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RESEARCH REPORT

Executive Summary:

Electric Drive Buses

Hybrid, Battery Electric, Plug-In Hybrid, and Fuel Cell Buses: Global Market Analysis and Forecasts for Heavy Duty and Medium Duty Segments

NOTE: This document is a free excerpt of a larger report. If you are interested in purchasing the full report, please contact Pike Research at sales@pikeresearch.com.

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Section 1
EXECUTIVE SUMMARY

1.1 Market Overview

The light duty vehicle market – passenger cars and light trucks – has been in the lead in the adoption of hybrid and battery electric technology for the past 20 years. Within the heavy duty category, buses have been the segment with the most electric drivetrain adoption, with diesel-electric transit buses the first to demonstrate real commercial success. In 1998, a small number of 40-foot Orion buses equipped with a diesel-hybrid drive went into trials at New York City's transit agency. Data from this trial showed that the hybrid buses had improved fuel economy and lowered tailpipe pollutant emissions. These results essentially jumpstarted the hybrid bus market in North America. These buses also gave compressed natural gas (CNG) technology its first real competitor in the transit bus sector as the clean alternative to conventional diesel buses.

The bus landscape has changed substantially since then, with hybrids in North America capturing as much as 40% of new transit bus purchases in recent years. During this time, diesel engines have also become substantially cleaner in North America and in Europe, as more stringent regulations have been enacted. CNG continues to be a popular clean option for the bus sector, and is making headway in other heavy duty markets, especially in the United States where CNG prices are at historic lows. In the meantime, the light duty electric vehicle market has taken off, bringing with it significant advances in battery technology that can be applied to the bus market. Public policy in certain regions has begun to shift away from a focus on criteria pollutants and toward greenhouse gases (GHGs), spurring interest in low carbon and zero emission buses powered by batteries or fuel cells.

The three technology options covered in this report share one feature – the electric drivetrain. Electric drivetrains – whether for hybrid systems, battery electric, or fuel cell – hold appeal for the bus market for many of the same reasons they do for light duty vehicles. They offer the promise of decoupling a major transportation service from oil, serving energy independence demands. They offer efficiency gains, especially through the use of regenerative braking. They also offer quieter operation than a diesel bus, which can help make public transportation more attractive and spur higher ridership. Battery electric or fuel cell buses also provide zero tailpipe emissions, which helps reduce pollution levels in congested urban areas. Finally, depending on how the electricity or hydrogen is generated, battery and fuel cell buses reduce well-to-wheels GHG emissions.

As this list makes clear, much of the benefit of electric drive buses lies in the realm of the "public good". While this continues to drive interest in these technologies, all three bus options come with higher price tags than diesel or CNG buses, threatening the large scale penetration of these technologies. Bus operators must find the sum of financial and public benefits sufficient to offset these costs. Lower fuel costs and other operating costs offer real value, but

it still can take too long for the price premium to be paid back in lower operating costs. Since many of the other benefits of electric drive buses are "public goods", public policy will continue to play a major role in driving adoption of these technologies, either through mandates, GHG emissions targets, or direct subsidies.

1.2 Status of Electric Drive Buses

The three top regions for hybrid, battery electric, and fuel cell bus adoption are North America, Asia Pacific (specifically China), and Europe.

Hybrid Buses: Hybrid buses are a mature technology. They are generally best suited for lower speed, stop-and-go driving, as is typified by the New York City Transit bus operations where hybrids have offered a 25% to 50% fuel economy improvement, with 30% the more typical result. A parallel hybrid system is more suited to duty cycles where there is both stop-and-go and higher speed or steady speed driving. Hybrid buses today can cost around $200,000 more than a comparable diesel bus, although the exact differential will vary depending on the bus specifications.

North America has been the leading market for this technology, with hybrids capturing 30% to 40% of annual transit bus sales. Europe is behind on hybrid bus deployments, but stimulus funding in the United Kingdom has spurred a 50% increase in the sales of hybrids over the last few years. Germany has a hybrid bus demonstration program, although results have been mixed. Annual sales of hybrid buses in China actually surpassed that of North America in 2011, reaching almost 1,700. Although they capture a much lower market share than in the United States, the sheer size of China's bus market means it will likely continue to have the largest hybrid bus sales annually.

