

How to kickstart decarbonization for off- highway machinery

Off-highway conference 2023

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Roland Berger

Brussels, Belgium – October 25, 2023

**Off-Highway
CONFERENCE**

Your contacts on "How to kickstart decarbonization for off-highway machinery"



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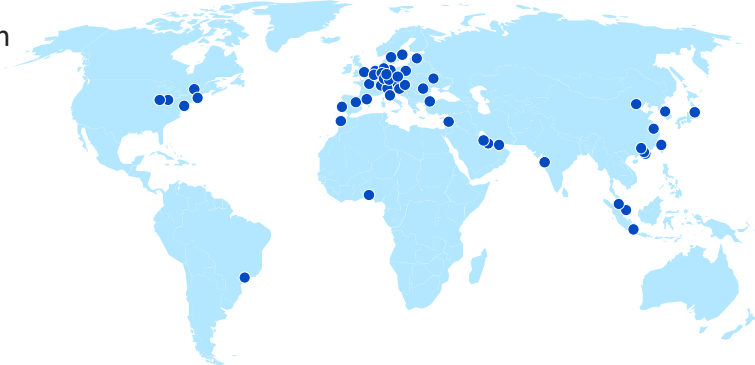
Roland Berger is a leading global strategy consulting firm, with a balanced portfolio across regions, clients and project focus

Our profile

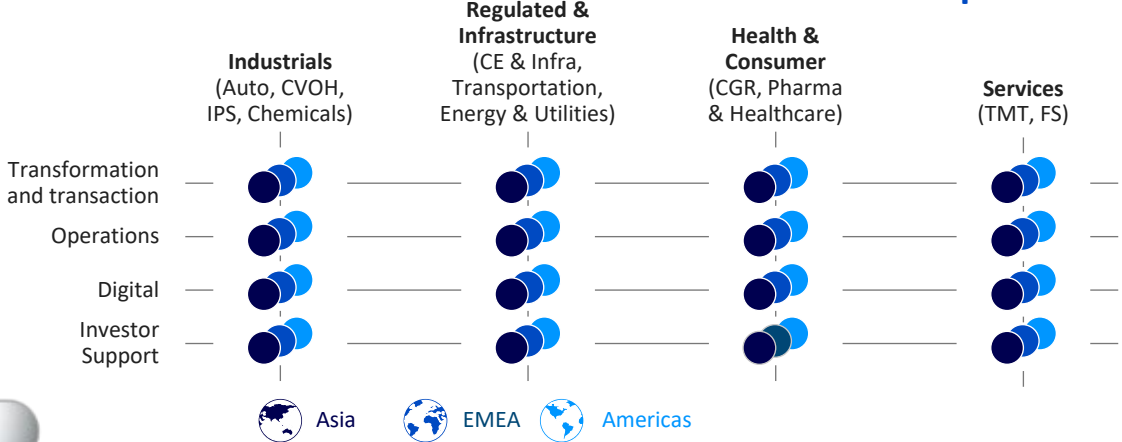
Created in **1967** with focus on **Industrials**

51 offices in **36** countries with **2,700** employees

Over **300** partners and more than **1,000+** clients



Our capabilities



Entrepreneurship

We follow an entrepreneurial approach and provide creative and pragmatic solutions

Excellence

We achieve excellent results and develop global best practices to ensure measurable and sustainable success

Empathy

We are insightful and responsible advisors who contribute to the greater good

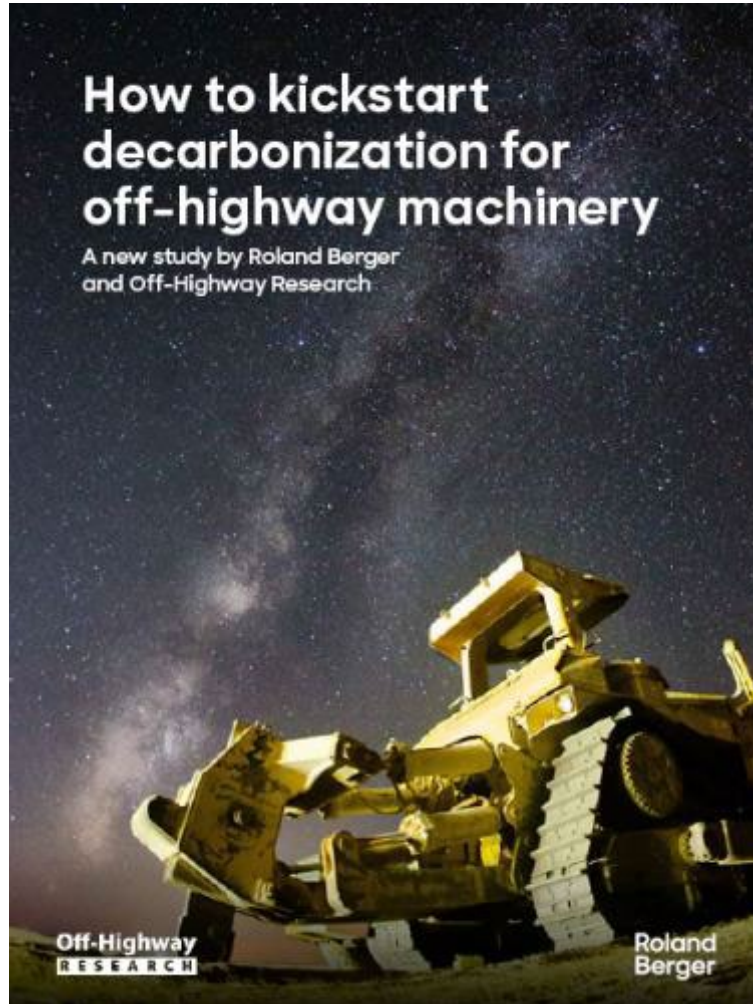
Our values

We support off-highway OEMs and suppliers, on key strategic topics globally

- ...Corporate and technology strategy including electrification, autonomous driving & digitization
- ...Sustainability strategy including emissions scope 1-3
- ...Growth and M&A strategy and post-merger integrations
- ...Operations and performance improvement

Our commercial vehicle work and clients

Our study together with Off-Highway Research shows that key steps must be taken to kickstart decarbonization for the industry



The off-highway sector is just beginning its journey toward decarbonization, with electric powertrains and alternative fuels as a major focus. There are significant obstacles to overcome – keys to progress include achieving production scale, advancing battery technologies, and lowering alternate fuel costs.

