

# Hydrogen or battery tractors: what potential for sustainable grape growing?

>>> Capping greenhouse gas emissions and reducing air pollution on the farm challenges the place of the diesel tractor in future sustainable vineyards. Tractors are responsible for the largest share of all CO<sub>2</sub> emissions at vineyard plot scale, mostly resulting from pest and disease management and soil maintenance<sup>1</sup>. Electric vehicles will thus be required to meet climate change reduction goals. In this article, the characteristics of battery and hydrogen electric tractors are compared, and their potential in the grapevine growing sector is assessed. <<<

## ■ Hydrogen and battery tractors

Electric vehicles are replacing internal combustion engines (ICE) as the availability of affordable petroleum reserves is decreasing and CO<sub>2</sub> emissions need to be reduced. Electric motors are highly efficient (90 % compared to 20 % for ICE<sup>2</sup>) and robust, thereby lowering maintenance costs. Most importantly, electric motors do not emit CO<sub>2</sub>, NO<sub>x</sub> or particulate matter and can be powered by renewable energy sources, such as wind or solar energy. The challenge of this technology lies in storing electricity onboard the vehicle to feed the motor. Two main options exist: battery-electric vehicles (BEV) and hydrogen fuel cell electric vehicles (FCEV). Batteries store electricity directly, while hydrogen conversion is an indirect form of storage. To generate hydrogen, electricity is used to split water molecules into hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>) via a process called electrolysis. The oxygen is released into the air, and the hydrogen gas can then be easily stored in tanks. When needed, H<sub>2</sub> can be recombined with O<sub>2</sub> from the air to form water and electricity in a fuel cell.

Each of the systems - battery and hydrogen - have their own advantages and pitfalls. Batteries can retrieve 95 % of stored electricity, which, combined with a 95 % converter and 90 % motor efficiency, yields a high "tank-to-wheel" efficiency of 81 %. However, batteries suffer from a very low energy density: a classic Lithium-ion battery can store 0.13 kWh/kg, compared to 12.7 kWh/kg for diesel<sup>3</sup>. The integration of these heavy battery packs into vehicles can be challenging, and the range of motion of BEVs is usually smaller than for conventional ICE, or even hydrogen vehicles. In other words, a 50 kW vineyard tractor with half a day of autonomy (4 h) would need a 245 kWh battery, weighing 1895 kg. The battery in the John Deere electric tractor, SESAM, shown in Figure 1, is fed by a 150 kWh battery, weighing 1150 kg. This tractor can run for one hour at full power; i.e., 130 kW. Besides its limited range, the battery of the electric tractor takes about 3 hours to fully recharge<sup>4</sup>.

Hydrogen FCEVs are not perfect either. Their efficiency is much lower: converting hydrogen to electricity has an efficiency of 60 %, and when combined with an inverter, the motor yields a tank-to-wheel efficiency of 51 %. Hydrogen gas can be stored in a tank, which is more convenient than storing electricity in a battery.



**Figure 1.** John Deere's battery electric tractor SESAM presents an enormous battery pack<sup>4</sup>.

Hydrogen molecules, however, need to be compacted. Such pressurisation involves an energy cost as well. Nonetheless, hydrogen gas benefits from a high energy density of 39 kWh/kg<sup>3</sup>. As a result, FCEVs reach bigger driving ranges without adding much weight to the vehicle, which is of critical importance for vineyard tractors to avoid soil compaction. A 50 kW vineyard tractor with half a day of autonomy needs 390 kWh of hydrogen, or the equivalent of 10 kg. Adding a tank and a fuel cell gives an estimated weight of 50 kg, 1100 kg less than the battery system. New Holland actually built a showcase fuel cell electric tractor, NH<sub>2</sub>, able to run for about 3 hours (depending on the load) on a hydrogen tank of 8.2 kg pressurised at 350 bar<sup>5</sup>. Moreover, fuelling the tractor takes about as long as fuelling diesel vehicles, saving time compared to battery tractors.