Battery Electric Buses: Battery electric buses offer zero tailpipe emissions, low noise operations, and support the shift of the transportation sector away from petroleum dependence. Battery electric buses are still in development and demonstration for most parts of the world, including the United States and Europe. The exception to this is China, which has been undertaking a major initiative to deploy electric vehicles of all types through its "Ten Cities, Thousand Vehicles Program." Since 2009, hundreds of battery buses have been deployed through this effort, and China has become a leading developer of battery electric buses, with more than 10 electric bus original equipment manufacturers (OEMs). While China is expected to continue leading the world on deployments, there are several OEMs in the United States, Canada, and Europe that are producing and deploying battery electric buses, typically with the support of government funding.

Fuel Cell Buses: Fuel cell buses are currently in a pre-commercial phase, although there are buses being deployed in regular transit operations and transit fuel cells being offered with conventional warranties. As do battery electric buses, fuel cells offer zero tailpipe emissions and low noise operation. Most fuel cell development in the transit sector has focused on the full-size 40-foot buses, with the fuel cell providing primary propulsion. This requires a high power fuel cell – typically around 125 kW to 150 kW. The cost of these buses is still quite

high, and the next several years will be devoted to manufacturers refining the technology while bringing down costs. The key markets will be the United States, where California's Zero Emission Bus regulation is spurring development and Europe, where the European Union is funding a 28 bus deployment. China and Japan will also see development and deployment activity, although China is not pushing as aggressively in fuel cell as with battery electric buses.

1.3 Market Conditions

Fundamentally, all of these buses require either government emissions or fuel economy policy that essentially requires a shift from conventional diesel buses or government subsidies and grants to offset the price premium. The biggest challenge for electric drive technologies has been the cost premium over a conventional diesel bus or a CNG bus. This premium has maintained for hybrids, even as they have seen significant adoption in the North American market. For hybrids, the fuel economy savings are critical to making the case for bus operators to pay more, especially in developed countries that are facing increasing austerity in their public budgets. Hybrid buses need to show fuel economy improvements of around 40%, at current diesel prices, to pay off the price premium over the life of the bus. While bus operators experience a real cost savings from a hybrid's lower fuel consumption, this cost savings is not always sufficient to provide a return on investment (ROI) from the upfront costs, or this return occurs only toward the end of the bus's life.

The price premium is even more considerable for fuel cells and battery electric buses. In addition, fuel cell and battery electric buses are still in pre-commercial or very early commercial production and have some operational limitations arising from the respective technologies. For the near-term, hybrid buses will still see strong demand in North America, mostly in transit applications, but would benefit from cost reductions in the hybrid system. Battery electric buses and fuel cell buses are still in development stages and will mostly be seen in small numbers (tens to dozens) over the next few years in most markets

The need to bring down costs presents some opportunities for suppliers to this market. The biggest opportunity is bringing down the price of energy storage, whether for batteries or ultracapacitors. Ultracapacitors have been selected over batteries in some hybrid bus applications. They are also being used in combination with batteries for some hybrid and fuel cell buses, but it appears to be in the hybrid applications that there is the greatest opportunity. China has seen significant uptake of hybrids with ultracapacitors, and this potential has yet to be seen in North America or Europe.

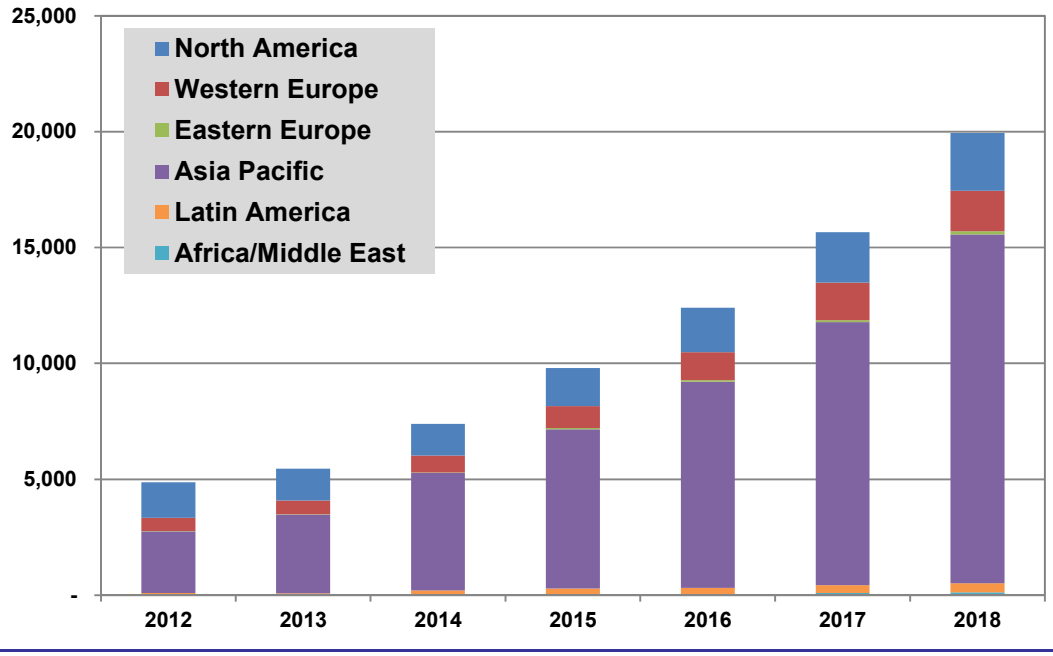
While the hybrid market is now split between nickel metal hydride (NiMH) and lithium ion (Li-ion) batteries, with NiMH securing a larger market share, it is likely that Li-ion could see more uptake in the hybrid sector. If prices come down the benefits of using Li-ion in hybrids will increase, pushing this market more toward the lithium chemistries. In addition, this market would benefit from further improvements in fuel efficiency through electric drive auxiliaries and more efficient air conditioning systems.

