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Harnessing momentum for electrification in heavy machinery and equipment

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Battery-electric adoption could offer sizable potential in heavy machinery. There's a strong business case for some applications already—and addressing barriers could unlock more opportunity.

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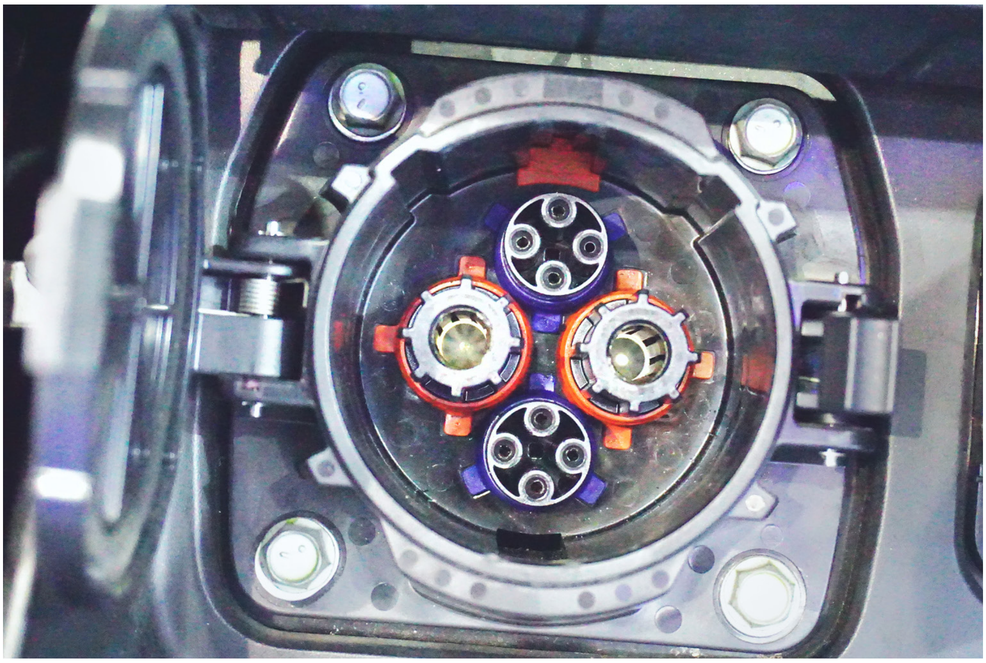
Contents

Introduction and key insights

Since the beginning of the 20th century, internal combustion engines (ICEs) have been the predominant mode of propulsion of both people and goods. Increasingly, however, battery-electric cars, buses, and trucks are rapidly reshaping the road-based transport of goods and people. This change is happening at a pace that few would have foreseen a few years ago, and it is driven by both traditional OEMs and new entrants alike (see sidebar “Adoption of battery-electric vehicles in the passenger-car and commercial-vehicle industries”). Recently, substantial advancements in battery performance and cost, global and local environmental concerns, and better and more available charging technologies have also contributed to the shift. This evolution is top of mind for all executives in the transportation industry, but it seems that less attention to vehicle electrification is coming from heavy machinery and equipment, despite the sector’s large and diverse fleet of vehicles and set of applications.



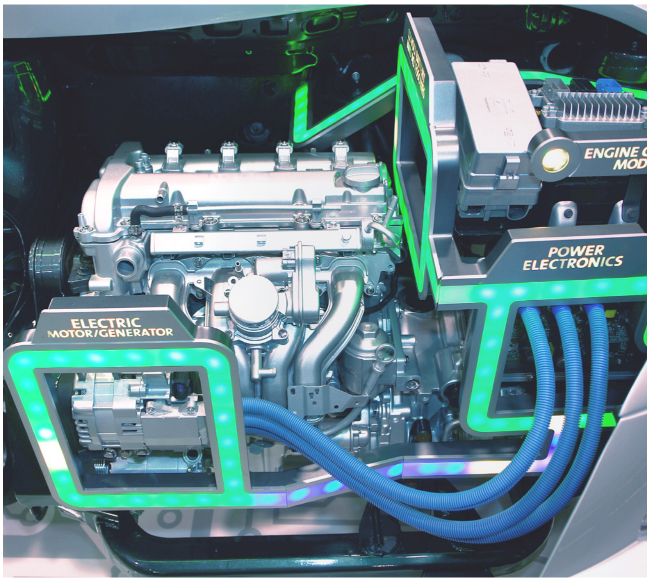
Sidebar 1: Adoption of battery-electric vehicles in the passenger-car and commercial-vehicle industries

One example of the growing presence of battery-electric vehicles (BEVs) is the passenger-car industry, where at least 50 BEV models are expected to be available in the market by the end of 2019. The McKinsey Center for Future Mobility expects that the share of BEVs among new cars sold to be 10 to 20 percent, depending on the scenario, by 2030.

