to build 27 fueling stations along Transcontinental Hydrogen Highway™ by 2022.

Management Team

- ▶ CEO Chris McWhinney has over 16 years of operational and engineering experience and more than a decade of experience developing automated water electrolysis models.
- ▶ CTO Dave Erbaugh has extensive experience in electrochemical engineering together with project development and design experience.
- ▶ Additional leadership information in Appendix H.
- ▶ Strategic partnerships with Blue Planet Research, Ohio State Center for Automotive Research, Stone Edge Farm Microgrids, TIG/m, Hawaii Center for Advance Transportation Technology, University of Dayton Research Institute, US Navy Research Lab, U.S. Army Tank Automotive Research, Development and Engineering Center, Air Force Research Laboratory, Hickam Air Force Base.

Partnerships and Domain Expertise



Funding History

- ▶ MRE raised \$6.7 million to date, funding the development of its AutoARK® alkaline electrolyzer as a clean primary fuel source, and the Scalable Hydrogen Fueling Appliance (SHFA) to enable hydrogen to power cars and trucks, and provide energy storage for independent microgrids. Outstanding loan owed to founder is \$539k to establish the company in 2008. \$3.5MM was raised in 2013 to improve the electrolyzer and hydrogen fueling stations to operational efficiency. Another \$2.6MM was raised in 2017 to bring technology to its commercial-ready state. The company installed systems in several US states and United Arab Emirates, and is partnering with 3 major military sites. MRE is currently raising a bridge round of \$2MM to build out the management team and operations, and continue building joint ventures with major retailers and car dealerships for the planned Transcontinental Hydrogen Highway™ across the US. The company plans to raise \$20MM in late 2019 to build the highway, partnerships with solar and wind companies to provide large megawatt clean storage during off-peak production hours, and partnerships with Small Island Nations and other developing world sites where microgrids are most expedient for energy production.

Deal Type	Year	Amount
Series B	2019	\$20MM
Bridge Round	2019	\$2MM
Series A	2013-17	\$6.1MM

Technology

- ▶ Millennium Reign Energy LLC uses its AutoARK® technology to produce hydrogen from any electricity source.
- ▶ Most of the hydrogen produced in the world today comes from steam methane reforming, a process that involves the separation of methane from natural gas into hydrogen and hydrocarbons (CO and CO₂). MRE technologies uses electrolysis to produce hydrogen, meaning that its only inputs are water and electricity.
- ▶ Current MRE hydrogen generators can produce from 4 to 64 kg of hydrogen per day with an average electricity consumption of 57 kWh per kg of hydrogen. That electricity can come from any source of energy, specially renewable.

Operations

- ▶ Headquarters in Dayton, Ohio.
- ▶ Installed systems in Texas, Hawaii, Oahu, Ohio State University, Dubai, LA, Sonoma California and the US Navy Research Lab.
- ▶ Transcontinental Hydrogen Highway™: 27 hydrogen stations to be built from Los Angeles to New York City.

■ Current Base of Operations



Environmental Highlights

Main impact parameters and codes relative to sector. Metrics outline the most important factors that help investors understand how a technology is impacting the environment through a variety of lenses. The codes refer to the United Nation's [Sustainable Development Goals](#) (SDGs).



Greenhouse Gas Emissions

The production of hydrogen through the use of MRE technology has lower emissions on a per kg of hydrogen produced basis compared to coal gasification, steam methane reforming, and electrolysis using proton exchange membrane (PEM) with conventional grid energy. Using one of MRE's electrolysis stations, an average of **~7.8 kgCO₂e** can be saved per kilogram of H₂ produced. (Refer to the Methodology in Appendix A for additional detail). As points of reference, currently **~9 kg CO₂e** are emitted to produce one kilogram of hydrogen, since 96% of the hydrogen is produced using coal and natural gas. Therefore, using MRE technology to produce hydrogen would represent 86% reduction on emissions. Hydrogen produced via MRE technology for automobiles would also have a positive impact in a per mile basis compared to fossil fuel, biogas and electric vehicles (EVs). Fueling a car using hydrogen would save **~45 kgCO₂e** per 100 miles, a **96% reduction** on emissions. Note that this analysis uses the 100-yr GWP for methane. Using an alternative 20-yr GWP assumption would show greater emissions reduction potential. Relevant code: [SDG 13](#)



