

# Hydrogen Fuel Cell Powertrains for Lightweight Transportation Vehicles

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Powertrains for lightweight transportation vehicles, operating around the clock. Green, smart, environmentally friendly, emission-free and noise-free.

Designed for vehicle owners demanding large payloads or on-site power production, combined with long operating times - in modern, on-demand economies worldwide.



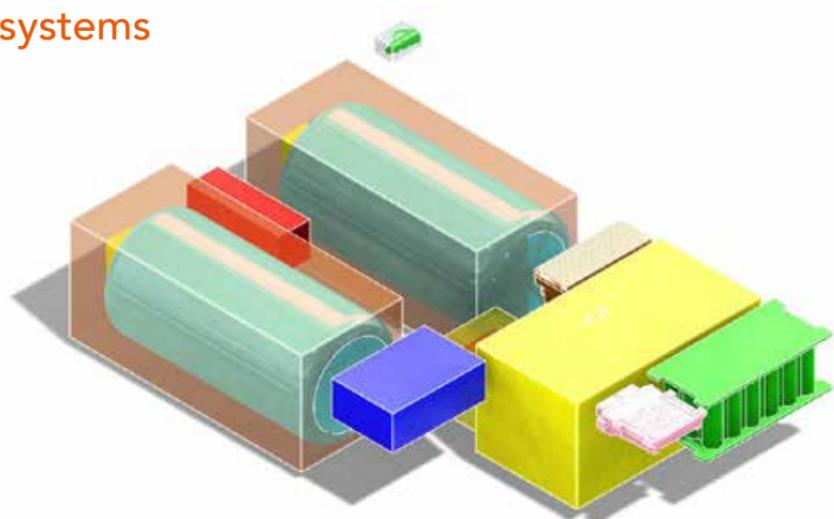
1. Summary and Highlights	2
2. Value Proposition - Why Hydrogen Fuel Cell Power for Lightweight Vehicles?	4
3. Be Ready for Hydrogen! Grab the Opportunity!	6
4. 2-10kW Fuel Cell Powertrain & Hydrogen Tank Assembly	8
5. Virtual Concept - A Small Three-Wheeler 'Tuk Tuk'	9
6. Cooperation Proposal: One Stop Shop, More Than Just Delivering Components	12
7. Hypowa Ltd and Partners	13



# 1. Summary and Highlights

## HYPOWA offers vehicle manufacturers

- a complete integrated hydrogen fuel cell powertrain (2-10 kW) assembly including hydrogen tanks ( $\geq 1$  kg) and electric motors, to power small and lightweight transportation or utility vehicles - both three- and four-wheelers
- customized powertrain solutions for specific requirements and priorities, including autonomy, power take-off (vehicle-to-grid/load) and range extender systems
- short timescale from prototype to first series - a fully road-licensed prototype of any such vehicle in less than 12 months
- the opportunity to establish supply lines with HYPOWA's high-end manufacturing partners, for all the components required



- market development for the new vehicle
- customization into a dedicated utility vehicle, for example: food truck or pop-up shop, champagne bar, silent mobile power generator for construction work or greenery maintenance
- the capability to start the project right away because the virtual concept has been finished
- true cooperation for developing new vehicles and bringing them to the market successfully - HYPOWA and its partners are readily prepared





## 2. Value Proposition - Why Hydrogen Fuel Cell Power for Lightweight Vehicles?

### There are two critical requirements:

- **Environmentally friendly** a green vehicle that produces no harmful emissions and creates no noise
- **Commercially successful** a green transportation vehicle that offers both large payload and long operating times

Only a hydrogen fuel cell powertrain can meet those two basic demands together. The hydrogen fuel cell technology is an investment in continuously growing markets. It is green technology that complies with all ethical standards, to uphold the reputation of the vehicle manufacturer.

Every hydrogen fuelled lightweight transportation vehicle will be built to meet rigorous environmental standards. The vehicle must be emission-free and noise-free, the production of its components must be environmentally friendly, and all parts must be recyclable.

The short refuelling time and large payload combined with long operating times (up to 20 hours) serve the needs of growing, on-demand economies and rapidly expanding markets in both developed as well as developing countries, for commercial success.