Another industry example is that of larger commercial vehicles, in which fully electric vehicles were seen by many as fantastical as recently as the early 2010s. Yet in 2018, approximately 45 percent of newly sold buses in China were battery electric, and there are several battery-electric-truck prototypes and tests for middle and long ranges.

In both industry examples, significant innovation and development are now driven by incumbent OEMs as well as more recent entrants, such as BYD, Nikola, NIO, and Tesla.

Within the space of heavy machinery and equipment, there is still a very limited share of BEVs, even though electric propulsion (with cable) is not uncommon in some equipment. However, both operators and OEMs have started to invest in battery-electric solutions, with the first commercial solutions starting to emerge in the market.



Through research and analyses, we arrived at the following key insights, which will be explained in more detail in this article:

— Our research shows that in some segments of heavy machinery and equipment, under certain assumptions and requirements, there can be large potential for BEV adoption.

— In some segments and applications, there is potential for a positive economic case for operators already today when looking at total cost of ownership (TCO). This is driven by the significantly higher energy efficiency of electric vehicles, a lower lifetime maintenance cost, and continuously decreasing battery prices. Potential barriers to overcome include the lack of at-scale charging technologies and a limited track record and product availability.

— Sizable operational and economic benefits could extend to the operators, OEMs, suppliers, and other stakeholders choosing to spark the shift toward BEVs in heavy machinery and equipment. To capture these, barriers related to technology and accessibility need to be addressed adequately.

A strong business case already exists, but some barriers remain

Our research shows that BEV technologies can already be economically viable in several heavy machinery and equipment types and applications relative to conventional power trains. Actual market adoption rates going forward will be determined by drivers and barriers along five dimensions.

Customer economics

Adoption will ultimately be driven by customer economics, which, for the purposes of this article, is represented by TCO and is presented in greater detail in the next section. Our research shows that, under certain assumptions and scenarios, TCO for BEV could already be lower than it is for ICE in two of the four equipment and application types we investigated, with up to approximately 20 percent lower TCO compared with traditional ICE equipment. Given there are still few battery-electric models in the market, our performance and cost assumptions are based on existing battery and BEV power train technologies currently on the market for other heavy-duty applications. The BEV TCO advantage is driven by a significantly lower operating cost, despite the still higher up-front costs relative to ICE (for further details, see the next chapter).

In some scenarios, BEVs are already more cost efficient than ICE vehicles, with about 20 percent lower TCO compared with traditional ICE equipment.

Stricter regulation

Stricter regulation is emerging for heavy machinery and equipment on the global, regional, and local levels (for example, potential China and EU city bans on diesel and stricter regulation on nitrogen oxides and particulates). The emissions and noise-pollution standards set by these regulations will more easily be met with electric equipment.

Charging solutions

Downtime from charging is one of today's major barriers to the adoption of electrified equipment, but charging solutions are improving significantly. Battery-swapping solutions and high-power-charging (to 1.5 megawatts, up from approximately 150 kilowatts today) solutions are continuing to develop, but wide-scale commercial availability will be key to rapid BEV adoption. Still, even if these technologies materialize and become widely available, there will still be several heavy machinery and equipment types and applications where adoption will be slow due to the remoteness of work sites and limited or unreliable access to electricity.

~20%

BEV is already more cost efficient than ICE, with up to approximately 20 percent lower TCO compared with traditional ICE equipment.