Contents

- 1 What's driving decarbonization?
- 2 Barriers to progress
- 3 How to jumpstart adoption

Read more



The off-highway industry is early in its decarbonization journey, but internal and external forces will drive the transition moving forward

External Forces



Corporate sustainability pushes among value chain participants



Evolving government incentives and regulations

Internal Forces



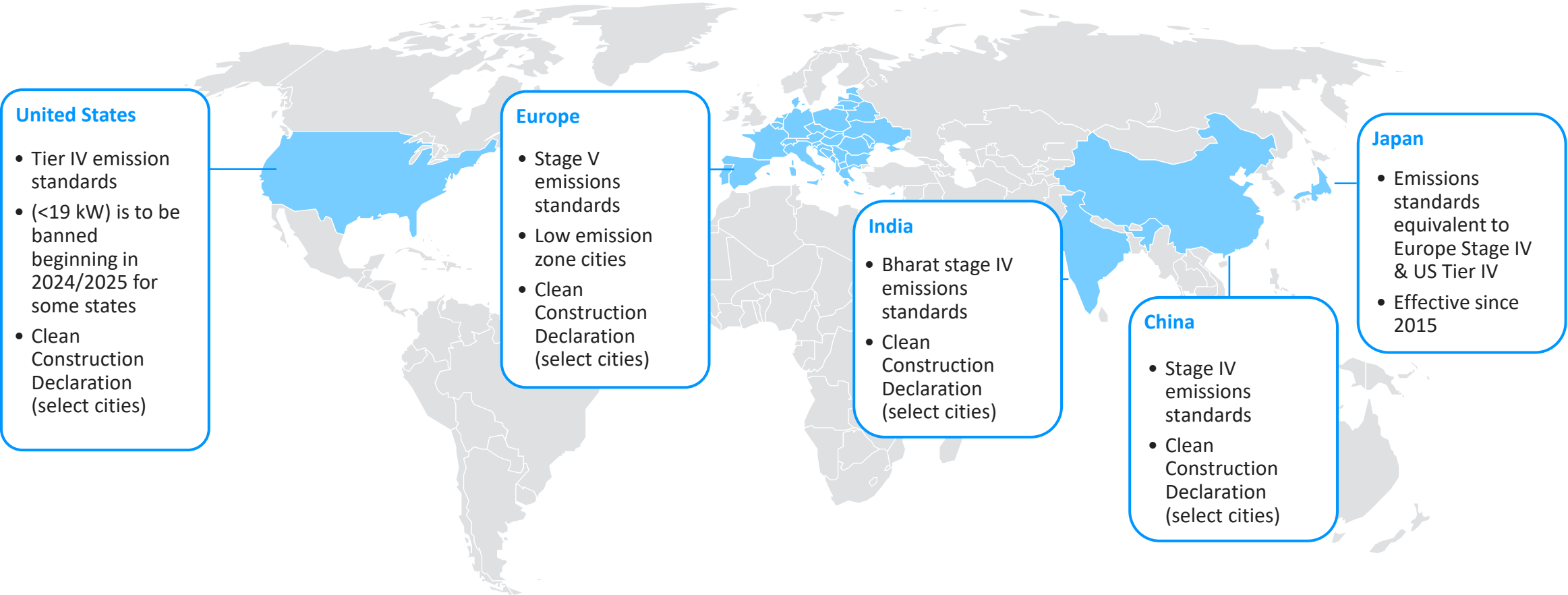
Total cost of ownership (TCO) benefits



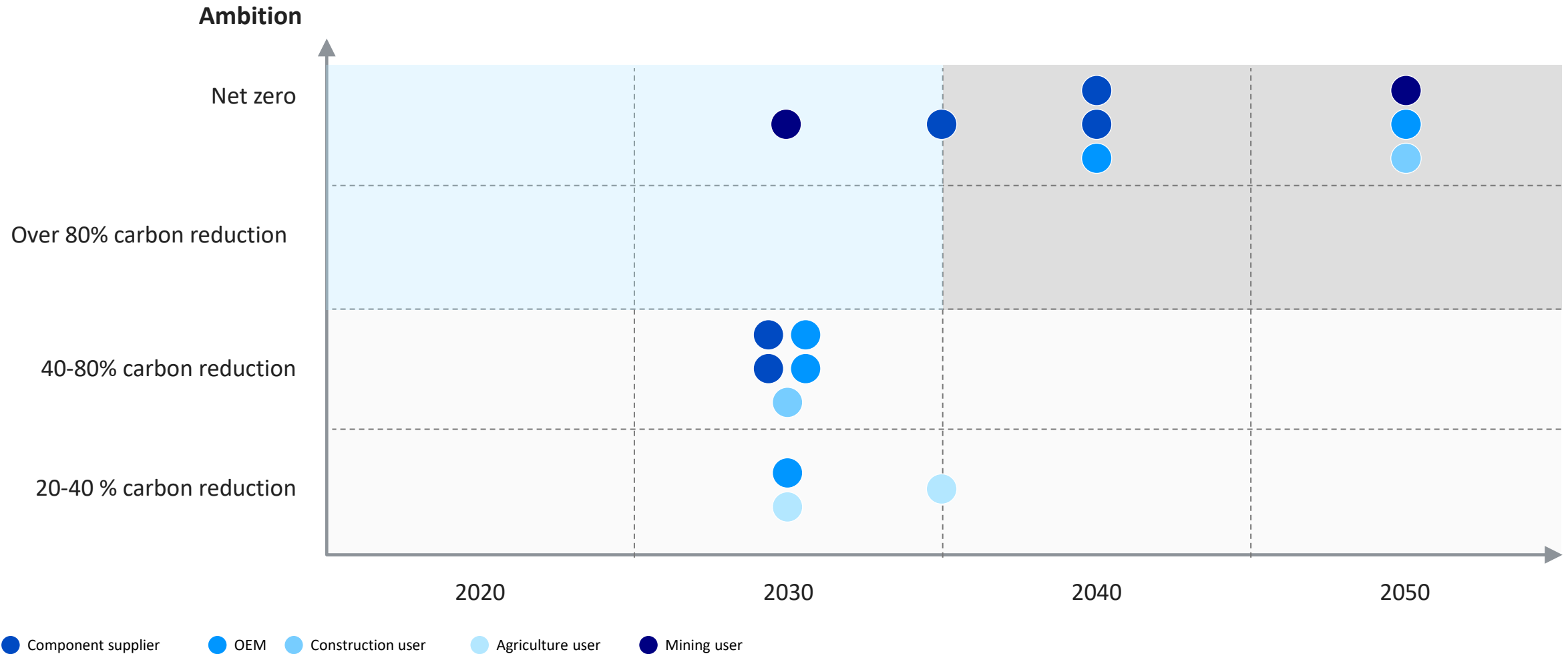
Improved operator experience

Regulation is a major driver of decarbonization, with countries across the globe implementing emissions regulations at the federal and local levels

