Electrifying!

Jonathan Welch reports on a German company which is re-powering mid-life diesel buses with electric drivelines

Electric buses have moved from being a novelty to being almost the norm over the last decade. The technology is no longer new or unusual, and most, if not all the major manufacturers have electric city buses in their portfolio. But what about all those diesel buses out there, which still have a lot of life left in them? And what about the operators or cities whose budget won't stretch to meet the high initial cost of brand new electric buses?

German company e-troFit is investing significant time and money into an alternative solution: re-powering existing mid-life buses with electric drivelines, helping fleet operators to reach their zero-carbon goals faster and at lower cost. In the UK, there have been examples of this on a small scale, including the re-powering of open-top double-deckers for Transdev's City Sightseeing York operation. However, e-troFit has much larger ambitions, and has developed its first series-ready solution for the Mercedes-Benz Citaro, with others to follow to allow conversion of the main types of

e-troFit's first prototypes were based on the first generation Mercedes-Benz Citaro. ***E-TROFIT***

vehicles available in the European market. We spoke to e-troFit's CTO Dr Matthias Kerler and Head of Sales Robert Reisenauer find out more about the company and what it can offer to operators on the road to electrification.

Starting small

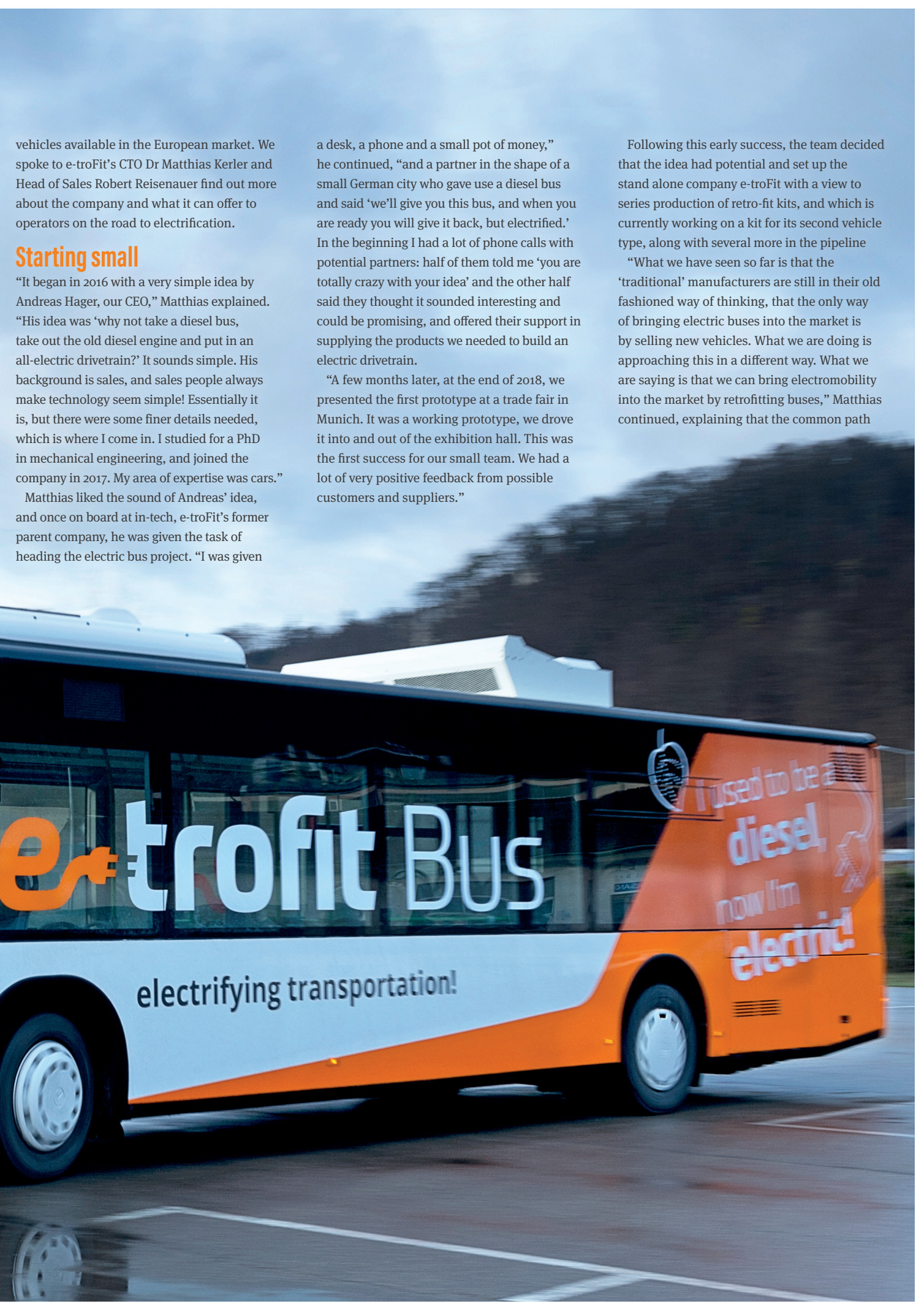
"It began in 2016 with a very simple idea by Andreas Hager, our CEO," Matthias explained. "His idea was 'why not take a diesel bus, take out the old diesel engine and put in an all-electric drivetrain?' It sounds simple. His background is sales, and sales people always make technology seem simple! Essentially it is, but there were some finer details needed, which is where I come in. I studied for a PhD in mechanical engineering, and joined the company in 2017. My area of expertise was cars."

