E-Mobility Challenges of Automotive Lithium-ion Batteries and Fuel Cells

By Lynn Walford

It's clear we are on the verge of a great transformation in the automotive industry from internal combustion engines to electric vehicles. How mobility will be electrified depends on many factors and what electric choices automakers and consumers make as well as what proves to be the most sustainable.

"Almost all the electric vehicles on the road today use lithium-ion batteries," said Dr Greg Less, technical director of the U-M Battery Lab, University of Michigan, Ann Arbor, where automakers and Tier 1 suppliers can build and test lithium-ion batteries with technical support. He notes that Lithium-ion batteries are the best choice for electrification of drivetrains owing to their energy/power density, life and reliability.
"Lithium-ion offers the ideal balance of reliability, safety, life cycle, energy density and thermal performance," reported Paul Beach, president, Octillion Power Systems, a Tier 1 supplier of module battery pack systems who works with all the major lithium-ion battery suppliers, adding: "It's pretty damn reliable technology."

The architecture of all lithium-ion cells is basically the same – the cells have a positive and negative electrode, an ionic conductive liquid and a plastic separator sheet that prevents the positive and negative electrodes from shorting. When cells show different capacities or voltages, it is down to changes in the chemistry of the components described above. At the pack level (an assembly of individual cells), engineers are able to increase both the voltage and capacity of the total pack based on the series or parallel connections made between the individual cells says Less.

Lithium-ion batteries currently on the market can handle very cold temperatures, -20 degrees Celsius or lower. Heat, however, can create problems and, therefore, automotive lithium-ion battery packs need to be cooled either with air, liquid, or in some advanced research, phase change materials. If lithium-ion batteries get too hot, they can experience what is called 'thermal runaway'. Thermal runaway is a situation where the chemical components of the battery begin to breakdown and, as they do, they generate more heat which speeds up the breakdown process, causing a dangerous build-up of heat and gasses. In this situation, batteries can catch fire or even explode. "No technology is perfect if you abuse it enough bad things can happen but you can build in multiple redundancies to mitigate risk," said Beach.

This article was created in association with TU-Automotive E-Mobility Detroit 2018 (6-7 June, Novi). This show is co-located with TU-Automotive Detroit 2018 (6-7 June, Novi) https://automotive.knect365.com/tu-auto-detroit/

Although there are safety measures built into lithium-ion battery packs, less notes that there could be improvements made for more safety at both the chemical component and the engineering levels.

Lithium-ion batteries degradation and loss of power

Lithium-ion batteries degrade over time reducing the distance-charge battery pack capacity. However, research shows that the battery capacity loss is keeping with what the manufacturers expected for Nissan LEAF and Tesla models says Tom Saxton, chief scientist for Plug-in America. “Electric vehicle drivers, like the better driving experience, fast acceleration, lower cost to operate and convenient charging,” said Saxton who says that even with battery capacity loss on his 2011 Nissan LEAF, he can still travel 50 miles (80.5 Km) on a charge, noting that 78% of the US population drives less than 40 miles (64.37 Km) a day.

“Lithium-ion batteries are like human beings they have an expiration date many factors contribute to the expiration date and we're not always sure when it's going to happen,” said Beach. “Or, you can compare them to the batteries in your smartphone after a while they don't keep a charge and they have to be replaced.”

What happens to the batteries when they are removed from cars? They can be reused or recycled. Toyota recycles batteries and is testing second-life use of batteries. The company works with Kinsbursky Brothers to recycle hybrid and electric vehicle batteries says, David G. Absher, senior manager environmental sustainability at Toyota Motor Company North America (TMNA). An example of the Toyota re-using batteries is at the at the Buffalo Ranch field campus in Yellowstone National Park. The facility is eleven miles from the electric grid. Previously, propane and diesel were burned to run electric generators.

Some 67,900 KwH of yearly energy from solar power and hydro power generated in a nearby creek is now stored in a 85KwH configuration of former battery packs from Toyota Camry hybrids to power the station. Not only is there less pollution and particulate matter from the generators, “It is lot quieter without the noise from the generators,” said Absher.

Solid state lithium-ion batteries

Although Beach and Less don’t see mainstream mass availability of solid-state batteries in the near future, some companies believe improvements can be made to lithium-ion batteries by changing the liquid into a solid-state material. Automotive designer disruptor, Henrik Fisker, who designed the BMW Z Series, the Aston Martin DB9 and the Fisker Karma hybrid, recently patented solid-state batteries for use in the Fisker Emotion luxury sports electric vehicle.