Both heavy- and lightweight non-combustion vehicles will have to use hydrogen fuel cells

in the future, since the energy density of batteries is too low. Hydrogen has a high energy density (compressed at 700 bar), so the payload of a hydrogen fuel cell lightweight vehicle can be much higher than a comparable battery electric vehicle. Fast refueling provides hydrogen vehicles with significantly longer daily operation times than battery vehicles, which is a critical factor for transportation businesses serving on-demand customers.

The ever increasing number of regulations for protecting the environment will restrict and reduce the market for vehicles with internal combustion engines (ICE). Tolerance of fossil fuels is continually declining, to become a dying model in many regions of the world.

The Total Cost of Ownership (TCO) of battery vehicles is low for higher payloads and operating times. More battery vehicles would be needed to achieve similar payloads and operating times. A hydrogen fuel cell vehicle can operate for up to 20 hours (subject to usage) without being refuelled and refuelling its hydrogen tanks takes less than 5 minutes. It's estimated that the capital expense of a hydrogen fuel cell vehicle and an ICE vehicle are comparable, once more than 4,000-10,000 units of the same powertrain are produced.

The next table provides a high level comparison of all major aspects. It illustrates the advantages and superiority of the hydrogen fuel cell technology.

Key: ICE = Internal Combustion Engine; BE = Battery Electric; H2 FC = Hydrogen Fuel Cell

Criteria	ICE	BE	H2 FC	Remarks
<b>Emission-Free</b>	1	3	3	BE and H2FC: Renewable energy for the production of green hydrogen and for recharging batteries results in emission-free power generation.
<b>Noiseless</b>	1	3	3	
<b>Environmentally Friendly Production</b>	2	1	3	BE: The production of lithium used in batteries is environmentally unfriendly. There are moral hazards associated with lithium and cobalt mining. Batteries require a lot of energy to produce.
<b>Recycling of Used Vehicles</b>	3	1	3	BE: A large scale recycling concept for batteries does not exist. H2 FC: Up to 98% of a FC can be recycled.
<b>Safety</b>	2	2	3	ICE: When petrol or diesel fuels leak, these fuels pool close to the ground, increasing ignition likelihood. When ignition does occur, it can result in a dangerous and long-lasting fire.* BE: Lithium-ion batteries can fuel hotter fires that release toxic fumes and are harder to extinguish. Small fires can leap into other parts of the battery to ignite them and cause a chain reaction.**
<b>Driving Range/ Operating Time</b>	3	1	3	H2 FC: Due to the energy density of H2 stored in 700 bar tanks, the driving range and operating time of ICE and H2 FC vehicles are comparable.
<b>Refuelling/Recharging Time</b>	3	1	3	BE: Full recharging of batteries takes hours, provided there is reliable electricity supply. H2 FC: Hydrogen tanks can be refuelled in few minutes (a similar time to diesel tanks).
<b>TCO</b>	3	1	2	H2 FC: The TCO of H2 FC will quickly approach the TCO of diesel vehicles, once sufficiently large numbers of vehicles are produced and supportive environmental regulations are in place. BE: The TCO of battery vehicles is low for higher payloads and operating times. More battery vehicles would be needed to achieve similar payloads and operating times, as demonstrated in the Materials Handling Industry (e.g. by Amazon, Wal-mart, BMW.)
<b>V2G (Vehicle-to-Grid)</b>	0	1	3	BE: The low energy density of batteries does not allow the combination of high driving autonomy, high payload and powering external or installed electric appliances for hours. The relatively long recharge of batteries compared to the refilling of hydrogen tanks makes a BE system less suitable for long term power generation in remote areas. H2 FC: Due to the high energy density of hydrogen compressed hydrogen (700 bar) the fuel cell can provide electricity for external and/or installed electric appliances for hours besides driving usage.
<b>Total Score</b>	<b>18</b>	<b>14</b>	<b>26</b>	

\*(Source: Pozzi, Silvano; "Hydrogen Fuel Safety: Essential Facts for Transit Operators"; Ballard Power Systems; 12th Oct. 2017)

\*\*\*(Source: Woodward, Aylin; "Why the Fire that Incinerated a Tesla Was Such a Nightmare to Put Out"; Live Science; 30th March 2018)

### 3. Be Ready for Hydrogen! Grab the Opportunity!

The market for hydrogen fuel cell automotive applications is expanding rapidly. The new technology is ready and available to use.

