Electric cars: It's not just about the battery, it's an energy issue, too

June 22 2022, by Behrooz Bahrani and David Klink

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Soaring fuel prices are pushing more Australians than ever to consider electric vehicles. Modern electric cars can drive for hundreds of kilometers, with short charge times that align perfectly with a coffee break on longer trips.

This increased attention will turn the spotlight on batteries, as manufacturers race for better, lighter, range-extending power sources.

But there's more to an electric car than the battery. This shift from internal combustion engines means a redesign of the fundamental mechanical systems we've refined for more than a century. This isn't just a battery problem—it's an energy problem, too.

Power in, power out

Let's talk about power, which, to put it as simply as possible, is what pushes things forward. Unlike a stationary appliance or machine, however, vehicles must transport the energy source required for their motion.

Essentially, every time you accelerate your car, you also must accelerate the source of energy used to make it move.

This is also known as the rocket problem, because space rockets need an enormous amount of power to escape gravity. That needs an enormous amount of fuel, which makes the rocket heavy—increasing the amount of power required to lift it. And so on.

The solution to the rocket problem is fuel density—you want the most bang (power) for your buck (weight), which is expressed as megajoules per kilogram. Petrol and other fossil fuels are extremely energy-dense—octane boasts an incredibly high 48MJ/kg, compared to an optimistic 1MJ/kg for lithium-based batteries.

But fuel density is only part of the picture. All that power goes into the engine, which turns the axle, which spins the wheels. Engineers refer to those three parts—power source, engine (or electric motor and inverter), and gearbox—as the powertrain.

With a combustion engine, energy is stored, converted to motion, then dissipated as heat, either steadily through drag and friction, or sharply during braking. Additionally, combustion engines are very inefficient, typically only utilizing 20–30% of the energy stored in the fuel, with the rest of it being dissipated as heat. Compared to a combustion engine, an electric powertrain can be more than 95% efficient.

Electric engines, on the other hand, offer different possibilities—such as capturing that released energy through regenerative braking and reusing it—that change the traditional power in, power out equations for transport.

So, when we reduce weight or improve efficiency of any part of an electric car, we're increasing its range with a compounding effect.

Powertrains (It's not a transformer)

To convert energy-dense fossil fuel into motion requires an incredibly complex system, precisely controlling thousands of explosions for millions of cycles using an extremely flammable fuel supply.

For more than 100 years, developments have chipped away at these engineering challenges to produce safe, cheap and efficient vehicles.

A smaller, lighter and more efficient powertrain allows for a much lighter energy store, as less energy is required to reach a given speed. This means physics favors designs that store energy in light and dense forms, and reduces the carried mass as it's consumed.

While the energy store is clearly a critical component of any vehicle

—and next-generation innovations in cell construction and lithium sulfur chemistry will further improve batteries—the power conversion system still plays a crucial role. In fact, it becomes relatively more important as energy storage improves.

Feedback effects are significant in electric vehicles, so even in designs with heavy batteries there's still significant value in increasing efficiency and decreasing mass. One percent of efficiency is equivalent to 1% of the battery pack, which carries a significant amount of mass and cost to the vehicle.

Electric powertrains use semiconductors and magnetic motors to convert electrical energy into motion, which makes power conversion and distribution a key challenge.

Lighter, smaller and more efficient motors and controllers within the powertrain reduce cooling requirements, internal losses and overall vehicle mass, which increases the vehicle's range.

And unlike a combustion system, expended energy is often reused multiple times, as the electric motors can recover energy through regenerative braking, rather than wasting it as heat in the brake disks.

This means the same powertrain efficiency is effectively applied several times, as the vehicle accelerates and decelerates. This makes the efficiency of the powertrain even more critical.

Electric motors can also be powered by a source other than a battery, such as hydrogen fuel cells that consume hydrogen produced in a number of ways, from natural gas to algae biomass.

What comes next?

Many people are working on these problems, including my colleagues and I at the Monash Energy Institute. My research aims to use new manufacturing methods and technology to create the next generation of cheap, light, efficient motor controllers and inverters.

Electric vehicles are inherently complex systems, but their performance can be significantly improved with intelligent system-level design.

For example, a motor and controller developed for a hydrogen-fuel cell vehicle in a truck would be extremely different to a motor developed for a battery-powered bus—despite very similar system mass and power requirements.

A truck typically travels at high speeds for long periods of time, whereas buses tend to be more stop-start. This drastically changes where the motor should be optimized to minimize energy loss.

A pricing issue

The energy source also changes the price of future upgrades. Hydrogen systems have extremely high upfront costs in expensive and heavy fuel cells and components—but as the cost of producing hydrogen goes down, it will be much cheaper to add power to a hydrogen engine than a battery-powered one.

Right now, we're standing somewhere near the start of the hundred-year design process that eventually gave us the modern combustion engine (albeit with all of the advantages of modern technology).

But the vehicles of the future won't just have batteries where the petrol tank used to be—it's a whole new world of powerful movement.

Provided by Monash University