Water Use

The production of hydrogen through electrolysis consists of the separation of H₂O molecules using electricity. MRE electrolysis stations use 2.3 gallons of water to produce 1 kg of hydrogen (H₂). Hydrogen is then recombined with oxygen to produce electricity: a completely sustainable process with no emissions and zero net water loss. Hydrogen generation is also safe with no process contamination. Any leaked gas quickly rises so that no dangerous build-up occurs. Relevant codes: [SDG 6](#)



Energy

MRE electrolysis stations use an average 57 kWh to produce one kilogram of hydrogen. Every kilogram of hydrogen has 33 kWh of embodied energy, equivalent to the energy consumed by a LED lightbulb during 1,500 hours. The electricity to produce hydrogen can come from renewable sources like solar, wind, geothermal or hydro, creating an opportunity to tackle the uncertainty inherent to renewable energy sources using a clean technology. Relevant code: [SDG 7](#)



Waste Reduction

Most of the materials that make MRE stations are highly recyclable. The station's enclosure, hydrogen storage tanks, and electrodes are made of 100% recyclable stainless steel. Only between 1 and 9 grams of plastic can be allocated to the production of one kilogram of hydrogen in an MRE station. Finally, there are no rare metals involved in the process that could damage the environment after the end of life of the station. Relevant codes: [SDG 12](#)