Performance

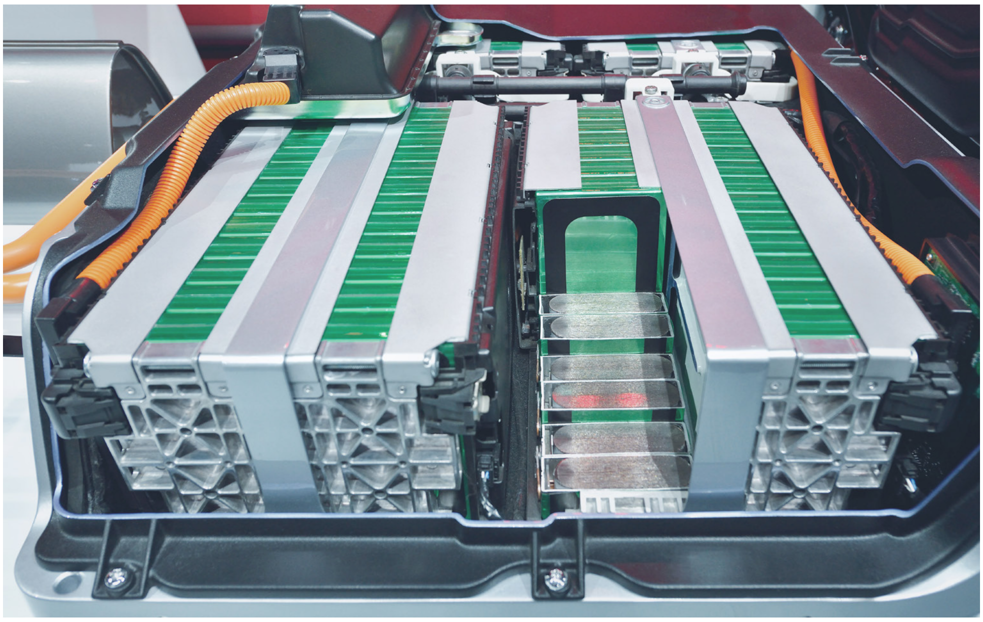
BEV performance is superior to that of ICE equipment in several aspects, including better maneuverability and drivability, with instant torque and independent wheel control, and significant synergy potential with automation and connectivity. However, there are also several equipment types for which irregular usage patterns and performance requirements will not allow for regular charging, which could limit large-scale battery-electric implementation in certain applications.

Product supply

Limited supply of products has historically been a significant barrier. However, now several commercial solutions are starting to emerge on the market, both from established OEMs and new entrants.

Deep dive into customer economics – operator TCO as key driver

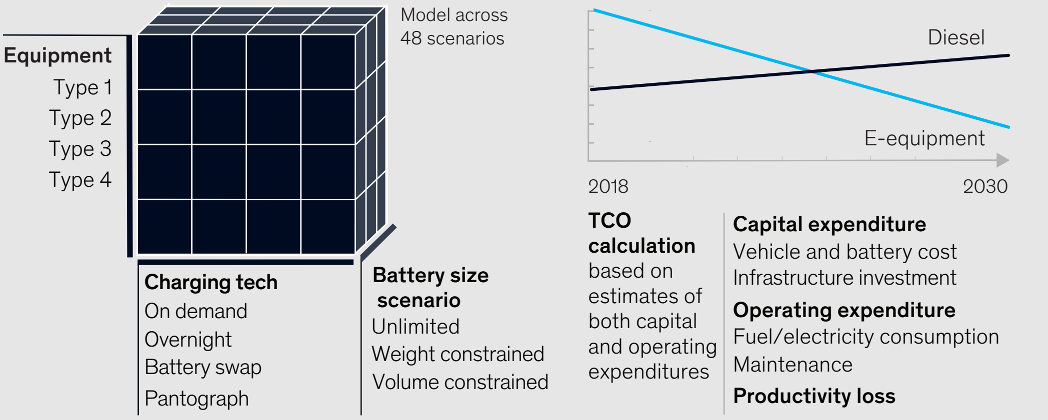
As pointed out, today there are few BEV machinery and equipment products on the market. Therefore, in our research and modeling we have made a number of assumptions. We have looked at four example equipment types and applications, where we have modeled the equipment lifetime cost for BEV and ICE, using a McKinsey TCO methodology (see sidebar "Our TCO model for battery-electric heavy machinery and equipment"). We take into account the up-front equipment costs (including, for example, cost of the battery and charging infrastructure needed for BEVs), the operating expenses (including cost of fuel, other consumables, spare parts, and maintenance), and the potential productivity losses (additional downtime from charging and/or reduced payload capacity compared with an ICE vehicle). For each example, we model several different scenarios. Our four examples were chosen to represent a wide variety of operations and applications.