The factors involved in the choice of tractor (battery or fuel cell) do not stand alone. For the tractor to be sustainable, the entire well-to-wheel chain needs to be considered. In other words, the logistics between the energy source and its final use will determine its overall efficiency and sustainability, as well as the cost of the system.

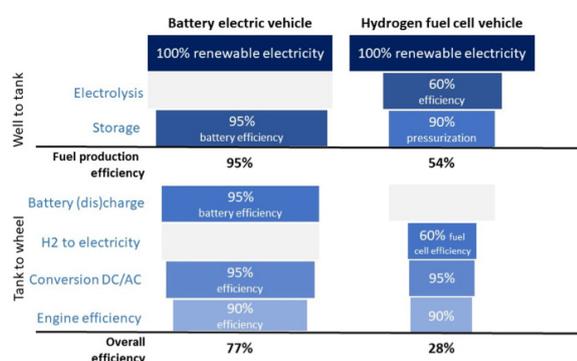
## ■ Infrastructures and well-to-wheel efficiencies

Electricity and hydrogen are energy *carriers*, vectors used to transport and utilise energy. Both can be produced from renewable or fossil energy *sources*, and are not sustainable per se. As an illustration, 95 % of hydrogen is currently being produced from fossil fuels (mostly via Steam-Methane Reforming), with associated CO<sub>2</sub> emissions<sup>6</sup>. Many factors affect the choice of an energy carrier, mainly economic, environmental and related to safety. Infrastructure also plays a role, as energy is - in most cases - not produced and used at the same place. Extensive use of ships, trucks, a dense network of pipelines and fueling stations facilitate the actual consumption of fossil fuels. An electricity infrastructure already exists, although it is not yet fully powered by renewable sources. However, for hydrogen to take off as a vehicle fuel, a comparative framework needs to be developed, which is both capital and time intensive.

The temporal scale also plays a role in the choice of the energy carrier. Batteries are known to be efficient electricity storage systems, but they are not suitable for long-term storage as they discharge with time. They are, however, very effective for day-to-day storage.

## ■ Efficiency and associated energy production

Harvesting energy from a source and transforming it into a carrier happens at a certain efficiency: the “well-to-tank” efficiency. Figure 2 compares the well-to-tank and tank-to-wheel efficiencies for a battery electric vehicle system and a hydrogen fuel cell vehicle system. The production of hydrogen from electricity and the transformation back to electricity in a fuel cell occurs at 60 % efficiency, lowering the overall well-to-wheel efficiency of the FCEV to 28 %. The BEV benefits from 77 % overall efficiency. In other words, compared to a battery electric tractor, more energy must be generated to produce the same work from a hydrogen fuel cell tractor. The following case-study highlights these differences.



**Figure 2.** Well to wheel efficiency diagrams for battery electric vehicles and hydrogen fuel cell vehicles. Adapted from InsideEVs.com.

## ■ Case study

An electric tractor and its support infrastructure need to be chosen for a vineyard in the South of France. The vineyard comprises 20 hectares of vines, for which one tractor is needed for approximately 800 hours per year. The maximal power required for work on the vineyard is 100 kW, such that the maximum yearly electricity demand by the tractor is 80,000 kWh. In order to be self-sufficient, the vineyard managers decided to produce this electricity on-site using photovoltaic (PV) panels. Solar energy is readily available at the location with 2000 hours of sun per year. Moreover, PV panels produce most of their electricity in summer, which coincides with the period in which the tractor is most needed. For this system, the company can choose between a battery-electric system and a hydrogen electric system. In the first case, a BEV type of tractor is used in combination with a stationary storage battery on-site. In the second case, a hydrogen fuel cell tractor is chosen, together with an electrolysis unit and a hydrogen storage tank at the farm.

An average PV panel of 1 m<sup>2</sup> produces approximately 100 W<sub>peak</sub> of electricity. With 2000 hours of sun per year, a 1 m<sup>2</sup> solar panel produces 200 kWh per year. The area of photovoltaic panels needed to supply the tractors with electricity differs per system. The overall efficiency of the battery-electric process is 77 %, which results in a PV area of 519 m<sup>2</sup> needed to power the BEV tractor. Accounting for the losses from the hydrogen route, 1429 m<sup>2</sup> of PV panels are needed to power the 100 kW FCEV tractor, or 2.75x the size needed for a battery system.