Matthias liked the sound of Andreas' idea, and once on board at in-tech, e-troFit's former parent company, he was given the task of heading the electric bus project. "I was given a desk, a phone and a small pot of money," he continued, "and a partner in the shape of a small German city who gave use a diesel bus and said 'we'll give you this bus, and when you are ready you will give it back, but electrified.' In the beginning I had a lot of phone calls with potential partners: half of them told me 'you are totally crazy with your idea' and the other half said they thought it sounded interesting and could be promising, and offered their support in supplying the products we needed to build an electric drivetrain.

"A few months later, at the end of 2018, we presented the first prototype at a trade fair in Munich. It was a working prototype, we drove it into and out of the exhibition hall. This was the first success for our small team. We had a lot of very positive feedback from possible customers and suppliers."

Following this early success, the team decided that the idea had potential and set up the stand alone company e-troFit with a view to series production of retro-fit kits, and which is currently working on a kit for its second vehicle type, along with several more in the pipeline

"What we have seen so far is that the 'traditional' manufacturers are still in their old fashioned way of thinking, that the only way of bringing electric buses into the market is by selling new vehicles. What we are doing is approaching this in a different way. What we are saying is that we can bring electromobility into the market by retrofitting buses," Matthias continued, explaining that the common path



The engine bay is re-purposed to house the batteries. ***E-TROFIT***

for European buses of being bought back by the manufacturer at the end of contracts and sold abroad, often to Eastern Europe or Africa, will no longer be sustainable against the background of electrification.

Adaptability

"This is where we come in. We have a basic battery-electric drivetrain kit which we are planning to adapt for many different bus models. There is always a little bit of work to make it compatible with different bus types and brands. We are also planning retrofit kits using hydrogen fuel cells, which we will deliver in the next few years.

"We identified that there are not enough zero-emission commercial vehicles in the market to fulfil the climate change goals in the coming years, and that OEMs are too slow in their transformation from producing conventional vehicles to producing zero-emission vehicles, and that there are still a lot of existing vehicles in the market. It would not be sustainable for everyone to buy new vehicles. We decided we could change the circular economy of build-use-recycle to build, use, retrofit and recycle to extend the life cycle of existing vehicles."

Matthias highlighted that many bus manufacturers also have car backgrounds, a market in which the accepted method to introduce new technology is by selling new products. He likened the bus industry more to the rail industry, where it is the norm for trains – which have a much longer life-cycle than cars – to be stripped and refurbished after a set time rather than replaced, to bring them back up to the expected standard. A refurbished vehicle might be an old shell, Robert pointed out, but once it has been refurbished then it has the latest technology on board, as well as the atmosphere of a new bus in the passenger area.

"Of course, there will be corrosion after years of service but you can repair that," continued Matthias, highlighting the amount of resources needed to produce a new shell compared to refurbishing an existing one and the increasing importance of sustainability.

Cost advantage

No matter how sustainable a product is, somewhere along the line the financial aspect will always be important. I asked about the cost benefits of retrofitting over buying new. "The e-troFit solution costs around €320,000 to €350,000", explained Robert, "whereas a new electric bus costs around €550,000. It is important to note that we are not using cheaper or lower quality components than a new electric bus. We are using the same suppliers as bus manufacturers." The €30,000 price bracket reflects the amount of refurbishment required beyond simply installing the new driveline, depending on the initial condition of the vehicle. Germany's Clean Air 2017-2020 programme made available up to €350 million for the electrification of public transport, which included the option of retrofit solutions.