Hydrogen and hydrogen fuel cell technology combined with P2G (Power-to-Gas) is the only environmentally friendly full-circle energy system. The hydrogen energy system is currently the only economically and technologically feasible solution for addressing the global challenges associated with increasing CO2 emissions and global warming: air pollution, use of critical mineral resources, recyclability and renewable energy storage. There is currently no other completely green energy system available as a feasible alternative.

The most technologically advanced regions globally (including Japan, South Korea, China, Scandinavia, Germany, France, the UK and California) have understood that there is no other green alternative. They have therefore started investing heavily in hydrogen infrastructure. For example, Germany is constructing more than 400 hydrogen refuelling stations, which will be

finished by 2023. China, South Korea, Japan, California have started similar infrastructure programmes. We estimate that there will be more than 2,000 hydrogen refuelling stations in the large metropolitan areas of technologically and economically advanced regions within three years.

The energy transition from fossil fuel to a green hydrogen energy system has started in many of the most technologically advanced nations. The transition has also gained momentum in emerging markets and developing countries, where severe air pollution in cities is often the main driver for clean, emission-free transport vehicles. Commercial growth is expected to accelerate over the next three years, as the automobile industry embraces hydrogen fuel cell technology.

Yongping Zhai, the Asian Development Bank's Chief of Energy Sector Group (Sustainable Development and Climate Change Department) is among the executives who have publicly recognized the great business opportunities and benefits of hydrogen for emerging countries:

**“Developing countries would be the big winners from a hydrogen economy”.**

(Asian Development Bank: <https://blogs.adb.org/blog/it-s-clean-powerful-and-available-are-you-ready-hydrogen-energy>)

**The time for grabbing the hydrogen opportunity is now, worldwide!**



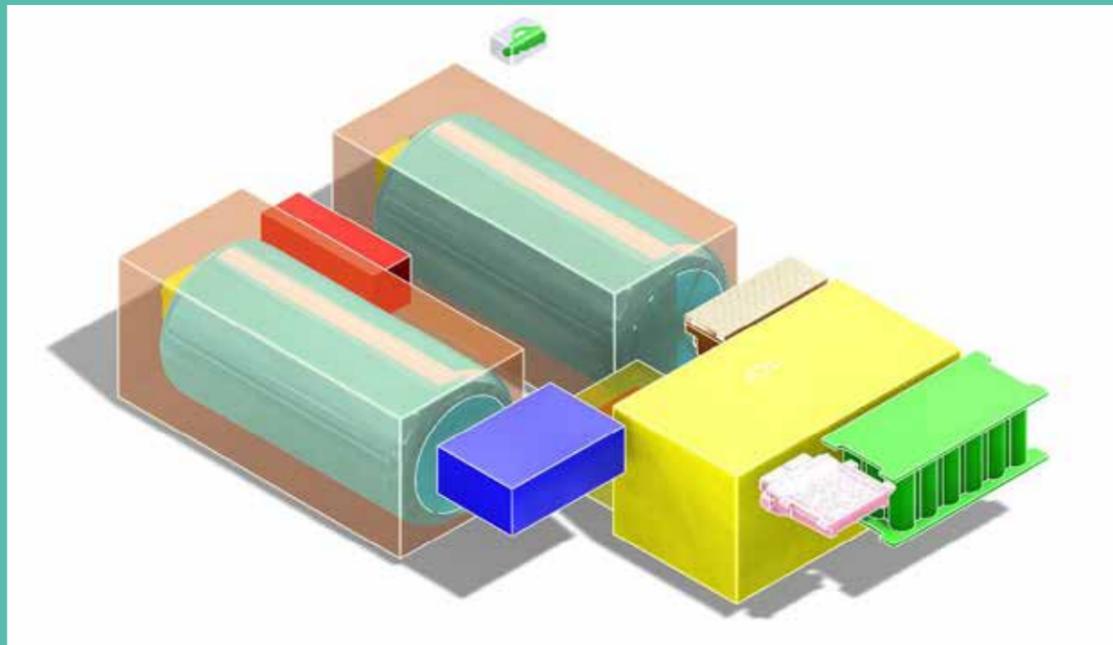
## 4. 2-10kW Fuel Cell Powertrain & Hydrogen Tank Assembly

Hypowa can supply complete air and liquid cooled Fuel Cell powertrain and hydrogen tank assemblies, and so create a 'fuel cell range extender' for existing battery electric vehicles. The powertrain or range extender can deliver continuous Fuel Cell power of 2-10 kW with tailored short term peak power via a traction battery or supercapacitors. Hypowa can also integrate a suitable electric motor including regenerative braking and a matching electric motor controller. In addition, we can assist in conversions from gasoline or diesel power to hydrogen fuel cell electric powered vehicles.