Countries leading the way on off-highway emissions regulations

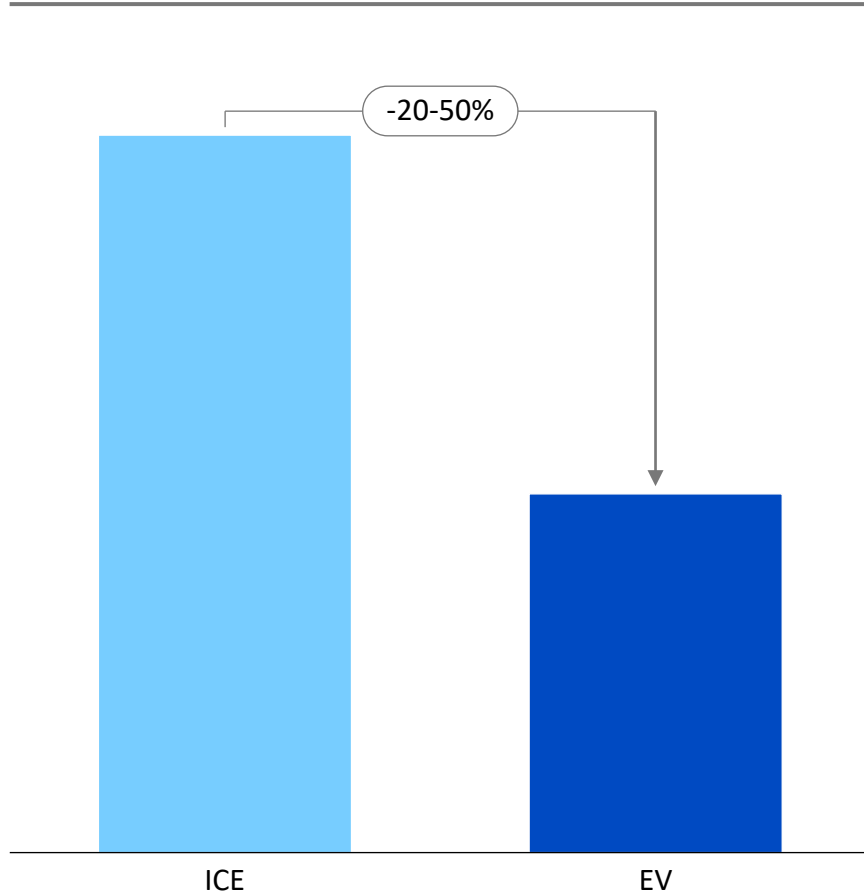


Responding to regulation and customer preference, players across the value chain are committing to ambitious sustainability goals

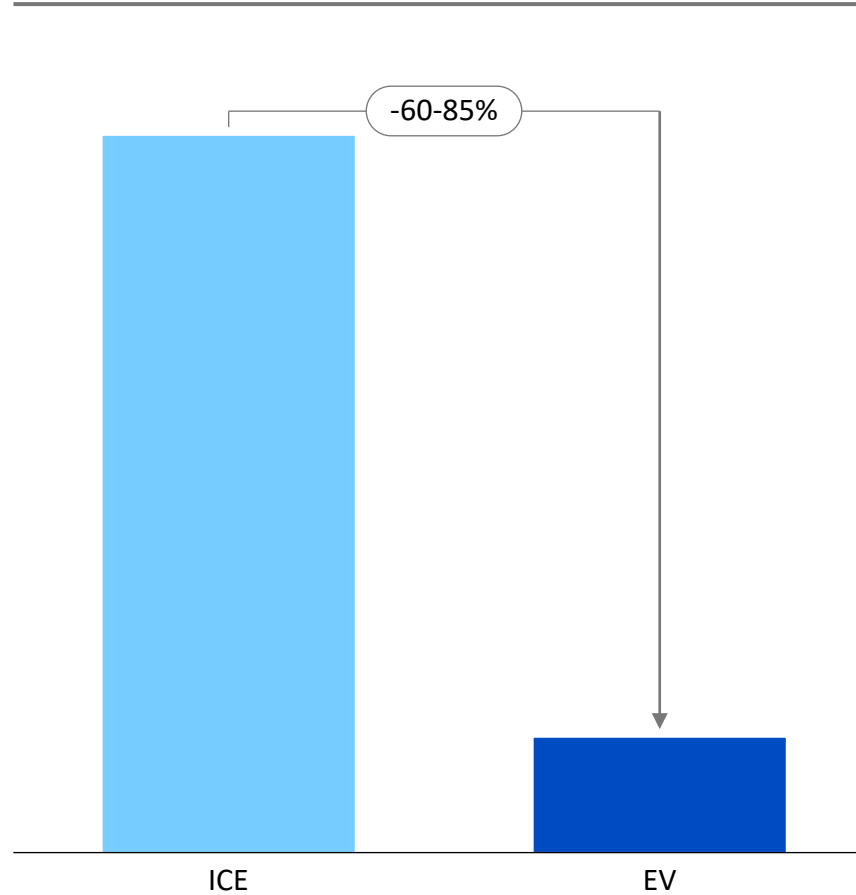


Electric off-highway equipment has TCO benefits relative to ICE, both in terms of fuel savings and reduced engine maintenance

Fuel cost index – ICE vs. EV



Number Moving Parts in Drivetrain – ICE vs. EV



- TCO benefits vary widely, but even in high cost electricity settings EV drivetrains cost less to operate and maintain
- Fuel cost delta highly dependent on charging approach (grid vs. behind-the-meter, time of day, rate of charge, local tariffs, etc.)
- Electric machines comprise fewer components and have a lower maintenance requirement due to the absence of the metal-on-metal contact which is inherent in IC engines and mechanical transmissions

Electrified equipment also has several performance advantages that make it preferable for certain tasks and work environments

Electric vehicle performance benefits

Electric machines make less noise and generate fewer vibrations as well as offering better controllability and traction.



This can lead to an improved operating experience and decrease training and repair costs.



Work environments where electrified vehicles are preferable

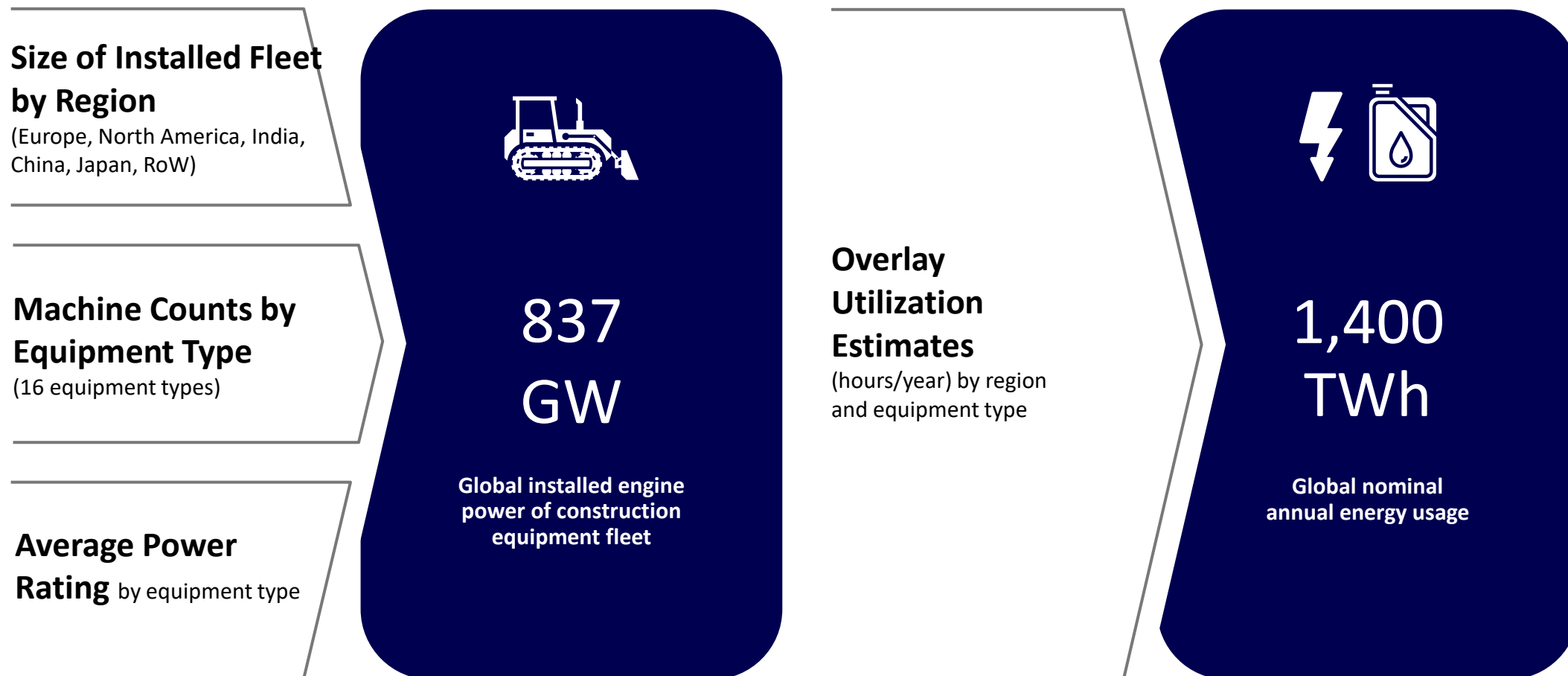
Inner cities: Comply with noise and emissions regulations



