THOUGHT PIECE

# How do we make Electric Vehicles Genuinely Sustainable?

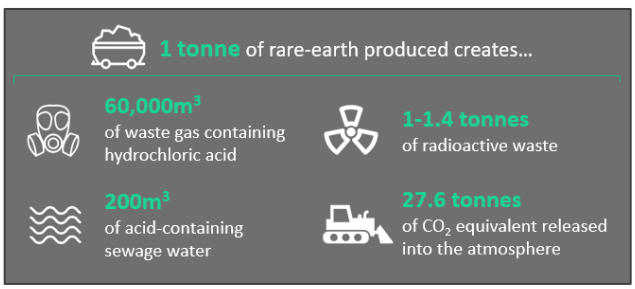
**There is no doubt that electrification is key to addressing climate change. Yet it is not as simple as merely implementing conventional infrastructure; the technologies that are developed must be more sustainable to manufacture, use and recycle than those they replace.**

At Advanced Electric Machines we have made it our mission to design and build the most sustainable electric motors on the planet, and supply them around the globe from our facilities in the UK. But how do we aim to do this? Here, we will run through the situation we're faced with, and we will demonstrate what drives us to achieve our goals, as well as laying out how we plan to make this a reality.

## THE MESSY BUSINESS OF RARE EARTHS

If you've followed our work over the past couple of years, especially during last year's COP26 summit, you'll know that we're not afraid to draw attention to the volatile world of rare-earth metals. In fact, we've been banging the drum of discontent ever since we started Advanced Electric Machines in 2017.

As a bit of background, most electric vehicles on our roads today use permanent magnet motors. This is because it's a proven technology and was, until now, thought to be the most efficient means of powering a vehicle. The issue we have with permanent magnet motor technology is that each unit uses some 2kg of rare-earth magnets.




Ultimately, however, things need to change – there are grave costs to using rare earth metals. The mining of rare earth metals is, in short, damaging to the environment and harmful to those involved. For every single tonne of rare earth metals mined, it's been reported that up to 1.4 tonnes of radioactive waste can also be produced. Mining 12 tonnes can generate enough acid-containing sewage water to fill an Olympic-sized swimming pool. If you compare rare earth mining to steel production, mining rare earths creates over 11 times more $CO_2$ than every tonne of steel manufactured.

It's not just the social and environmental issues of rare earth mining that need to be considered. As their name suggests, rare earth metals are only available in low quantities globally due to the highly complex process involved in their extraction. And scarcity, unsurprisingly, translates into a premium price point and a volatile trading market. From February 2020 to February 2022, the cost of neodymium has risen by 312%, with one kilogram now costing more than $236, compared to $42 just two years ago. How can vehicle manufacturers scale their models with fluctuations as dramatic as that?

## REMOVING RARE EARTHS

The only way to eliminate this problem is to eliminate the rare earths in motors entirely.

It's hard, however, to criticise the practice when it seems that no viable alternative is available. That's why we've spent several years developing our own semi-sinusoidal motor technology that does away with the rare earth magnets that limit an electric motor's scope.

By removing the magnet in our design, Advanced Electric Machines motors can spin twice as quickly as a permanent magnet motor. This makes it up to 12%

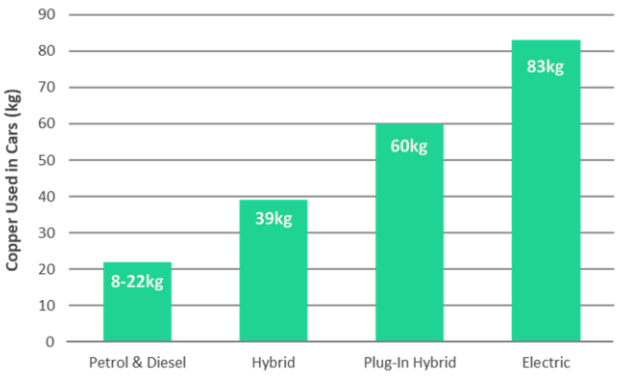
more efficient and kinder to the environment. We can also exchange the copper windings for a compressed aluminium design. It means that our motor is made almost entirely out of steel and aluminium – both of which are easy to recycle through existing channels.