## ■ Stationary storage: sizing and costs

If the hydrogen system does not stand out for its efficiency, it is still competitive as a result of its size and the costs involved. For the above-mentioned vineyard, a stationary storage system is needed to cover up to 3 days of autonomy (the equivalent of 8 hours) at a maximal wattage of 100 kW. Given the storage and tank-to-wheel efficiency shown in Figure 2, the hydrogen storage system would need a capacity of 5,198 kWh, the equivalent of 5.5 m<sup>3</sup> and 131 kg of hydrogen. The yearly cost of the electrolysis system (cleaning H<sub>2</sub>, drying, compressing and maintenance) amounts to 24,500 €<sup>7</sup>. In comparison, a stationary battery storage would require a capacity of 3,110 kWh, resulting in a higher storage to engine efficiency. A Tesla power wall has a capacity of 13.5 kWh for 0.12 m<sup>3</sup> and 114 kg. In other words, a 3-day autonomy system would require 230 Tesla power walls, which means 27.8 m<sup>3</sup> and 26,264 kg of batteries. Hence, the volume needed for a battery storage system is 5x that needed for a hydrogen system and its weight 200-fold! Moreover, the yearly cost of the Tesla battery stack reaches 137,770 € per year, 5.5x the price of the electrifying system<sup>8</sup>. The cost of the tractor itself should be added to the cost of this stationary system for a thorough comparison. The initial cost of an average fuel cell electric vehicle is currently higher than its battery alternative, but the costs are predicted to converge by 2030<sup>9</sup>.

## ■ Conclusion

Battery electric and hydrogen fuel cell tractors have the potential to reduce CO<sub>2</sub> emissions of vineyards, if the electricity used to drive them is produced from sustainable sources. Battery systems are very efficient, while hydrogen systems are more compact and lighter. Choosing an option will depend on local infrastructure, available space and future development of costs. ■

Lotta B. van Leeuwen

1 Adoir, E., Penavayre S., Petitjean T., and de Rességuier L. “Study of the viticultural technical itineraries carbon footprint at fine scale.” *BIO Web of Conferences*, vol. 15, p. 01030. EDP Sciences, 2019.

2 US Department of Energy (US-DOE). “All-Electric Vehicles.” *Fueleconomy.gov*. <https://www.fueleconomy.gov/feg/evtech.shtml>, 2017.

3 MacKay, D. “Fluctuations and Storage.” *Sustainable Energy-without the hot air*, p. 199. UIT Cambridge, 2008.

4 Future Farming. “Gradual switch from diesel to gas and electricity.” *Futurefarming.com*. <https://www.futurefarming.com/Machinery/Articles/2018/12/Gradual-switch-from-diesel-to-gas-and-electricity-373914E/>, 2018.

5 *New Holland Agriculture*. “New Holland presents the first NH2™ hydrogen powered tractor ready to go into service on a farm.” *agriculture.newholland.com*. <https://agriculture.newholland.com/eu/en-uk/about-us/whats-on/news-events/2011/nh2>, 2011.

6 *International Renewable Energy Agency (IRENA)*. “Hydrogen from renewable power, Technology outlook for the energy transition”, p.13, Abu Dhabi, 2018.

7 Lichner C., “Electrolyzer overview: Lowering the cost of hydrogen and distributing its production.” *pv-magazine-usa.com*. <https://pv-magazine-usa.com/2020/03/26/electrolyzer-overview-lowering-the-cost-of-hydrogen-and-distributing-its-productionhydrogen-industry-overview-lowering-the-cost-and-distributing-production/>, 2020.

8 Marsh, J. “Tesla Power Wall: a complete review.” *Energysage.com*. <https://news.energysage.com/tesla-power-wall-battery-complete-review/>, 2020.

9 Morrison, G., Stevens, J. and Joseck, F. “Relative economic competitiveness of light-duty battery electric and fuel cell electric vehicles.” *Transportation Research Part C: Emerging Technologies*, 87, p.183-196, 2018.