According to e-troFit's figures, a new diesel bus with a purchase cost of around €250,000 will have a total cost of ownership (TCO) of

Dr Matthias Kerler

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Robert Reisenauer

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E-TROFIT can also supply the charging infrastructure. ***E-TROFIT***

€814,000 after 10 years' service. A retrofitted bus with an electric driveline would cost €670,000 over the same period of time. A new electric bus would have broadly the same operating costs, but with the additional €200,000 initial cost. After around 5.5 years, using e-troFit's figures, the TCO of the retrofitted bus would fall below that of the diesel bus.

"From a total cost of ownership point of view, you won't find a more cost-efficient solution than ours today," continued Robert.

Matthias pointed out that there is no technical limit on the age of buses which can be retrofitted. "You could even electrify an oldtimer if you wanted to," he said. Robert explained that the first buses the company converted were 17-18 year old Mercedes-Benz Citaros, which had not been in excellent condition when they arrived but thanks to thorough refurbishment by e-troFit's partners who specialise in vehicle refurbishment it was possible to return the bus to a state where it feels like a new bus. "A driver won't feel like he is driving an old bus. He will be driving the latest technology, in a framework which is in good shape because it has been refurbished by an expert. We want to work together with experts in vehicle refurbishment and maintenance, as well as vehicle production," said Robert, hinting at a possible future route for expansion and development of the product on offer as a 'ready to go' package available to bus manufacturers.

Robert explained that the company looks for partners which are quality certified, such as ISO9001. "Our team are experts in software engineering, electrical engineering and parts of the mechanical engineering, the technology side comes from us but the actual conversion work is done by external partners."

Technical details

Matthias explained that the propulsion system is supplied by ZF, whose workshops are used carry out the mechanical and electrical conversion, and is the same as that used by Evobus, with the same specifications. The standard ZF low-floor portal axle has a maximum output of 250kW, with a maximum torque of 22,000Nm, and uses standard brake and wheel components ensuring no issues with fleet compatibility.

The passenger saloon temperature is maintained using a heat pump system from Valeo, which also supplies the water pump, while smaller items such as the air compressor and power steering pump are supplied by German manufacturer Moteg, which Matthias said was chosen for its reputation for low noise levels, a vital consideration on an electric vehicle. The battery systems are supplied by another German manufacturer, Voltabox, and have been specially designed for e-troFit to provide a good balance between flexibility of installation in the pre-determined space available in the former engine compartment and energy density. The lithium-ion battery cells themselves are from a Chinese supplier, which already supplies similar items to other automotive manufacturers. The batteries are all

Buses receive a thorough refurbishment and re-engineering to give the feel of a new bus. ***E-TROFIT***

housed in the former engine compartment, and the total capacity can be lower if the customer does not require the full capacity, allowing for a weight saving. The standard conversion offers a net capacity of 240kWh, but this could be reduced to 180kWh or 120kWh thanks to the modular nature of the system.

Battery charging is by means of a plug in system with a maximum capacity of 150kW, allowing a full charge in under three hours, with e-troFit also able to supply the charging infrastructure and software, developed by a sister company within the group and using in-house expertise.

Heating is in the form of a heat pump, which is supplemented by an electric auxiliary heater. In addition, a diesel heater is fitted, and an automatic control unit will select which one is used and when, with the diesel heater only being brought into use if the battery charge is low or the temperature very cold. A new modern air-conditioning system is fitted too, which is compatible with battery operation.

Bespoke software

One key feature about the e-troFit product is that while it uses the same hardware as other manufacturers, the software which controls the systems is bespoke, having been designed and created in-house by the e-troFit team. "What we have measured so far is that the efficiency of our drive system is better than the new eCitaro. The software in our vehicle control unit is designed by our software engineers to fulfil the standards for functional ssafety ISO262626, which is vital for the transport sector. This is why we have looked very closely and tested what could happen if there were electrical disturbances within the bus, for example what if a cable or wire broke or there was a bad contact, is the system still safe? To this we can answer yes, the system is always safe, and can self-diagnose and put itself into a safe mode."

"This level of safety is part of the USP of e-troFit," added Robert, "we work on a development level and have the same expertise as the OEM end of the market." Matthias went on to explain that not only does the retrofit have to be safe, but it is also vital that the way the new technology interacts with the existing systems on board which are retained, such as door controls, must also be safe, which is another vital focus for the company. "You can buy the parts and assemble them. We put the prototype together in six months, there are some companies who would just do that and begin to sell it. We have spent time working on the topics of liability, reliability and functional safety to make a system which is of the same quality as you would expect from a new bus. Homologation and reliability are two halves which have to be joined together."

In addition, all the components of the drivetrain are monitored by a telematics unit, which will allow operators to diagnose errors online remotely and plan maintenance. It will also be possible to update the bus' software remotely.