Underground mining operations: Improve safety and reduce ventilation costs

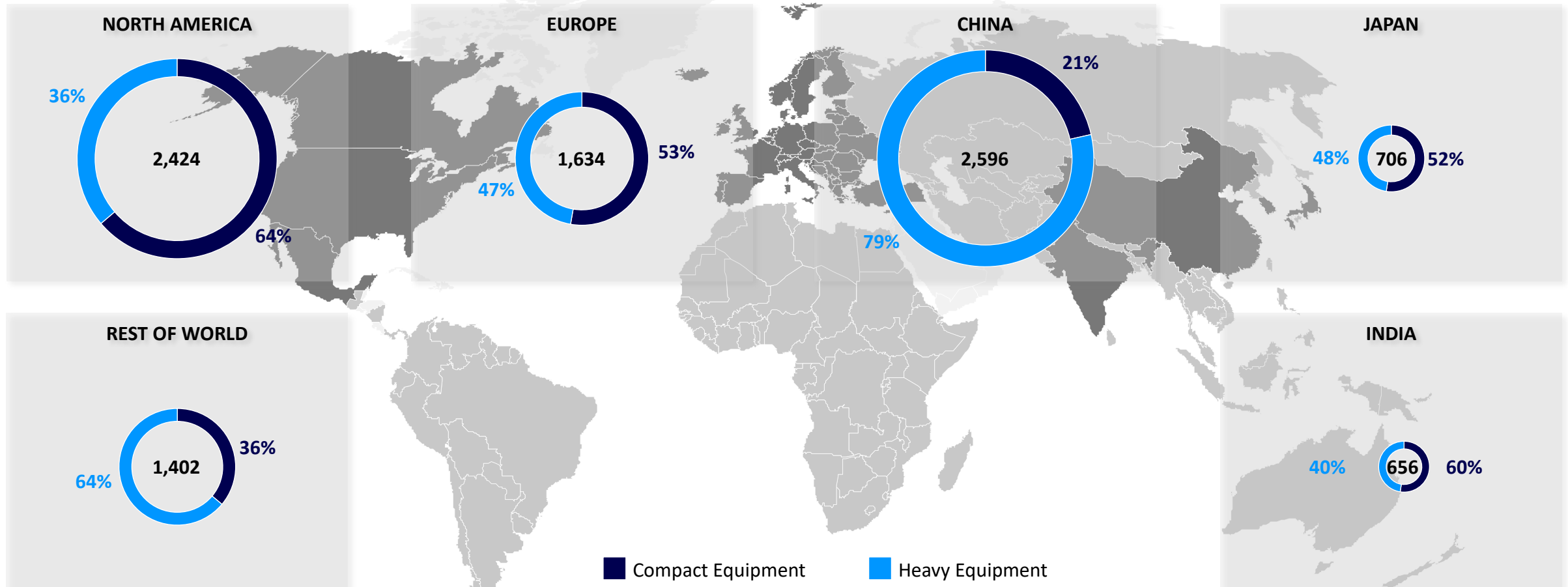
To characterize the decarbonization opportunity, we built a model to measure global installed construction equipment engine power and energy usage

Global installed engine power and annual energy usage model



China and Rest of World represent the majority of the heavy duty construction equipment fleet

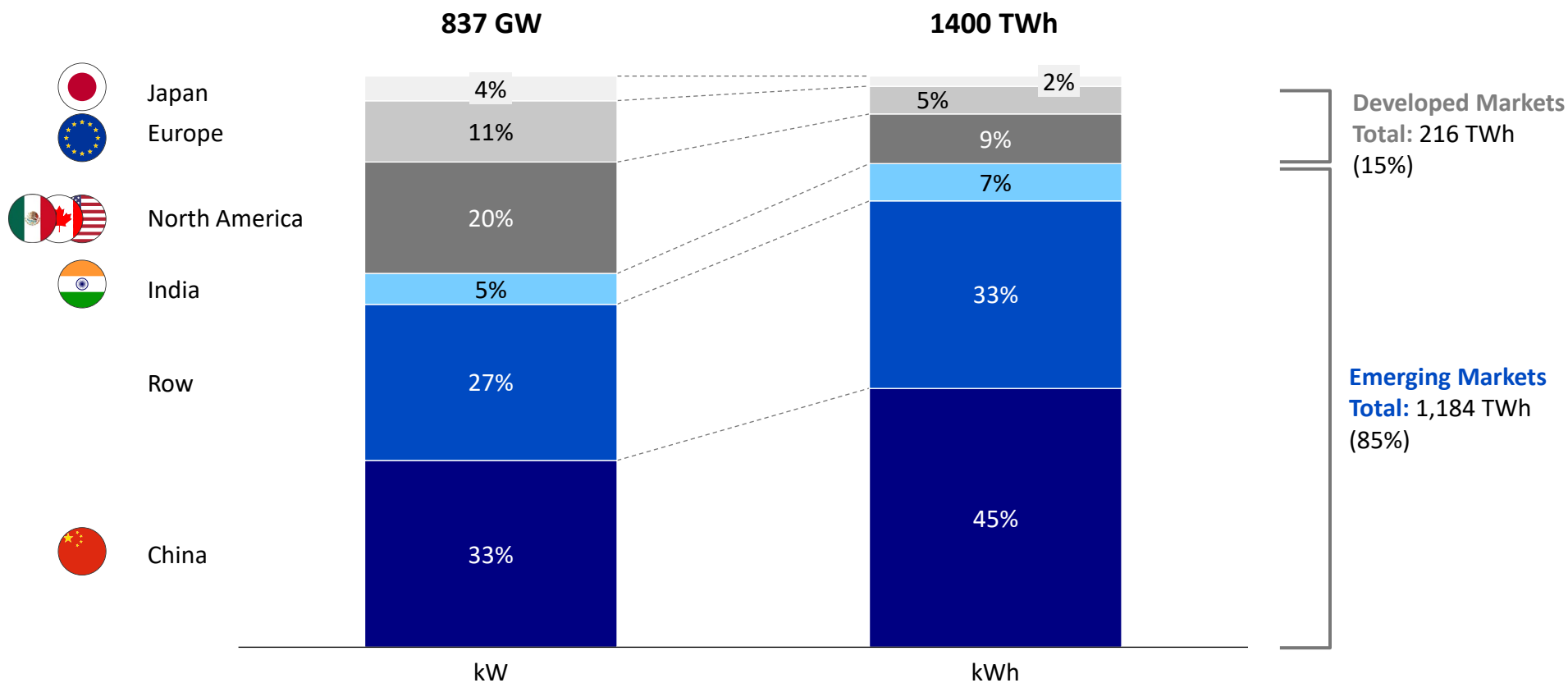
Construction equipment fleet size by region [number of vehicles in thousands]