Thankfully, we're starting to see the awareness around rare-earth mining grow. We've seen it not only amongst the major automotive manufacturers and their engineers, but with the rising number of environmentally conscious product buyers, too. We all have an appetite to go green, but it will be all in vain if we don't remember our duty to do so sustainably.

## COPPER – WHERE THINGS STAND

This desire to become increasingly sustainable is an excellent and highly necessary initiative, but it hasn't come without difficulty.

One of the greatest challenges we are beginning to understand the true scale of is the growth in demand for raw materials; from neodymium to cobalt to copper. Copper is central to the new technologies being created to meet the world's environmental goals, with The Institute for Human Rights and Business predicting there will be a 300% rise in demand for copper by 2050. This equates to 60 million tonnes of the metal being required every year, but at what cost?




## THE COSTS OF COPPER

As demand increases, so does the environmental, human, and financial cost. Up until now, the demand for copper has remained at a manageable level. The capacity to recycle the copper in circulation to meet demand has been hugely beneficial, as it has reduced the need to mine for it. Copper mining has a known detrimental impact on people's health and the natural environment, leading to land degradation, deforestation, and water and air pollution. Unfortunately, with demand on the rise, recycling the existing copper will no longer be sufficient, leaving no option but to greatly increase the levels of mining.


Acid waste water from copper mine, Portugal

We must also consider the financial cost of copper. In March 2022, prices spiked for the third time in less than a year, as copper stocks approached historically low levels of just 200,402 tonnes – that does not even cover three days of global consumption at the current rate. As the world risks 'running out of copper', CNBC reports that prices could rise to $20,000 per tonne in the next five to ten years, which, when combined with the expected rise in demand, begins to paint a very costly picture.

## COPPER AND THE ELECTRIFICATION REVOLUTION

Since Michael Faraday discovered electromagnetic induction using copper coils over 200 years ago, copper has been the metal of choice for an electrical conductor. It is, therefore, no surprise that copper is at the very core of the electric revolution. Electric vehicles are key in the global drive towards net-zero, but their batteries, motors, electrical components and even charging equipment all use copper to function.

In electric vehicles, traction motors contain copper coils that an electric current passes through to

generate mechanical energy that will spin the motor and propel the vehicle. This contributes to the average battery-electric car containing 83kg of copper, which is four times that used in petrol and diesel cars.

With governments across the world setting deadlines to ban the sale of petrol, diesel, and even hybrid vehicles, battery-electric vehicles will begin to monopolise the market. According to the Financial Times, if electric vehicle sales hit the expected 40% increase by 2030, around eight times more copper will be required for annual vehicle production.

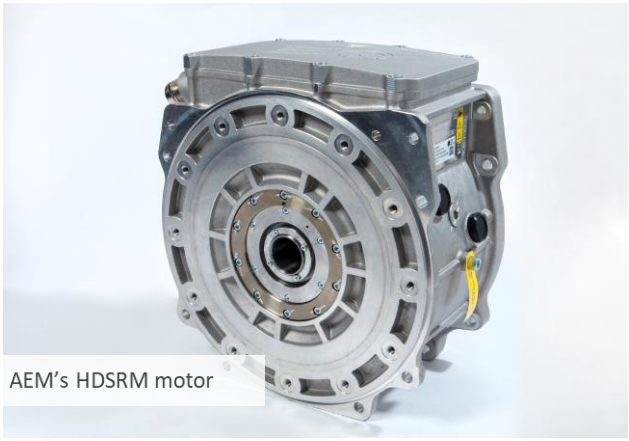
The argument goes that copper is one of the most highly recycled metals, with around two thirds of all copper mined still being used today. However, demand has never been this high, and the copper in electric motors is extremely difficult and expensive to extract for recycling, which means the motors, and the copper in them, often just ends up in landfill. As EV production ramps up, so does the amount of copper being demanded but not recycled. Unless an alternative is found, more copper will have to be mined, but is this really a sustainable future?

