Mid-Power, Multi-Function Charging Systems for Compact Mobile Machinery Electrification

Increasingly impactful electrification drivers are now leading to more compact non-road mobile machinery (NRMM) and equipment transitioning to electric drive. However, this represents untread territory for many original equipment manufacturers (OEMs).

Compact NRMM like skid steers, 1- or 3-ton excavators, small tractors, and more traditionally relied on internal combustion engines (ICEs) and fossil fuels for their power source due to operational requirements and considerations. But environmental regulations, continually improving battery and charger capabilities, and other incentives erode that reliance.

In this article, we'll examine these drivers and what OEMs need to know to take advantage of this emerging market.

The Impact of Government Regulations

In recent years, government concerns over the environmental impacts of compact NRMM have led to increasingly strict regulations on their manufacture and operation. These climate change mitigation attempts range from greenhouse gas (GHG) and particulate matter (PM) reduction to comprehensive bans of small off-road engines (SOREs).

Some of the most notable include:

- **EU Stage V** – First active in 2019, Europe's regulations represent the strictest requirements for NRMM. Stage V introduced an extended scope that now covers smaller, previously unregulated engines (i.e., <19kW). Compared to Stage I, Stage V requires OEMs to meet a 97% reduction in PM and a 94% reduction in GHGs.

- **US domestic transport decarbonization** – Affecting both on-road and non-road transportation, the US Department of Energy made $96 million in funding available for research and efforts toward improving charging infrastructure, NRMM emissions, and EV efficiency and affordability.

- **CARB's zero-emissions regulation** – Taking effect in 2024, the California Air Resources Board's (CARB) zero-emissions requirement for ≤25hp engines bans selling a wide range of new gas- and diesel-powered machines and equipment within the state. This effort coincides with a $273 million voucher program to aid this transition and curb a category of emissions that has already outpaced light-duty passenger vehicles.

- **UN COP 26 targets** – The United Nations Climate Change Conference established new and revised goals for member nations—including "ambitious 2030 emissions reductions targets" and achieving net-zero emissions by 2050. Although these commitments are non-binding, they strongly indicate more and increasingly strict domestic regulations for OEMs to navigate on the horizon.

Municipal Regulations Becoming a Key Driver for OEMs

More than 100 US cities enacted NRRM or SORE regulations aimed at reducing emissions. Toronto and Vancouver have similarly pledged to achieve net zero emissions by 2040 and carbon neutrality by 2050, respectively.

Other cities around the globe that have enacted community carbon emissions targets include:

- **Barcelona, Spain** – Carbon neutral by 2050
- **Bristol, UK** – Carbon neutral by 2030
- **Copenhagen, Denmark** – Carbon neutral by 2025
- **Glasgow, UK** – Carbon neutral by 2030
- **London, UK** – Zero emissions by 2030
- **Melbourne, Australia** – Zero emissions by 2040
- **Morning Peninsula Shire, Australia** – Zero emissions by 2040
- **Oslo, Norway** – 95% emissions reduction by 2030
- **Stockholm, Sweden** – Fossil-fuel free and climate positive by 2040
- **Sydney, Australia** – Net zero emissions by 2040

Electrification of Non-Road Mobile Machinery

NRRM environmental regulations are a major driver behind the electrification of numerous industries. But they're far from the only factor.

Recent advancements in battery and charger capabilities and application-specific considerations incentivize these ongoing, major industry transitions.

Construction

Aside from environmental regulations, reductions in the following drive the construction industry's electrification:

- **Costs** – Despite upfront costs, the total cost of ownership (TCO) advantages electric NRRM achieves provide a significant return on investment due to no fuel consumption, fewer breakable parts, lower maintenance requirements, improved telematics data and diagnostics, and less repair-related downtime.

- **Noise** – Construction operations must comply with municipal noise bylaws and ordinances to keep nearby businesses, hospitals, universities, and other organizations unaffected. Additionally, metropolitan areas must often work on construction projects at night, when ICE-powered machines and equipment would cause significant disturbances.

- **Health hazards** – Particularly concerning indoor operation, operator and workers' close proximity to NRRM poses significant health and safety risks—both short- (e.g., headaches, nausea, irritation, missed work days) and long-term (e.g., cancer).