Hydrogen storage at 700 bar can range from 1 kg up to several kg, depending

on the packaging into the vehicle and autonomy requirements. The hydrogen fuel receptacle complies with international standards and allows communication between the vehicle (in-tank temperature and pressure sensors) and the hydrogen fuelling station for safe and fast refuelling times.

Power take off (PTO) or Vehicle-to-Load (V2L) or Vehicle-to-Grid (V2G) is an extra option for further versatility. While driving, the vehicle can power a device such as a cooling unit. When parked it can serve as a mobile and noise- and emission-free generator. There are many applications, from food preparation facilities, pop-up shops or lighting for a construction site to powering commercial gardening tools.



Layout of Virtual Powertrain Concept



## 5. Virtual Concept - A Small Three-Wheeler 'Tuk Tuk'

**Hypowa has developed a virtual concept for one of the smallest available three-wheeled lightweight transportation vehicles, sometimes called a Tuk Tuk or Rickshaw. The concept clearly demonstrates the technical feasibility, for even the smallest vehicles.**

The hydrogen fuel cell system is a liquid cooled PEMFC (Proton Exchange Membrane Fuel Cell) with a rated power of 1,800 W (maximum power 2,000 W) and an operating voltage 21 ~ 33 V. The system can operate in ambient temperatures of -10 to +50 °C.

The fuel cell system is proven: it has already been used for a similar lightweight, two-wheeled vehicle, of which large numbers have been produced. It's robust and durable, depending on the load cycle, achieving several thousand hours of operation with minimal performance loss. Additional filters prevent damage by harmful gases in regions with high air contamination.

The gas assembly consists of a hydrogen refuel receptacle and either one or two 26 litre 700 bar hydrogen tanks that can each store 1 kg of hydrogen. The 700 bar tank assembly includes tank, tank valve, pressure regulator and a low-pressure interface. 2 kg of hydrogen has an energy density of ~ 70 kWh. Depending on the load cycle, the fuel cell system can generate approximately

30-35 kWh of electricity. The hydrogen in the tanks is therefore sufficient to operate the vehicle for up to 15-20 hours, subject to mode of usage.

A small traction battery and/or super capacitor assembly is included for regenerative braking and fast acceleration.