1) Compact Equipment includes mini excavators, skid-steer loaders, wheeled loaders <80 HP, compact tracked loaders, backhoe loaders, and rough terrain lift trucks. Heavy Equipment includes crawler excavators, telescopic handlers, wheeled excavators, wheeled loaders >80 HP, motor graders, crawler dozers, crawler loaders, asphalt pavers, and dump trucks (articulated and rigid)

Emerging markets represent disproportionately high level of emissions relative to engine capacity due to higher utilization rates

Installed engine power vs. nominal annual energy usage¹ of global CE2 fleet by region, 2023 [GW, TWh]

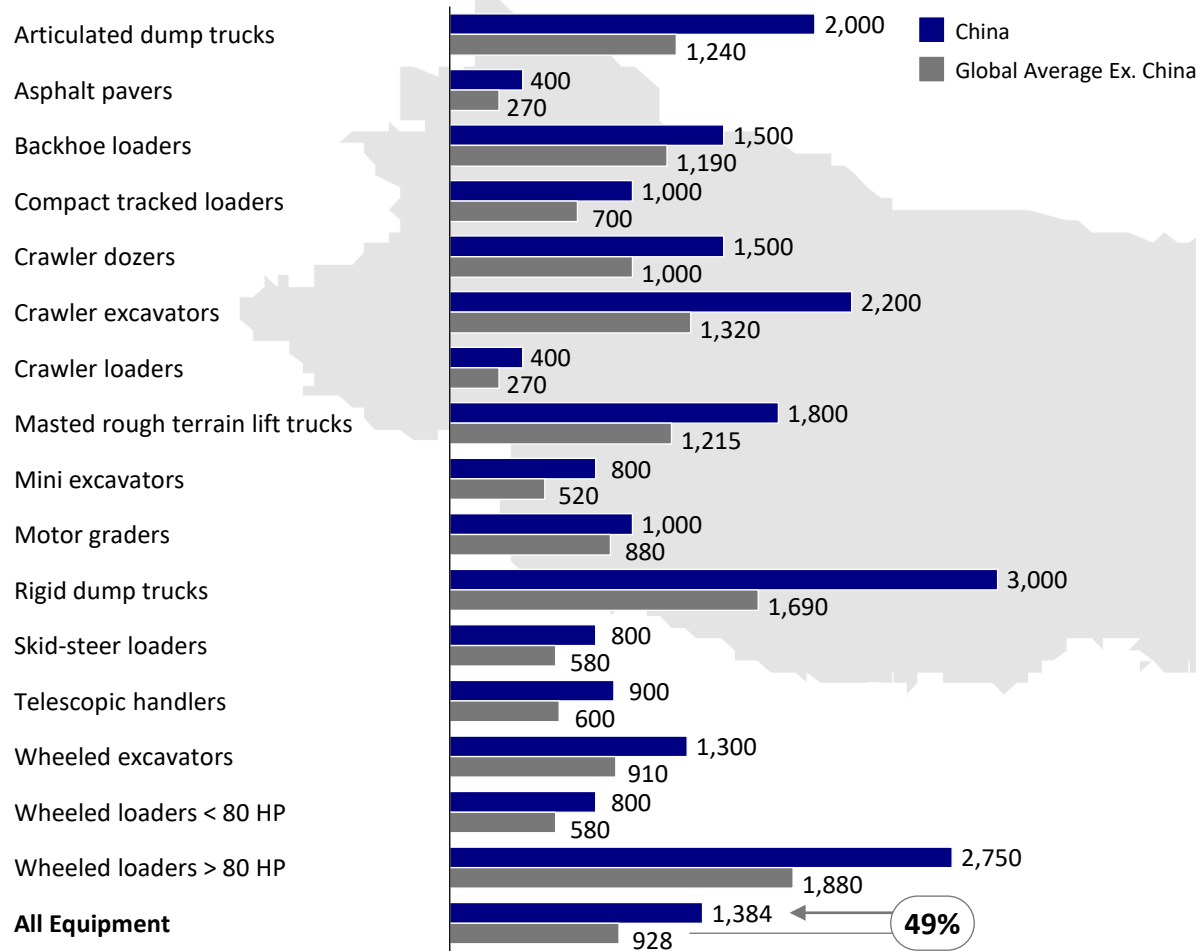


- Emerging markets' outsize energy usage is due to tendency toward larger machines, higher utilization rates, and volume of install base
- RoW contains a mix of regulatory environments, but the majority is comprised of low-regulation countries in Africa and Central/South America