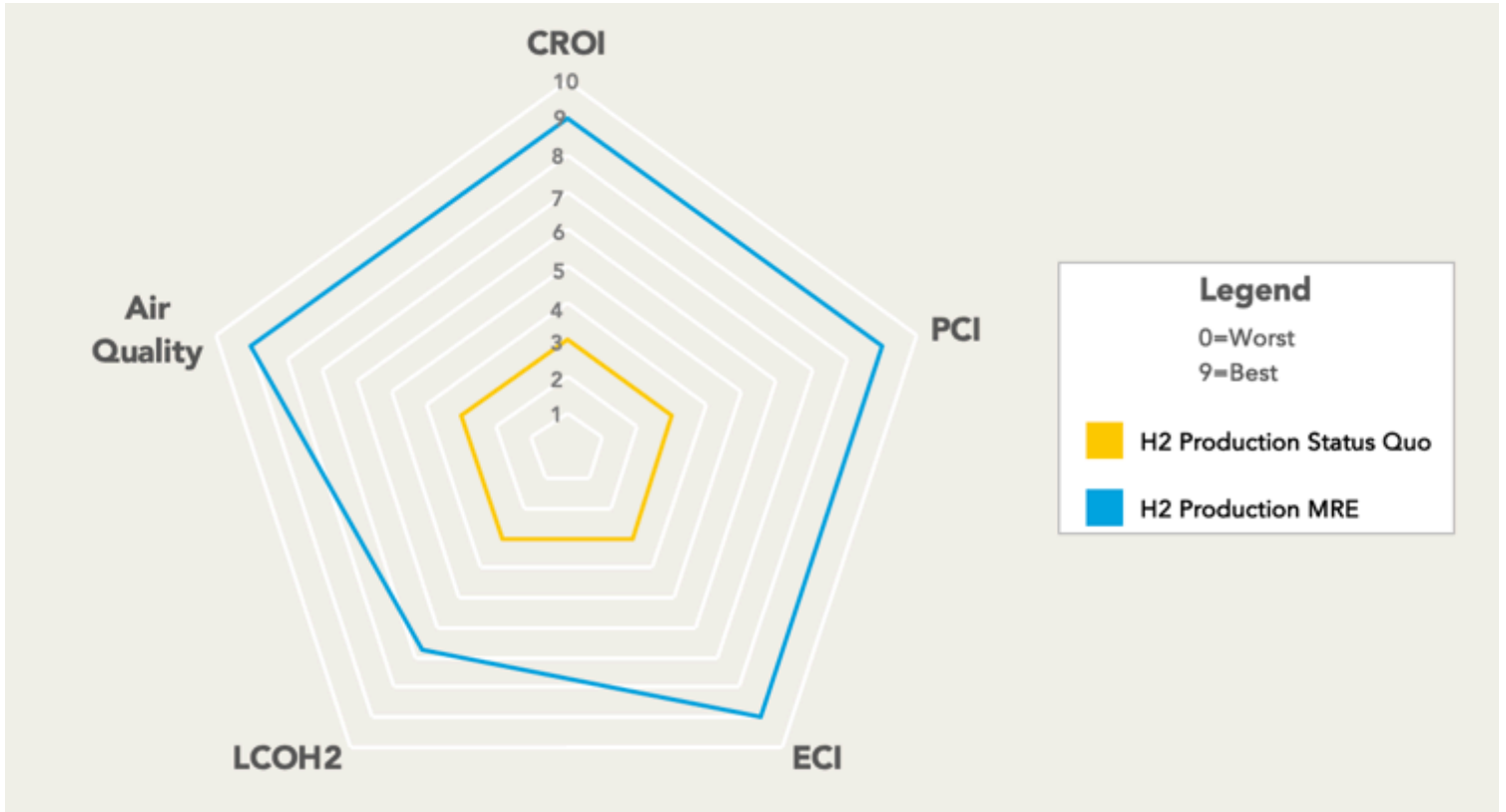


Air Quality

Instead of releasing to the environment carbon monoxide and carbon dioxide, as other traditional hydrogen production processes, electrolysis releases 7.9 kg of oxygen per kilogram of hydrogen produced. Furthermore, whilst fossil fuels emit hydrocarbons and particulate matter when combusted, hydrogen only produces water when converted to electricity. Relevant code: [SDG 3](#)

Benchmarking

Hydrogen production using MRE technology and use of that hydrogen in the transportation sector, relative to the status quo for production of hydrogen and the transportation sector. In these examples, hydrogen is generated using the current mix of energy sources feeding the USA grid. The complete set of metrics are available in Appendix B.



Conclusions

Millennium Reign Energy LLC offers an innovative solution to produce hydrogen through electrolysis, using their patented technology AutoARK®. Depending on the source of the electricity to split the hydrogen from oxygen in the water molecule, the production of hydrogen using MRE’s technology shows a strong carbon return on investment (CROI). Compared to the status quo on hydrogen production, mainly fossil fuel based, MRE shows considerable environmental benefits. The technology is flexible and expandable. Small, compact and autonomous stations, using renewable energy, can be placed at existing petroleum stations or can easily be positioned in an urban context with a minimal land footprint.

The environmental benefits of MRE technology electrolysis are numerous compared to fossil fuel (FF) technologies. Hydrogen produced for the transportation sector by MRE can be used to supply hydrogen fuel cell (HFC) cars. A direct comparison with diesel, ethanol, petroleum, natural gas, and even electric vehicles show a substantial decrease in carbon emissions per mile. If 30% of all US automobiles were replaced by FCV, CO2 savings would be 550,000 metric tons per year. As an additional benefit, hydrocarbons and particulate matter currently emitted by FF cars would be replaced by water and warm air. Furthermore, EVs using Li-ion batteries have a higher GHG impact compared to hydrogen because of the minerals used in storage manufacturing. Hydrogen storage in HFC cars is carbon-fiber wrapped around polypropylene liner or aluminum lined with carbon-fiber wrap.

Even though hydrogen has high environmental benefits, its current price makes it less competitive than other fuels. Electric vehicles and natural gas fuel vehicles, for example, have larger CROIs as a result of their lower costs. But when compared to the most common fossil fuels, every thousand dollars invested in MRE’s technology will save four times more CO2eq than gasoline technologies, the most commonly used fuel in the road transport industry.

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About Boundless Impact Investing

Driven by the latest research by independent industry and academic experts, Boundless Impact Investing offers analysis, market trends, and evidence of best practices in a growing number of emerging sectors that address major social and environmental challenges. We are an advanced consulting firm that enables investors to connect with industry leaders and peers for expert analysis, diverse perspectives, and real-time collaboration. Our investor education and expert advisory services offer proprietary access to both subject-matter experts and other impact investors.

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