1.4 Market Forecasts

Overall, the global market for all electric drive buses is expected to grow steadily over the next 6 years, with a compound annual growth rate (CAGR) of 26.4% from 2012 to 2018. The Chinese market will constitute the majority of global electric drive bus sales, while some of the more developed markets will see fluctuations in electric bus uptake. This is due as much to the fact that developed bus markets may experience a general slowdown, due to austerity measures and the end of stimulus funding, as to any changes in demand for electric drive buses. North America will experience a rebound in a few years, as it is expected that the economy will have stabilized and so will public transit funding levels.

Sales of electric drive buses in Western Europe will experience steady growth (around a 20% CAGR), as the hybrid market begins to take off and there is continued interest in building the electric and fuel cell bus markets. The Latin American market will be driven largely by uptake in Brazil, but other countries will also spur adoption, notably Uruguay which recently indicated it would purchase 500 battery electric buses. The Africa/Middle East countries will see very little uptake due to the high cost of electric buses and infrastructure.

Chart 1.1 Annual Electric Drive Bus Sales by Region, World Markets: 2012-2018



(Source: Pike Research)

1.4.1 Lithium Ion Battery Demand

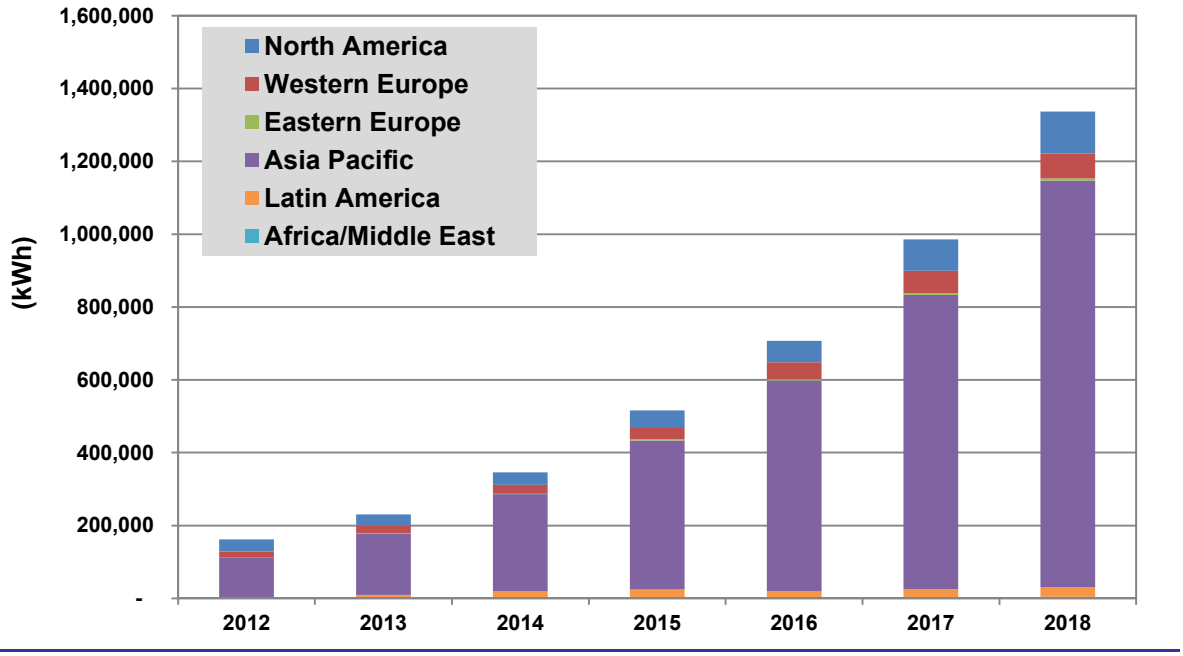
Global demand for Li-ion batteries in electric drive buses will be over 162,000 kWh in 2012. Pike Research expects that demand to grow to more than 1.3 million kWh by 2018, a CAGR of 42%. In 2012 the hybrid bus segment is expected to provide the greatest demand, with around 91,000 kWh needed to fulfill hybrid bus orders. This does not correspond directly to hybrid bus