Sidebar 2: Our TCO model for battery-electric heavy machinery and equipment

We developed a proprietary model of TCO for battery-electric heavy machinery and equipment. In this study, the model focused on four specific equipment types, four charging technologies (on-demand charge, overnight charge, battery swap, and pantograph), and three battery size scenarios (battery size constrained by volume, battery size constrained by weight, and no battery size constraint) (see exhibit below). The approach and input data build on previous McKinsey research on battery technology and economics, passenger-car and commercial-vehicle electrification models, and a proprietary database of heavy machinery and equipment operations.

A granular model simulated TCO to assess when BEVs could be cost competitive with ICEs



Source: McKinsey

For equipment types and vehicles for which few or no commercially available battery-electric solutions currently exist, we have estimated the up-front vehicle cost by starting with the cost of the traditional ICE vehicle, subtracting the cost of the conventional power train, and then adding the cost of an electric power train. In this case, the cost of the electric power train considers not just the smaller scale of production and shorter track record of continuous improvement, but also the availability of basic technologies already in the market today (for example, batteries, battery management systems, and electric motors).

For each combination of equipment type and charging technology (48 scenarios in total), the customer TCO is assessed for today and modeled for the future, taking into account capital expenditure investments (vehicle cost; battery costs, including for battery replacements during the lifecycle of vehicle; and charging-infrastructure investment), operating expenditure costs (fuel or electricity consumption and maintenance), and productivity losses (additional downtime from charging and/or reduced payload capacity compared with an ICE vehicle). The TCO of the battery-electric version of a particular equipment type is compared to the TCO of the ICE version of that particular piece of machinery or equipment in order to determine if and when the BEV will be cost competitive with traditional ICE equipment. Non-equipment-related synergies (such as the long-term opportunity to reduce ventilation in underground mines and electrification that enables further automation) have not been taken into account but are likely to strengthen the case for BEVs.

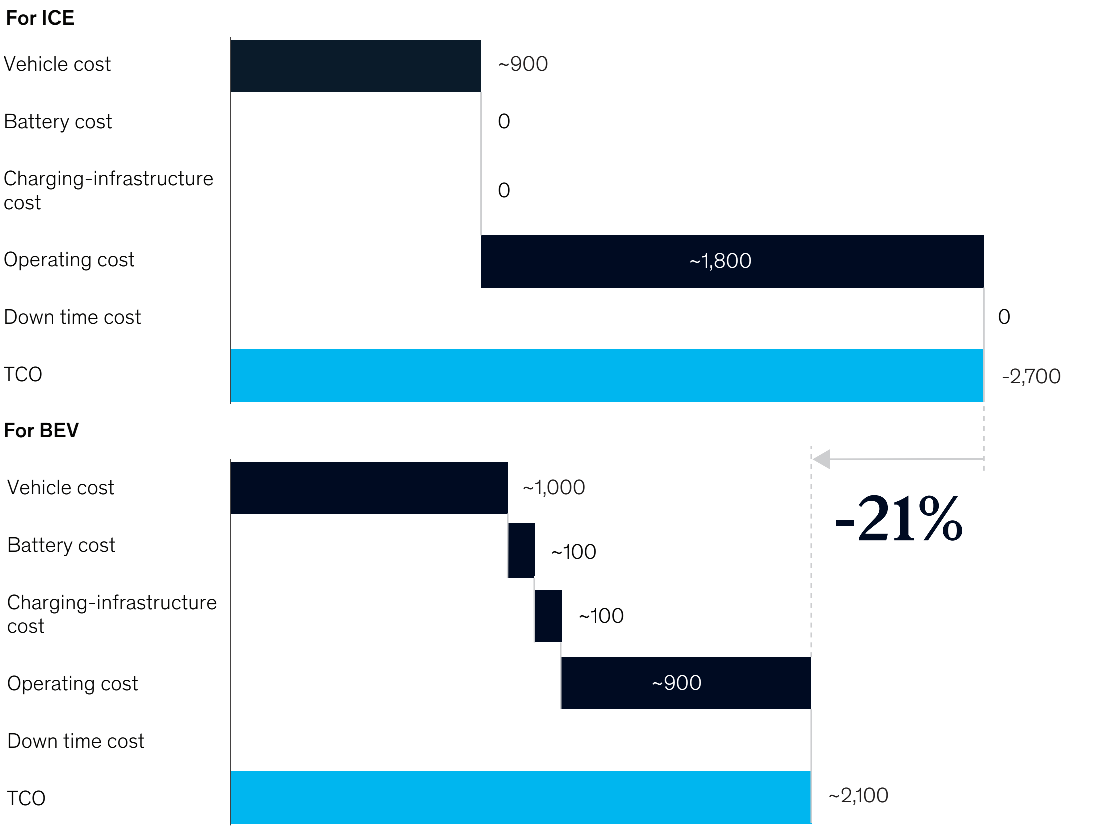
Our modeling indicates that a positive case for BEV TCO could already be achieved. Specifically, TCOs for two out of the four equipment types analyzed could already be about 20 percent lower than for ICE equipment (Exhibit 1). TCO for the other two equipment types is expected to be positive around 2020 and 2023, respectively (Exhibit 2).