“We chose to use solid state batteries in the Fisker EMotion (going into production in late 2019) because of the batteries’ greater range capacity, faster charging time and higher energy density. In addition, these batteries can be charged many more times than traditional EV batteries, which wear out after a few years,” said Fisker.

Fisker says, a battery scientist working in-house at Fisker Motors, Dr Fabio Albano, a University of Michigan-Ann Arbor PhD in Materials Science, is developing a way to manufacture solid state batteries for mass production. “It’s a challenging engineering process for sure, but solid-state batteries will be the future of smartphones, consumer electronics, EVs and more within a few short years,” said Fisker.

Fuel cell technology

Another way to electrify vehicles is through fuel cell technology the uses compressed hydrogen gas. “A hydrogen fuel cell vehicle is an electric vehicle that has its power plant onboard,” said Absher. The electricity is made from hydrogen and oxygen in the air through an electrochemical reaction. The only emission is water vapour.

“The Hyundai Nexo in the US holds 6.3 kgs of compressed hydrogen that is expected to equal approximately 370 miles (609 km) range and the usability is very similar to gasoline vehicles,” said Jerome Gregeois, senior manager eco powertrains, Hyundai America Technical Centre. “Fuel cell electric vehicles offer the advantages of electric vehicles overall with a very quick response and instant access to torque. The electric motors are almost identical for hydrogen fuel cell and batteries.”

Fuel cells offer some advantages over battery electric vehicles. In cold weather, battery electric vehicles drain battery power very quickly to heat the cabin. In fuel cell vehicles, the coolant fluid that surrounds the stacks that convert the hydrogen into electricity heats up and can be used to heat the vehicle. Hyundai has tested the Nexo in Alaska and Sweden and found that it has great quick starts even in freezing climates and maintains its high mileage. Another positive factor is that the hydrogen weighs than same as distance range battery packs and thus reduce the overall weight of the vehicles.

Hydrogen gas, however, still labours under the reputation from the Hindenburg disaster of 1937 where the airship exploded in flames while docking in New Jersey, in the US. “There's a lot of misinformation about the Hindenburg disaster and the use of hydrogen. It is not the hydrogen that caused the burning problem, the skin of the dirigible was highly combustible,” said Keith Wipke, programme manager, fuel cell and hydrogen technologies National Renewable Energy Laboratory Hydrogen fuel cell vehicles are very safe. Hydrogen is stored strong high-pressure tanks made of carbon fibre that can hold 1,000 pounds per square inch of

pressure says Wipke. Gregeois notes that the hydrogen tanks in the Hyundai Nexo have ¾-Inch (9mm) to 1-Inch (25.4mm) thick walls that have long durability. When exposed to fire, the hydrogen will quickly vent out of the tank.

“Hyundai customers who live by fuel cell stations are very impressed with the dependability reliability, packaging and driving of Hyundai fuel cell vehicles,” said Gregeois who notes that it takes about the same to fill hydrogen tanks as it does gas tanks. In order for hydrogen vehicles to be sold and deployed there must be a network of fuelling stations says Wipke.

In the US, fuel cell stations and ownership are growing. There are approximately 3,000 hydrogen fuel cell vehicles in California with about 32 stations notes Wipke. California Governor Brown announced recently ordered the building 200 stations across California by 2025. The state of California is also supporting the use of fuel cells for the transportation especially at the Port of Los Angeles, a major transportation hub, where big rig tractor trailer class 8 trucks contribute to extremely poor air quality.

To help reduce air pollution at the Port of Los Angeles, Toyota launched Project Portal fuel cell vehicles including a fuel cell class 8 truck travelling through the port are powered by hydrogen produced from biowaste. Biogas is very dangerous to the atmosphere and is 20 to 27% more destructive than other greenhouse gases. Using the biowaste to create hydrogen helps decrease the effects of the biogases, says Absher.

The future of e-mobility and electric cars

There is great hope for what electrification can do for the automotive industry. “While still at early stages of eco vehicles at Hyundai, we are offering electric plug-in, hybrid, hybrid plug-in and fuel cell vehicles to see how the market will respond,” said Gregeois.

At Toyota it’s not about what method of electrification is better. “We are taking a portfolio approach to sustainability, focusing on our 2050 Environmental Challenge,” said Absher, “Toyota wishes to exist in harmony with nature, do no harm and make the world a better place.” Lithium-ion batteries could mean greater profits under the right conditions. “When you couple electric vehicles with ride-sharing services and artificial intelligence/ autonomous driving you can change the world. With electric vehicles the more you drive them the more money you make and the higher pay off and more ROI. In the long run electric vehicles will save more money than internal combustion engines,” predicted Beach.