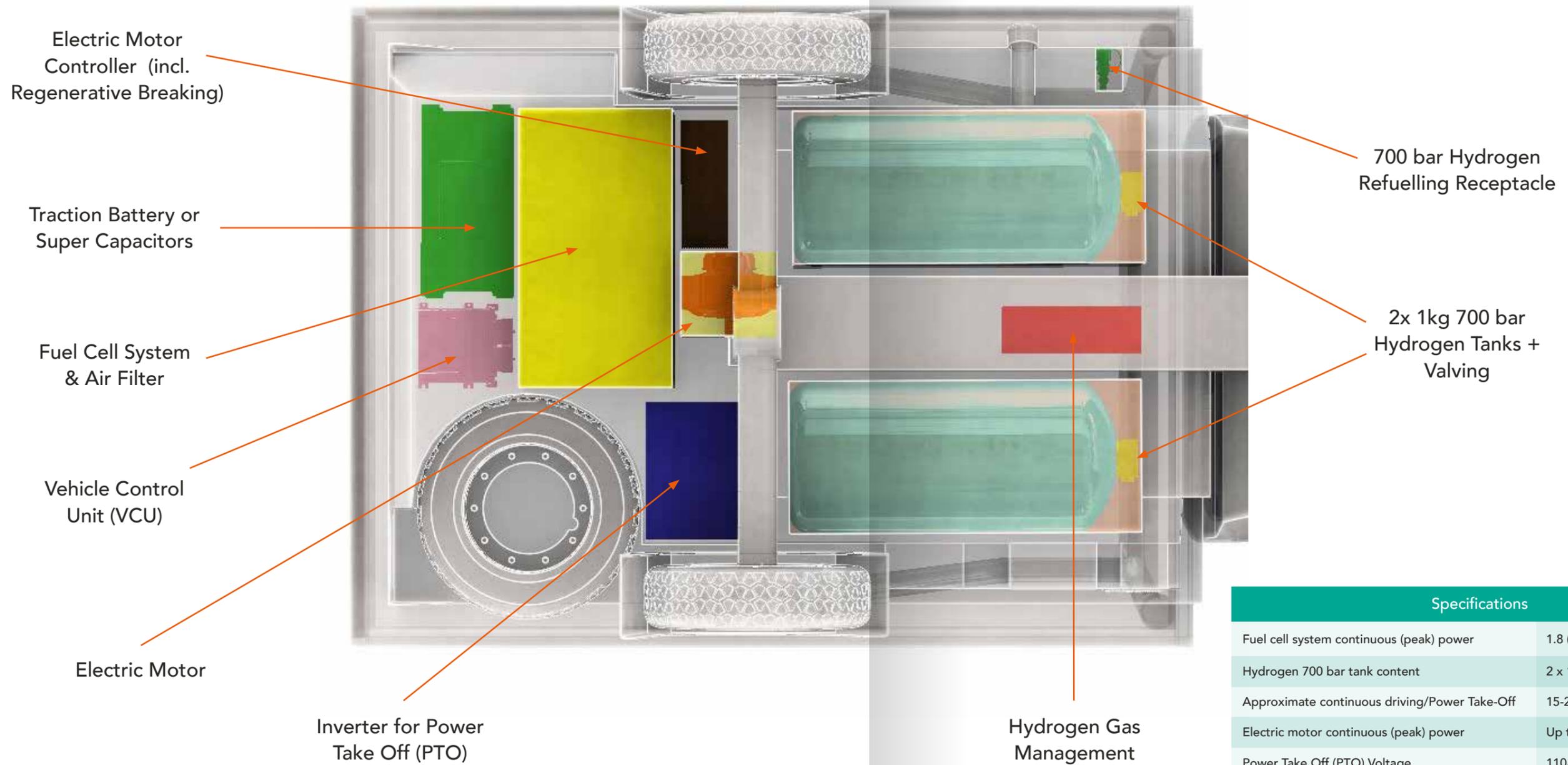
We also anticipate the use of Power Take-Off (PTO) or Vehicle-to-Grid (V2G) or Vehicle-to-Load (V2L). The tuk tuk can power a cooling unit while driving, or act as an 1800 W mobile, noise- and emission-free generator when parked. Tailored solutions for 220 Volt Alternating Current (AC) or different Direct Current (DC) options (12/24/48 V) are also available.

The diagrams below show the location of the fully sealed electric motor, motor controller, single phase inverter, vehicle control unit and the super cap. The bodywork is not compromised: there is still space for a spare wheel and no loss of ground clearance. The fuel cell components are within the dimensions of the existing chassis and protected by it.

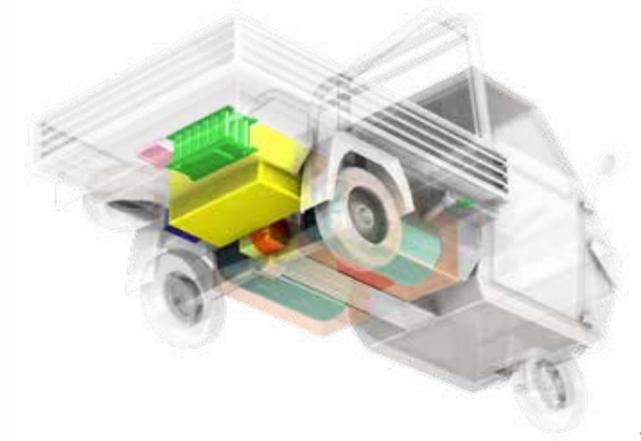
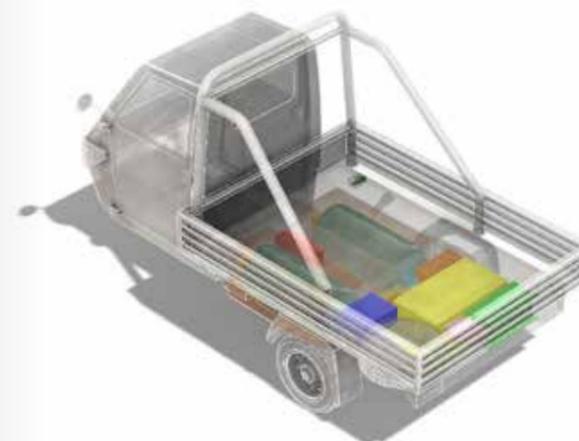
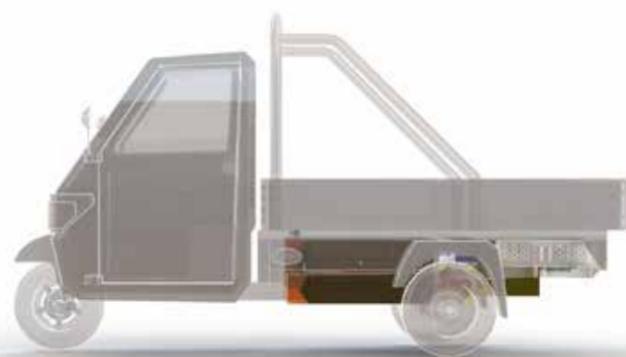