Exhibit 1

TCO for 1 BEV equipment type is already -21% lower than for ICE

TCO break down – example equipment

TCO, in EUR thousands, 2018



Source: McKinsey

This improvement is mainly driven by the 40 to 60 percent lower operating costs of electric equipment compared to ICE equipment. This is due to electric propulsion being inherently significantly more efficient than conventional engines, with 70 to 75 percent higher tank-to-wheel energy efficiency, reducing fuel consumption. In addition, the simpler electric power train would require somewhat lower maintenance spend compared with a conventional power train (mainly due to having fewer parts that can break down compared with ICEs).

Even though the total cost to operate a BEV is lower, the BEV is likely, in the short and medium term, to incur a higher up-front investment than incurred with an ICE vehicle. We assume that the actual electric machine (excluding the battery) will be approximately 10 percent more expensive than the comparable ICE machine for roughly another five years (driven by higher up-front product development costs) but that prices will gradually go down because of production scale effects and the relative simplicity of electric power trains compared with conventional

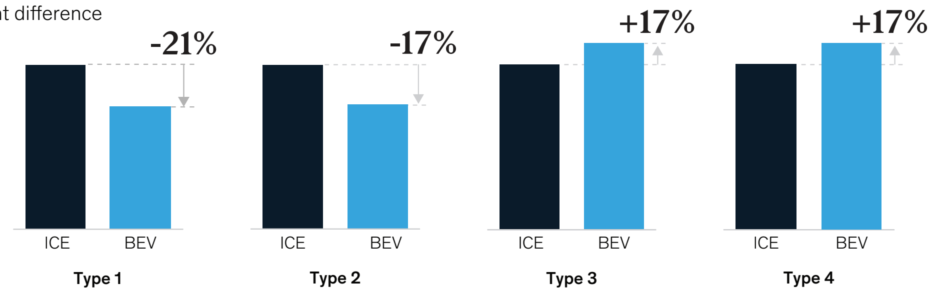
ICEs. The battery cost will require a significant up-front investment – approximately 10 to 40 percent of the equipment cost, assuming battery prices today of around EUR 280 per kilowatt-hour, based on a McKinsey model, and including a cost premium for smaller-scale production and adaptions to sustain rough environments. But this up-front investment will be compensated for by higher efficiency over the BEV lifecycle. In addition, investments in high-power charging solutions, or in battery-swapping technology (necessitating two batteries per vehicle), will be required.

Exhibit 2

An analysis of operating costs and battery-charging/-size/-range scenarios suggests ICE-BEV TCO parity today for 2 equipment types, in one year for the third, and in four years for the fourth