growth, because NiMH and ultracapacitors continue to take a significant part of the energy storage market share for hybrids. At the latter part of the forecast period, Pike Research expects lithium ion to capture more of the hybrid market share as the batteries' prices come down. Indeed, the bus market represents an early opportunity for Li-ion battery companies looking for additional markets but who are not necessarily focused only on automotive size production quantities.

By 2018, it is perhaps not surprising that battery electric buses will drive the most demand for Li-ion batteries. Since battery buses are expected to be almost 100% powered by lithium ion, and they require much larger batteries than hybrids, this market offers the greatest growth potential. It is expected that Li-ion battery capacity for battery buses will grow from 69,472 kWh in 2012 to over 1 million kWh in 2018, a 57% CAGR.

Finally, fuel cell buses will drive demand for Li-ion batteries as well but to a much lower degree. Pike Research estimates that they will require around 1,600 kWh in 2012, but will grow to 22,240 kWh by 2018.

Chart 1.2 Annual Electric Drive Bus Lithium Ion Transportation Battery Capacity by Region, World Markets: 2012-2018



(Source: Pike Research)

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SCOPE OF STUDY

Pike Research has prepared this report to provide participants at all levels of the electric drive bus market, including bus OEMs, battery manufacturers, electric drivetrain suppliers, component suppliers, infrastructure providers, and trade associations and governments, with an analysis of the market for electric drive technologies within the heavy duty and medium duty bus segments. This report looks at hybrid electric, battery electric, plug-in hybrid, and fuel cell buses. In terms of end markets, the report considers the transit sector, shuttle services, and school buses.

The report's major objective is to determine the state of the industry and likely future growth of hybrid, battery, and fuel cell buses globally within the selected bus applications. It also provides a review of major demand drivers, as well as key industry players within the competitive landscape.

The report's purpose is not to provide an exhaustive technical assessment of the technologies and vehicles covered, but rather a strategic examination from an overall tactical business perspective. Pike Research strives to analyze new markets to aid readers in the development of their business models. All major global regions are included, as well as key countries. The forecast period extends through 2018.

SOURCES AND METHODOLOGY

Pike Research's industry analysts utilize a variety of research sources in preparing Research Reports. The key component of Pike Research's analysis is primary research gained from phone and in-person interviews with industry leaders including executives, engineers, and marketing professionals. Analysts are diligent in ensuring that they speak with representatives from every part of the value chain, including but not limited to technology companies, utilities and other service providers, industry associations, government agencies, and the investment community.

Additional analysis includes secondary research conducted by Pike Research's analysts and its staff of research assistants. Where applicable, all secondary research sources are appropriately cited within this report.

These primary and secondary research sources, combined with the analyst's industry expertise, are synthesized into the qualitative and quantitative analysis presented in Pike Research's reports. Great care is taken in making sure that all analysis is well-supported by facts, but where the facts are unknown and assumptions must be made, analysts document their assumptions and are prepared to explain their methodology, both within the body of a report and in direct conversations with clients.

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NOTES

CAGR refers to compound average annual growth rate, using the formula:

CAGR = (End Year Value ÷ Start Year Value)$^{(1/steps)}$ – 1.

CAGRs presented in the tables are for the entire timeframe in the title. Where data for fewer years are given, the CAGR is for the range presented. Where relevant, CAGRs for shorter timeframes may be given as well.

Figures are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in year 2012 U.S. dollars unless otherwise noted. Percentages may not add up to 100 due to rounding.

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