

FAQ

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Hydrogen Safety

The critical aspect to that is consumer education as the reality is that [hydrogen is safer than most fuels currently in widespread use](#) (i.e. gasoline, natural gas, etc). In fact, hydrogen is safely used in passenger cars and trucks, passing stringent crash tests. Further, no fires or explosions of Fuel Cell Electric Vehicles have been recorded. Nor have there been issues with its use as a process gas in production of semiconductors and in other advanced manufacturing industries.

To evaluate hydrogen's safety, it must be compared to that of other conventional fuels like gasoline, propane, and diesel. While no fuel is 100 percent safe, green hydrogen has been shown to be **safer than conventional fuels** in a multitude of aspects.

Hydrogen is not toxic, unlike conventional fuels. On the other hand, many conventional fuels are toxic or contain toxic substances, including powerful carcinogens. Moreover, when it comes to vehicles that run on hydrogen fuel cells, hydrogen produces only water, while vehicle combustion of conventional fuels generates harmful air pollution. A hydrogen leak or spill will not contaminate the environment or threaten the health of humans or wildlife, but fossil fuels can pose significant health and ecological threats when leaked, spilled, or combusted.

Hydrogen is 14 times lighter than air and 57 times lighter than gasoline vapor. This means that when released, hydrogen will typically rise and **disperse rapidly**, greatly reducing the risk of ignition at ground level. However, propane and gasoline vapor are heavier than air, making it more likely that they will remain at ground level, increasing the risk of fires harming people and buildings.

Hydrogen flames emit much **lower radiant heat** than conventional hydrocarbon fuel flames (e.g. gasoline), meaning that objects in the vicinity of the flame do not get as hot as around a gasoline flame. Therefore, the risk of hydrogen secondary fires is lower.

While hydrogen's **explosion limit** in air is wider (18% - 59%) than that of gasoline (1% -3%), the minimum concentration required for explosion is much higher (18% vs. 1%). Considering that hydrogen rises and diffuses so quickly, concentration will rarely accumulate near an ignition source.

As with any fuel, even with the greater safety of hydrogen, it's about **responsible handling and following safety rules, guidelines, and industry standards**. Our plan is to use off the shelf, reliable storage canisters to store the hydrogen at relatively low pressure, perform continuous monitoring for leaks, and implement automatic shutdown protocols.

Compared to the widely used Low Temperature (80 C) systems, the safety implications for our High Temperature (160 C) are very similar, both surfaces would be too hot to touch and the exhaust too hot for contact. Shielding from touch and directing exhaust away from people are common techniques to ensure safe operation.

H₂ leakage: While the hydrogen molecule is small and leaks more easily than most other gases, **reliable techniques have been developed to prevent leaks**. Hydrogen is extensively used in the semiconductor manufacturing industry, at pressures several times higher than used in HyWatts' systems. The same control procedures and detection systems (e.g. hydrogen detectors) will be used.

Specifications and technical capabilities of the hydrogen storage system

1. The specifications of the system depend on the requirements. In general, the system is capable of storing large amounts of energy, from MWh to GWh. The storage is loss free, there is no self-discharge.
2. The system can be integrated seamlessly with solar or wind energy systems. Based on load profile and location (weather parameters), we will size the system components to provide a reliable power supply.

Post Sales Service

A big focus of our service system will be remote monitoring to stay ahead of any issues that may arise to ensure maximum uptime, which likely will be in-house as it will also be a part of our continuous improvement plan given the nature of the data.

For those instances that require physical maintenance it will most likely make sense to leverage the capabilities of our local B2B partners and their teams (i.e. those responsible for the whole system including the renewable energy and other non-HyWatts components) as well as other local contractors. Given this I agree that there is an opportunity in terms of workforce development and green economy jobs, with potential for public/private partnerships around that. This is also a reason why we are excited that Shivani Ganguly has joined our founding team as COO, bringing her rich experience in setting up operations, and will be a key driver of this aspect of our work.

Hydrogen Storage

We generally store hydrogen in Type 1 (steel) **gas tanks at 200 bar** as this is the lowest cost option to safely store H₂. Other options are possible if required:

Simple plastic containers could only hold low pressure and would thereby need to be very large (read expensive) to store the H₂.

Tanks made from **composite materials** would hold higher pressure and require less volume, but are used only in special applications (passenger cars, airplanes) due to their high cost. Another downside would be the increased energy use for compression.

Metal hydride provides very low volume, low pressure storage, however at very high cost.

Liquid H₂: Liquification systems are very expensive and the economics for smaller scale systems are very unfavorable. While liquified H₂ is highly preferable over gaseous H₂ for transportation via trucks, our on-site generation, storage, and consumption strategy avoids all cost associated with transportation and therefore has no need for liquification.

	Storage Tank Cost	Energy needed for Compression	Energy needed for Storage	Technology Maturity (TRL)	Safety	
HyWatts (200 bar)	Low	Medium	None	High	Very Good	
Low pressure	Medium	Low	None	Medium/High	Very Good	
High pressure (300+ bar)	High	High	None	High	Good	
Liquid H ₂	medium	Very High	Medium	High	Good	
Metal Hydride	High	Low	None	High	Very Good	

Durability and stability of materials

Celtec-P MEAs from BASF have been commercially available for almost 20 years now. Lots of testing has been done and described in literature, some tests for up to 20000 hrs. For our conditions, pressurized and high current, there is not much data – we will have to do extensive testing ourselves. Optimization if required of:

1. Operating conditions (lowest flow rates possible to decrease acid leaching),
2. Low temperature gradient -> allows operation at lower temperature at BOL and later increase to cover for voltage degradation.
3. Minimum load cycling.
4. Minimize exposure to high potential (startup/shutdown).