## A DIFFERENT FUTURE

We see a different future. As experts in designing and manufacturing the most sustainable electric motors, we have developed an alternative technology that will allow us to remove copper from our next generation motors. Advanced Electric Machines has designed highly compressed aluminium windings to replace traditional copper coils that maintain the performance characteristics of the electric motors, but in a more efficient and sustainable way.

It is undeniable that copper will have a huge role to play in the future of the electric revolution, and required supply will need to greatly increase to meet the demand. Nevertheless, at Advanced Electric Machines we are always striving for the most sustainable solutions.

## AEM – OUR TECHNOLOGY EXPLAINED



AEM's HDSRM motor

As has been established, electric vehicles are not without their drawbacks. By now, you will be well aware that recycling issues and the modernisation of rare earth mining practices are big obstacles that need to be overcome in order to ensure a sustainable transition to implementing electrified transport. To compound this, any alternative solutions put forward are challenged with the need to be at least as powerful, torque dense and efficient as existing technologies.

The electric motor is a critical element of the EV powertrain, and must not be overlooked in the search for greater sustainability. For years now, the conventional permanent magnet machine has been the motor of choice for automotive manufacturers, and has been regarded as the most effective solution for electric vehicles. We have already established the environmental issues that this technology brings to the fore, and this has not been lost on vehicle manufacturers, who are now actively seeking rare-earth free alternatives.

The problem with this type of motor is not just environmental, but its relative cost and complexity. However, as some manufacturers move to rare-earth

free options, they are finding themselves compromising efficiency and performance, and in some cases, their solutions are even less sustainable due to their increase in size and the increased amounts of alternative materials they use.

Patented compressed aluminium windings

Step forward Advanced Electric Machines. Our solution takes away these concerns, removing the problematic rare earth magnets from the motor design and simultaneously improving efficiency, increasing performance and lowering cost.

How? Well, we've replaced the rotor magnet with electrical steel, and can swap the copper coils in the stator with highly compressed aluminium windings. As we've established, this has a hugely positive environmental impact, as our choice of materials means our motor is fully recyclable at end-of-life, leading to less e-waste.

The benefits of removing magnets from the motor also mean that operating risks are reduced, with no chance of short circuit currents or the high voltage spikes which can be experienced with permanent magnet motors. We can therefore ensure safer failure modes should something go wrong. In addition, our magnet-free motors have no risk of demagnetisation, as temperatures increase at higher rotational speeds, which allows for our motors to run much faster, whilst also enabling a simpler thermal management system for the vehicle.

## THE BENEFITS

In terms of cost, it is expensive to use rare earth magnets in motors, with each motor containing at least $200 worth of magnets alone. The volatile supply of neodymium – the main rare earth metal used in electric motors – also means there is significant scope for the price to increase much further. Put simply, vehicle manufacturers will find it difficult to plan the scale-up of electric vehicles in the numbers required when the cost of a key component can be so volatile.

And then there's package efficiency. The faster a motor spins, the more power dense it can be. Typically, this faster spin will lead to problems with rare earths, but our motor is, of course, a little bit different. Without magnets, we can make the motor spin twice as fast, making it easier to package and lighter in weight. The fact that our motors are inert when not being driven enables the vehicle to coast. This has led to an increase in efficiency of up to 12% being reported by our customers over conventional permanent magnet motors throughout a typical vehicle drive cycle.

As you can see, our solution solves many of the problems that are found in producing electric motors. In order for electric vehicles to be as sustainable as possible, change needs to be embraced, and if it is, then a truly green future can be a reality right now.

Advanced Electric Machines