Rising demand

One of the company's first demonstrators has been in service in the town of Landshut in Bavaria, with no problems encountered, said Matthias. To date five vehicles have been converted, four buses and one truck which is at the first prototype stage. "We plan to manufacture 25 vehicles this year," he continued, "and we plan to scale up to over 100 in 2022. We see an 'electrification gap' with not enough new electric buses in the coming years, and we predict retrofitting up to 8,000 by 2030. Through the European Commission's Clean Vehicle Directive, from August this year 45% of buses purchased need to be clean vehicles. We don't believe that manufacturers are able to supply this number of vehicles, so the retrofit market will increase. Up to this year, a lot of operators still bought diesel vehicles which means the potential market for us is still growing."

"We're hearing from big cities that in order to fulfil their climate goals they will have to look at retrofitting, as by purchasing new buses alone they will not be able to reach their goals," added Robert. "For smaller to medium fleets, retrofitting is also often the only economic way they can meet the new standards."

"Up until today we have had interest for up to 10,000 units," said Matthias. "Cost is a critical factor, but so is the availability of vehicles. We are seeing a growing acceptance of the

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retrofitting solution, and in Germany funding will be available from the second half of this year."

Robert explained that responsibility had shifted from the German Ministry for the Environment to the Ministry for Transport, which is more aware of the benefits of, and need for, retrofitting, and that the solution has equal status with new electric buses when it comes to forthcoming funding. "We have done a lot of work with politicians and official bodies over the last year to explain to them that there is another solution which can bring them to the same goal but cheaper," he said, "and hopefully a lot faster. At the beginning they thought retrofitting meant something which was low quality or experimental. We explained that you can do this in a professional, quality way with the same results as new vehicles. At least in Germany now, if not Europe, we're at a point where retrofitting is equal to purchasing new buses.

A six month trial of a Citaro in Landshut proved a success. ***E-TROFIT***

Volume production

"A big difference with e-troFit is that other retrofitters never get past the prototype stage. You need to be at the highest level with development. Many of them think that you just need to put components together but for serious heavy-duty use in public transport you need to do more," Robert continued.

"The goal from the beginning was to develop a replicable solution," Matthias added. "We have detailed technical documentation, and we are creating manuals for each vehicle model. It is also important to work together with companies which are willing to carry out large numbers of conversions and who have the experience to do it." He explained that working with good quality local and regional partners will be key to the company's success.

An additional information display is mounted in the cab. ***E-TROFIT***

"What we are planning is that if we have a request from a country for retrofits, we want to build local value. We have had enquiries from companies, including in the United Kingdom for example," he continued, remaining tight-lipped about who those companies might be. "We want to work with a local partner which will do the conversion and refurbishment of the vehicles, with us providing experience, qualification, coordination and monitoring to the process. This is important to us, as with local value in the product, we believe that it will be more accepted. We want to work with the best in class partners across Europe."

Looking forward, Matthias also sees a market for e-troFit in supplying local manufacturers which traditionally might have bodied diesel chassis from the likes of Volvo or Scania, but don't have such easy access to a range of electrically-driven chassis options, the ADL-BYD tie-up being the only significant example of this in the UK and wider European market at present. The company believes that this is a gap it can help to fill, which will create a wider market in the shorter term, as well as ensuring an ongoing outlet for its drivetrain solutions as the number of diesel buses dwindles in the 2030s. Being able to purchase and body an electric chassis in the same way as a diesel chassis would be a big benefit for small-volume manufacturers, Matthias said, who might want to produce electric buses as the diesel market slows down, but don't have the opportunity available. "We would like to work together with these manufacturers," he said, "as they have expertise which we can benefit from, and we can provide electrification systems for existing and new vehicles."

In the immediate future, e-troFit will continue to expand its range of retrofit options available, and is currently working on systems for the facelifted version of the Citaro 1, the Citaro 2 and by the middle of 2022 expects to have a system available for the MAN Lion's City, all initially in 12-metre format. Matthias explained that articulated buses would prove more of a challenge, since the space available to house batteries in the former engine compartment is the same as a 12-metre bus, yet articulated buses typically need more battery capacity. This could mean installing additional batteries on the roof, but not all buses are capable of taking this weight without modification. He said that the solution would become more viable once e-troFit is able to offer a conversion which uses a hydrogen fuel cell range extender, as the hydrogen tanks are considerably lighter and could be accommodated on the roof more easily compared to batteries. However, in the shorter term, the company's priority remains battery power, as it believes that that is where the city bus market is heading, with fuel cells more suited to longer distance work, both freight and passenger. //