# Architecture and Layout Concept



Specifications	
Fuel cell system continuous (peak) power	1.8 (2.0) kW
Hydrogen 700 bar tank content	2 x 1 kg hydrogen
Approximate continuous driving/Power Take-Off	15-20 hours
Electric motor continuous (peak) power	Up to 10 (15) kW
Power Take Off (PTO) Voltage	110/220 VAC or 12/24/48 VDC
Traction Battery Peak Power (Energy Content)	Up to 10kW (up to 3.5 kWh)



## 6. Cooperation Proposal: One Stop Shop, More Than Just Delivering Components

Hypowa offers a commercial collaboration to develop a new hydrogen fuel lightweight transportation vehicle, bring it to existing markets and to support vehicle manufacturers in developing new markets. Hypowa can develop the hydrogen fuel cell powertrain in close cooperation with a vehicle manufacturer, to meet the manufacturer's specific requirements and needs in less than 12 months. The prototype can be a fully road-licenced vehicle ready for series production on the vehicle manufacturer's assembly line and distribution via its dealer network. In association with a vehicle manufacturer, Hypowa and our partners can also establish supply lines in less than 12 months.



### Experience and expertise for a successful project

Hypowa offers vehicle manufacturers first mover advantage as well as fastest time to market. Our highly effective and efficient engineering team has a proven track record of delivering hydrogen fuel cell powertrains for passenger vehicles and motorbikes. The powertrains' fully certified components are provided by carefully selected leading manufacturers only.

Working with Hypowa offers manufacturers the shortest time to market, top quality, and minimal development costs. It's the most effective and efficient process for bringing a hydrogen fuel cell lightweight vehicle to the market.

Grab the opportunity now!

## 7. Hypowa Ltd and Partners



Hypowa was established in 2018. It's a UK based company managed by Siegfried Huegemann and Vincent Oldenbroek. Hypowa's focus is on the development of hydrogen fuel cell powertrains for lightweight transportation vehicles.

HYPOWA cooperates with these industry partners for specialist components and services:

- **Hydrogen Gas Assembly**
  - Leading hydrogen receptacle manufacturer
  - Leading hydrogen tank manufacturer specializing in small 700 bar tanks
- **Fuel Cell System**
  - Three leading of the most innovative fuel cell manufacturers from the US, Sweden, and China
- **Electric Motor**
  - Top quality manufacturer from Europe
- **Integration Engineering**
  - Engineering company with long experience in numerous hydrogen fuel cell technology integration projects in the automotive sector

### • Technology Management

- Engineering expertise and Vehicle-to-Grid (V2G) knowledge gained from research conducted at TU Delft

### • Development and Testing Facilities - Locations

- Specialized facilities for the development of small vehicles with airfield for testing purposes

### • Customization

- Full conversion into a champagne or coffee bar, greenery maintenance, food truck, or for other business purposes

The components selected for Hypowa powertrains are proven, off-the-shelf and reliable. Our cooperation partners are chosen for their outstanding capabilities and expertise.





HYPOWA

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