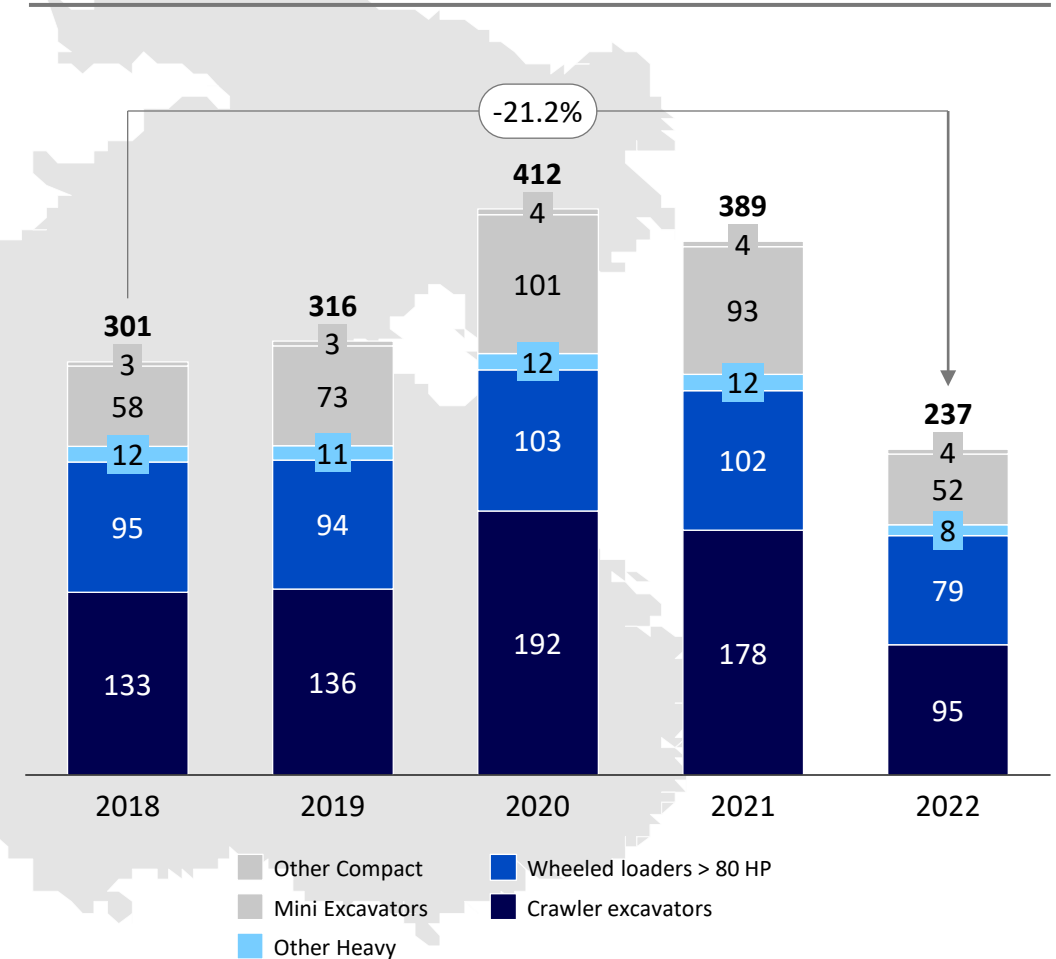
1) Annual work = Installed engine power [kW] x Annual utilization [# of hrs/year]; 2) Construction equipment

A bias toward heavy equipment and above-average utilization rates contribute to China's significant estimated share of energy usage

Average annual equipment utilization, China [hours]

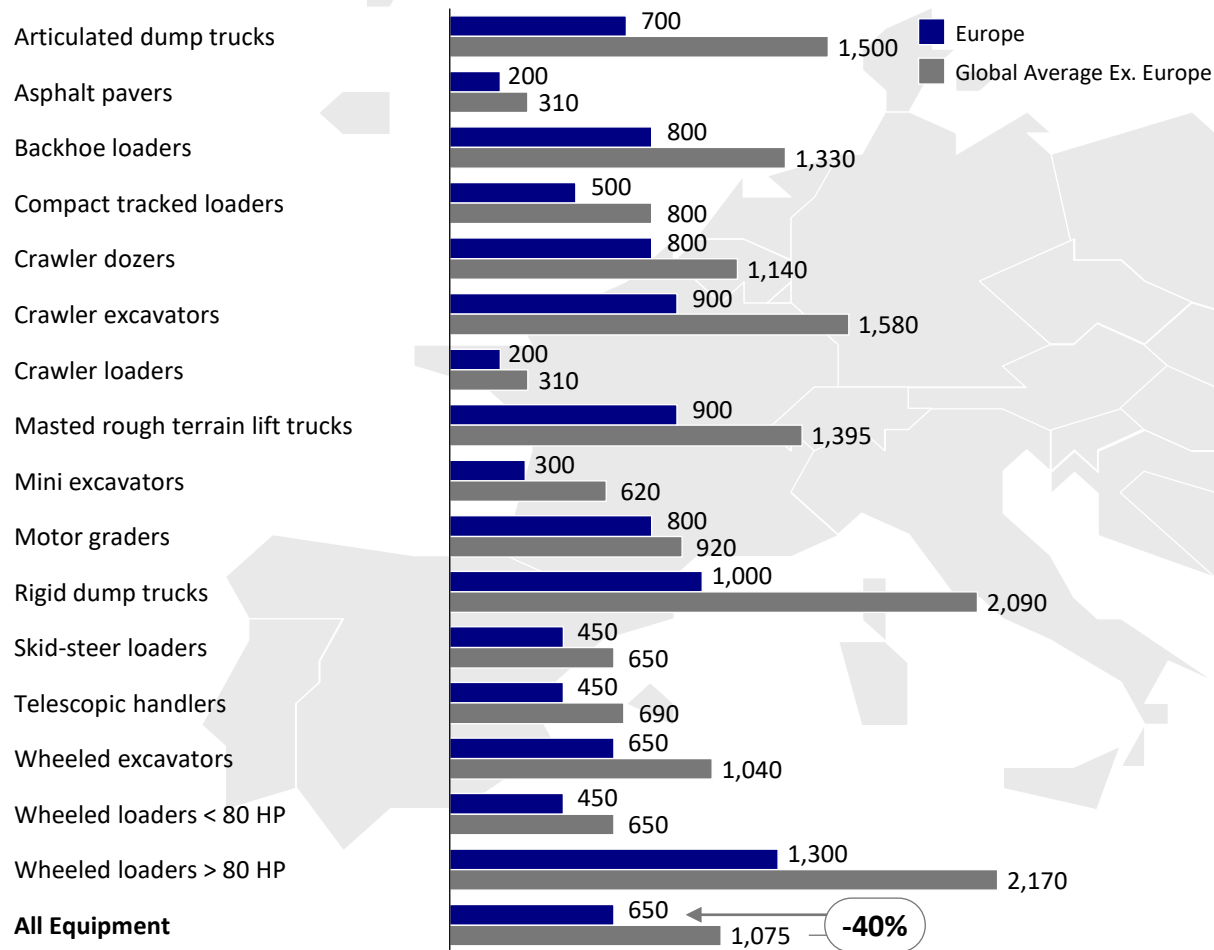


Annual unit sales for major equipment types, China [thousands of units]