Overview of results and key assumptions

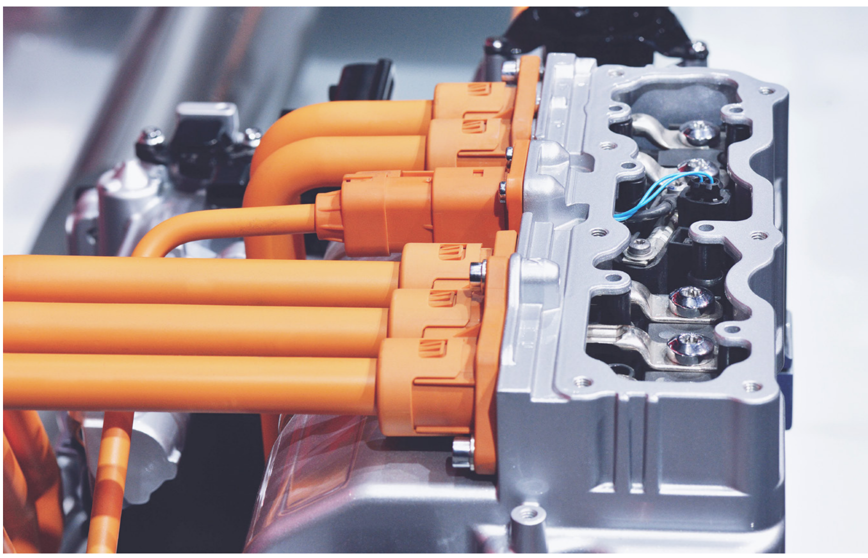
TCO, 2018, percent difference



	Type 1	Type 2	Type 3	Type 4
TCO parity year	Today	Today	~2023	~2020
Charging tech	Battery swap	Battery swap	Overnight charging	Overnight charging
2018 battery size	~220 kWh[1]	~2,200 kWh	~40 kWh	~460 kWh
Range	~2.5 hours	~5 hours	~8 hours	~10 hours
Vehicle cost (including battery)	~EUR 1,200,000	~EUR 5,200,000	~EUR 60,000	~EUR 350,000

[1]Kilowatt-hour

Source: McKinsey



Electrification has implications for all stakeholders along the value chain

The likely challenges and modeled benefits of battery-electric equipment will certainly apply to stakeholders in the heavy machinery and equipment industry. How individual players experience the adoption of electrification and the strategic considerations they must make moving ahead, however, will primarily be determined by which parts of the value chain they occupy.

Operators

For operators, a large-scale shift toward electric equipment could yield combined annual savings of more than USD 30 billion in operating costs. However, this long-term savings would require an initial new-equipment investment of about USD 16 billion.

For operators, a large-scale shift toward electric equipment could yield combined annual savings of more than USD 30 billion (assuming full adoption in approximately 20 percent of applications).

Operators should consider what role they can take to capture electrification's potential, including whether they should be a fast adopter through selected pilots, bet on large-scale electrification, or wait for new technology to develop further.

OEMs

For OEMs, there is an opportunity to drive innovation in this new and promising field. Beyond equipment, new service-type opportunities could arise in areas such as battery-as-a-service solutions, peak-balancing services, and connected services around energy optimization.

OEMs need to make a conscious strategic choice on EV product offers and development that considers market position, product range, customer exposure, product- and component-standardization strategy, cost model, and so on. One core part of this choice will be finding a convincing answer to the "make or buy" strategy question, which has implications for potential speed to market, cost competitiveness, access to core technologies, and room for differentiation. They will also need to determine whether to follow a first-mover or follower strategy in bringing EV products to market, which promising categories or applications to target first, which customers to target first, and how to secure access to battery capacity.

USD >30 bn

For operators, a large-scale shift toward electric equipment could yield a combined USD >30 bn in savings.

Suppliers

For suppliers, the adoption of battery-electric equipment means shifts in landscape and value chain. Suppliers have the opportunity to transform and reinvent themselves to capture these opportunities. Preparing for this transformation will require suppliers to build the right assets and skills by investing in talent and upskilling.

Suppliers will also need to consider how the relevance of their components will develop if electrification happens at scale, including if there are new technology areas to expand into. Current car and commercial-vehicle suppliers should consider whether supplying a blended (ICE and battery electric) heavy machinery and equipment landscape will be similar to supplying the blended passenger-car or commercial-vehicle landscape, as well as where synergies may exist and where differentiation may be the best strategy.

Broader technology integration considerations

Across the entire value chain, all stakeholders will need to consider the interconnections with the other major shifts, including autonomous vehicles, connectivity, and digitization, happening in the industry. We believe there are significant synergies among these areas, similar to what can be observed in the general transportation industry.

In addition, all stakeholders need to consider the implications of a potentially new value chain in which partnerships and ecosystems around battery technology development, analytics, and charging solutions might be new drivers of technology development.

Outlook

The proliferation of electrification in heavy machinery and equipment is far from the levels observed in passenger cars and commercial vehicles, but there might be even bigger potential in certain applications, given the operating characteristics of this segment (for instance, predictable usage patterns). Several use cases have been identified, and the case for a positive TCO can already be made today. The development of these technologies is happening rapidly at this very moment, and a growing set of new BEV-enabled business models is already imaginable. Close monitoring of TCO and technology maturity will be critical for stakeholders. Operators, OEMs, and suppliers that begin thinking about their business and operational strategies now will be well positioned to capture a significant competitive advantage.

Authors and contacts

Erik Östgren is an Associate Partner in McKinsey's Stockholm office, where Markus Forsgren is a Partner, and Andreas Tschiesner is a Senior Partner in McKinsey's Munich office.

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