Material Handling

As a mainly indoor industry, the same health hazard concerns contributing to construction's electrification apply to material handling, warehousing, and logistics. The major additional driver is demanding—often 24/7—operations that require greater battery capacity and faster charging.

Traditionally, material handling operations would dedicate facility space for battery charging and cooling along with space on machines for additional batteries to extend capacity. Having a central, indoor location negates some of the electrification challenges outdoor industries face, but this prevents an operation from using all of its valuable floor space.

However, battery and charger innovations (e.g., lithium battery weight and size reductions, on-board and opportunity charging) enable efficiency gains and minimize potential downtime.

Agriculture

Agriculture historically represents one of the most difficult sectors to electrify due to concerns over battery capacity, charging time, and power source availability.

Many of the larger NRRMs and equipment used for farming only leave the barn during certain seasons, while lengthy days demand batteries that can last from sunup to sundown. And when out in fields, farmers haven't had access to reliable power sources to facilitate opportunity charging as in other industries. Until recently, fossil fuels have simply proved a better option despite the effect of air pollution on crop yields.

But larger battery capacity, fast charging, increased adoption of self-generated electricity within farming, and the growing availability of large-scale portable power storage continually diminish these challenges.

Outdoor Power Equipment (OPE)

As with agriculture, the primary electrification considerations for outdoor power equipment (e.g., municipal and property ground maintenance) pertain to day-long use of NRRM away from power sources.

However, OPE's smaller NRRM and equipment better facilitates electrification, and operators now have access to a variety of battery-powered alternatives (e.g., mowers). As a result, electric OPE represents the fastest-growing market segment (by power source).

On-Board Charger Market Gap

Despite compact NRMM's electrification, there's a significant market gap for on-board chargers that meet OEMs' and users' requirements. Simply put, the recent electrification push requires larger, higher-performance batteries, which—in turn—requires higher-performance chargers.

OEMs looking to benefit from the growing electric NRMM and equipment market share will need to identify and collaborate with partners capable of delivering:

- **On-board chargers** – For most applications in the industries mentioned above and others, on-board chargers and the opportunity charging they enable is essential.

- **Lithium battery compatibility and fast charging** – One of the drivers behind electrification is the transition to lithium batteries for the advantages they offer over lead-acid. For example, the fast charging lithium batteries support is crucial for making electric drive viable in agriculture. However, some operations may utilize both batteries simultaneously, which requires dual-support chargers.

- **2-11 kW output** – Compact, electric NRRM requires chargers that can deliver enough power to restore larger batteries to full capacity.

- **Battery pack and BMS communication** – NRMM chargers require more sophisticated integration and data communication (e.g., telematics) between the battery pack and the battery management system (BMS) for optimal charging performance.

- **Industrial power outlets or EVSE** – The charging power requirements for replenishing the large batteries' capacity necessitates compatibility with either industrial power outlets or standardized electric vehicle supply equipment (EVSE).

- **Small size** – On-board chargers need to fit on NRMM and equipment already designed to be compact. Space remains a premium that chargers must conform to.

- **Ruggedness and reliability** – NRMM typically experiences significant stress (e.g., off-road terrain, impacts, liquids) that on-board chargers must be protected against to ensure long lifecycles and optimal component performance.

- **Charge quality** – Ensuring batteries attain their maximum lifecycle requires chargers capable of delivering consistent charge quality for that duration and monitoring any signs of potential failure.

- **Machine integration support and customization** – More complex NRMM designs and engineering necessitates integrable chargers, which may require greater customization to support.

- **Regulatory approval** – Chargers must meet demanding international standards.

- **Manufacturing quality and scale** – OEMs need the confidence that their partners will design, engineer, and manufacture chargers that maintain their quality and preserve product and OEM reputations when produced at scale.

Compact NRMM Electrification—An Opportunity with Significant Considerations

The sheer amount of compact NRMM relied on by numerous major industries and irreversible electrification drivers present OEMs with an enormous opportunity.

Compact, electric NRMM is a largely untapped market. And owners, operators, and fleet managers will continually transition towards it as environmental regulations on ICE NRMM become increasingly cumbersome and electric drive's advantages grow too difficult to ignore.

However, because compact, electric NRMM is mostly untread, OEMs face new design, engineering, and manufacturing challenges—which will necessitate reliable partnerships and collaboration to enter the market before oversaturation.

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