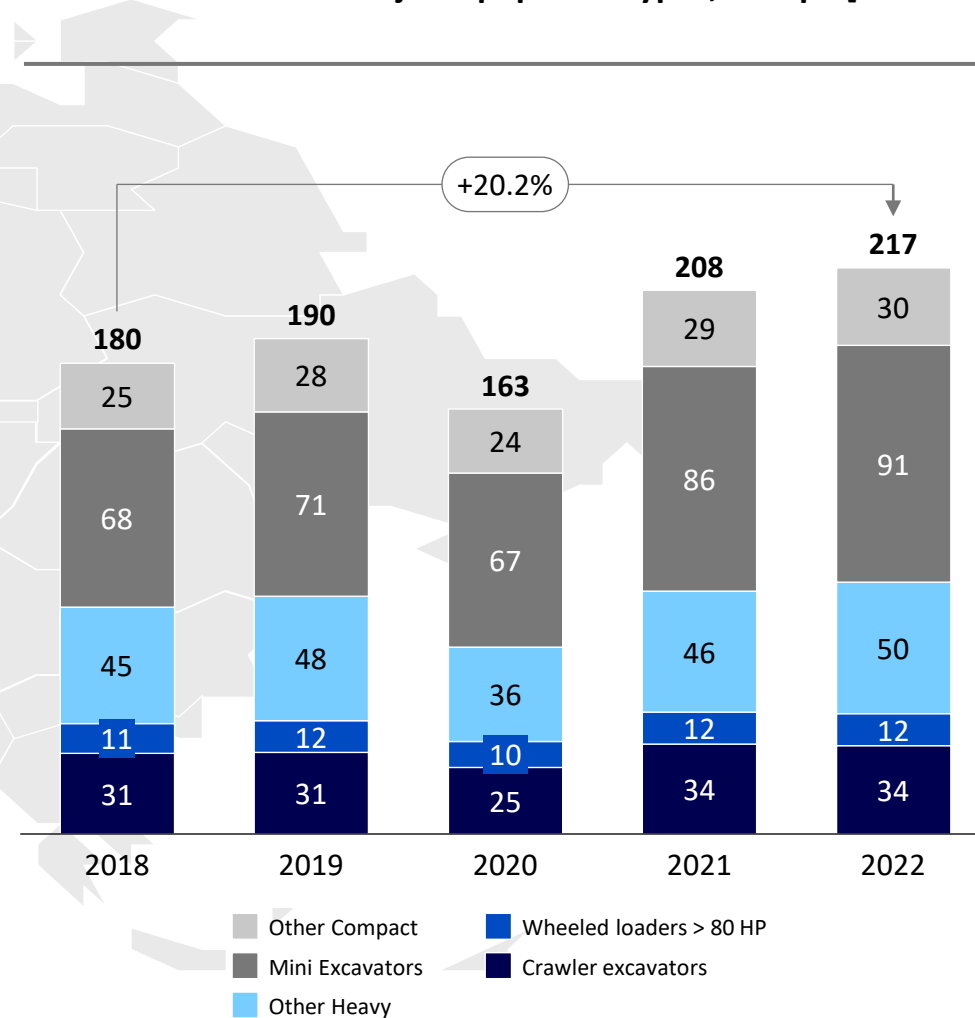


In contrast to China, Europe tends to buy more compact equipment, and uses it 40% less than the rest of the world

Average annual equipment utilization, Europe [hours]

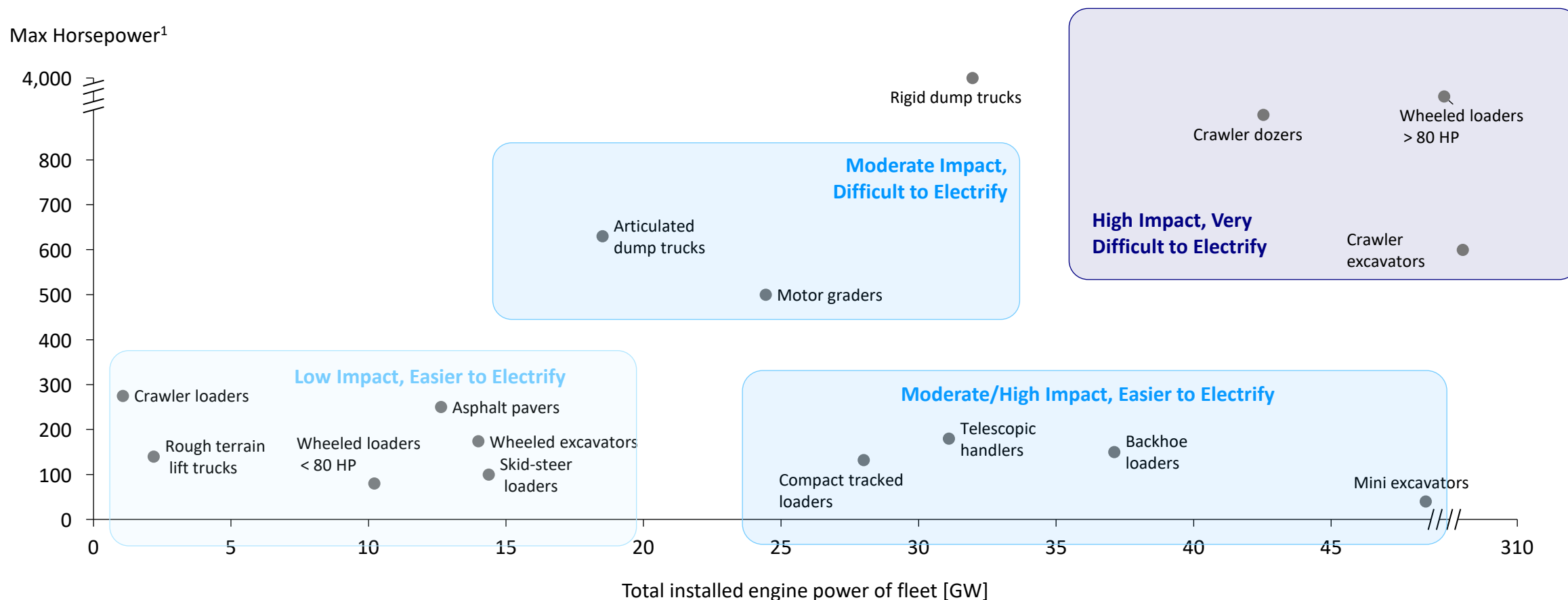


Annual unit sales for major equipment types, Europe [thousands of units]



The vehicles most likely to be electrified tend to represent a smaller share of the total installed engine power – other solutions will be required to decarbonize

Installed engine power of global construction equipment fleet vs. typical max horsepower¹ by equipment type, 2023



1) Excludes select "mega" machines such as the Caterpillar 6090 FS crawler excavator at 4,500 horsepower

Progress against decarbonization will require a two-pronged approach which recognizes the operating requirements of different types of vehicles