The High Temperature MEA is expected to last longer than a comparable Low Temperature MEA. However, we assume the High Temperature Reversible Fuel Cell to have a mean time between overhauls of 50,000 hrs. That compares to a warranted lifetime of competing Electrolyzers of 60,000 hrs. and Fuel Cells of 20,000 hrs.

As the balance of Plant (BoP) of the High Temperature system is simpler than that of the Low Temperature system, we expect lower maintenance and repair cost over the life of the system

Efficiency

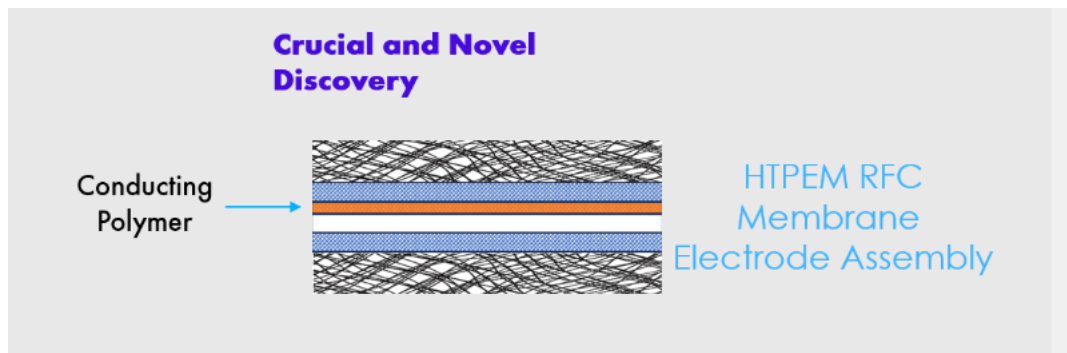
1. The round-trip efficiency of the system is around 40%, much lower than that of a Li-battery (~90%). However, the (by far) largest cost factor for a long duration energy storage system is capital cost. The higher energy cost due to the lower efficiency are not a significant factor in the overall cost.
2. Similar is the comparison of an electric drivetrain (90% efficiency) for a car with an internal combustion engine (25% efficiency). For a car used only a few hundred miles a year, the higher cost of the electric car would justify the much higher efficiency.
3. It is important to note that for our customers RTE isn't important as they are not focused on arbitrage. For them the critical metric is cost.

Intellectual Property

Our IP enables High Temperature PEM Reversible Fuel Cells, which will reduce the cost of hydrogen-based storage systems by 40%.

The primary reason that HTPEM electrolyzers aren't on the market is the fact that the phosphoric acid, the critical proton conducting membrane component, leaches out rapidly when the membrane comes into contact with water, making HTPEM electrolyzers non-viable.

HyWatts conducting polymer film protects the high temperature membrane from contact with water, and thereby prevents this degradation.



This crucial discovery allows HTPEM technology to be commercially viable as an electrolyzer, which in turn unlocks its ability to operate bi-directionally.

Technology maturity

Membrane:

We are building on existing and novel technologies.

Celtec-P MEAs from BASF have been commercially available for almost 20 years now. Extensive testing has been performed and described in literature, some tests for up to 20000 hrs. For our conditions, pressurized and high current, there is not much data – we will have to do significant testing ourselves, specifically of the assembly of membrane and protective polymer film. Test parameters include:

1. Operating conditions (lowest flow rates possible to decrease acid leaching),
2. Temperature gradient -> A low gradient allows operation at lower temperature and provide additional margin to allow for voltage degradation towards end of life.
3. Load cycling.
4. Exposure to high potential during startup/shutdown.

We are receiving DoE funding to support this work.

Catalysts:

Catalysts for low temperature FCs and electrolyzers are mature, however little work has been done to optimize catalysts for HTPEM systems. Fundamentally, catalysis at higher temperatures should be easier, and work will focus on finding lower cost alternatives for the currently used catalysts.

HyWatts is applying for an NSF grant to support the work.

Electrolyzer thermal management

Initially, for our first prototypes, we will use liquid cooling for the stack, and a heat exchanger that will use the waste heat to evaporate the feed water for the electrolyzer. Ultimately, we plan to use evaporative cooling to maximize heat transfer and minimize the thermal gradient across the bipolar plate and membrane.

- CFD models will show us flows and temperatures of MEAs and BPPs, and we will verify with short stack testing.
- BPPs will be made from thermally conductive materials
- Initial focus will be on longevity, for our system capital cost drives economic efficiency

Manufacturing

- Hard to manufacture is mostly the stack. Ultimately, we will use stamped sheet metal to make the bipolar plates, which will be inexpensive and easy to scale.
- For prototype development, lead times for stamped HW is unacceptable, so we will use milled plates. I expect 2-3 iterations until we have a working prototype.
- For scaling up, we plan to keep core functions like Stack manufacturing in-house. These are comparatively easy to scale. For non-core manufacturing steps such as BoP and system assembly, we have a MoU with a partner to outsource the work.

Other

Higher level System Integration for charging stations

There are a number of companies coming onto the scene in terms of improving ease of charging for the end user. I know of a few software startups that are looking to make it easy for fleet operators and others to easily access online, available chargers and optimize their overall use of ZEVs/Charging Stations, including [Presto](#) & [Epic](#). If you're speaking to the interconnection aspect, I know that is a reason a number of charging companies such as [WattEV](#), [Forum Mobility](#), as well as [Tesla](#), [Chargepoint](#), [Electrify America](#), [EVgo](#), and others are deploying their own networks and in many cases including grid-independent chargers as a part of their stations. Admittedly, given our focus on providing the storage solution and with ZEVs as only one market segment this is a question that I haven't dedicated much time to.