⚡ Pursue Electrification

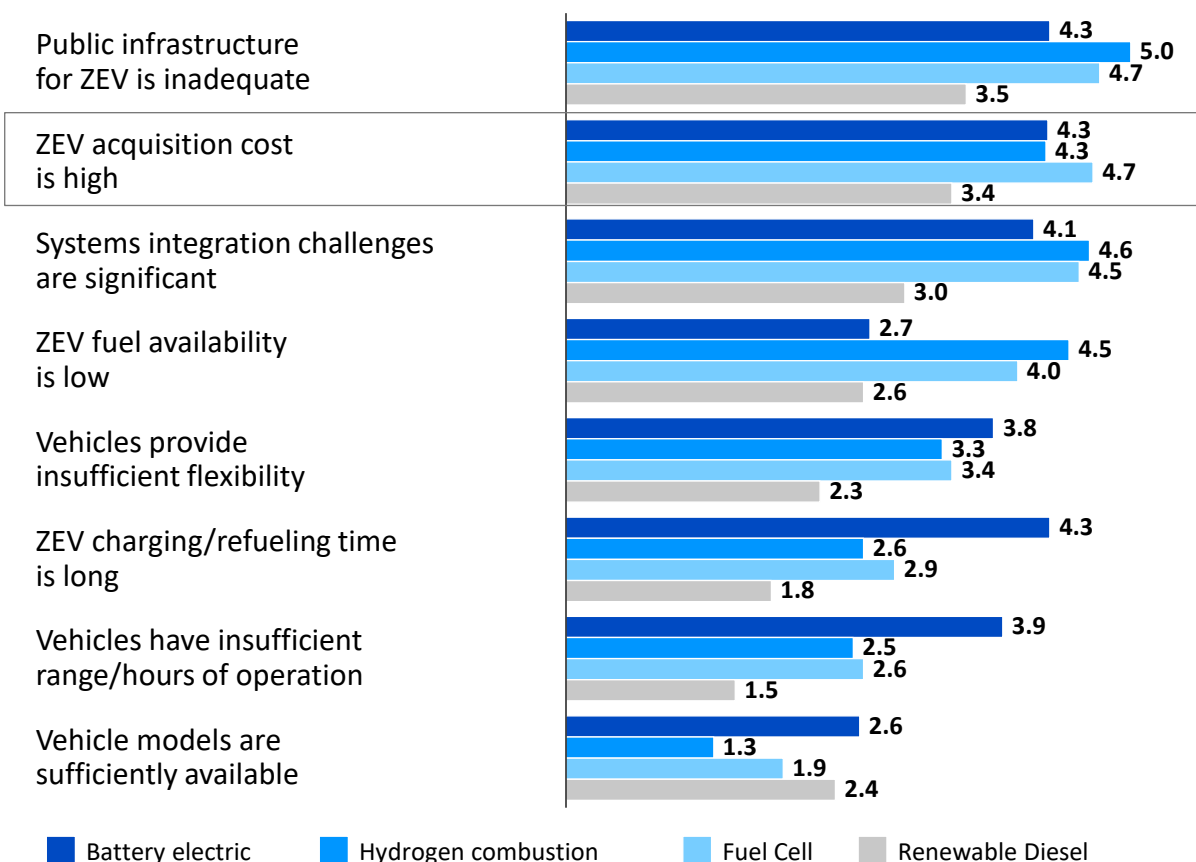
Pursue Alternate Fuels 



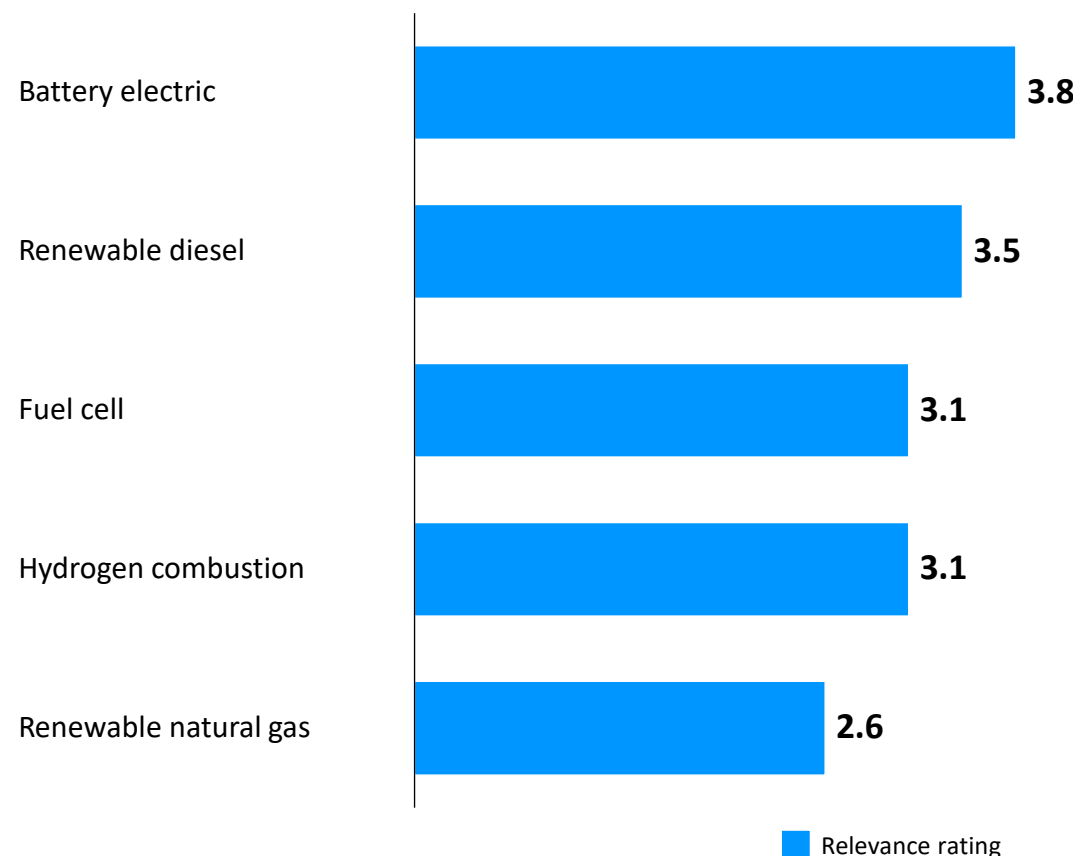
Equipment	Skid-steer loader	Telescopic handler	Excavator	Grader	Dozer
					
Typical max horsepower	20 – 100 hp	20 – 180 hp	10 – 600 hp	150 – 500 hp	70 – 900 hp
Equipment	Backhoe loader	Roller	Mobile crane	Wheel loader	Dump truck
					
Typical max horsepower	50 – 150 hp	20 – 500 hp	50 – 800 hp	30 – 2,000 hp	300 – 4,000 hp

Battery electric and renewable diesel are seen as the most viable paths to decarbonization, but concerns exist around infrastructure, cost, and integration

Industry concerns across ZEV¹ adoption factors
1 (strongly disagree) to 5 (strongly agree)



Powertrain technology relevance rating
1 (least relevant) to 5 (most relevant)



1) ZEV stands for zero-emissions vehicle

Reducing acquisition costs of electrified equipment through standardization of technology and increasing scale, potentially through partnerships

Vehicles and equipment use a variety of battery form factors and configurations, making scale benefits difficult to achieve

Manufacturing partnerships enable firms to achieve scale benefits not otherwise possible


Prismatic Cell




Example Application
In 2020, Sany and CATL entered strategic partnership for machinery electrification




Cylindrical Cell




Example Application
In 2022, Deere acquired majority stake in KREISEL, which focuses on cylindrical cell batteries



Pouch Cell



Example Application
Farasis provides pouch cell batteries for OEMs of excavators, cranes, and forklifts (specific customers not identified)



Case Study: Battery Partnership Between Accelera by Cummins, Daimler Truck, and Paccar



- Partnership structured as a JV with each entity owning 30% (remaining 10% owned by battery tech partner)
- Total investment is expected to be in the range of \$2-3 billion for a 21-gigawatt hour (GWh) factory
- The venture will initially focus on lithium-iron-phosphate (LFP) battery technology for commercial battery-electric trucks

Joint Press Release on PR Newswire

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