OEM QUICK ACTION GUIDE FOR ELECTRIFICATION PROJECTS

Actionable Tips & Knowledge from Vanguard™ Battery Experts When Converting Gas-Powered Equipment to Electric

VANGUARD™

INTRODUCTION

As many industries increasingly prioritize sustainability, the transformational shift in how we design, manufacture, and use outdoor power equipment is here. What is that shift? It's **electrification**, and it offers a compelling solution to reduce emissions and operational costs. Starting the electrification journey may seem daunting for original equipment manufacturers (OEM), but it can be achieved successfully with the right knowledge, resources, and a trusted partner.

In this guide, we'll walk through a step-by-step process and things to consider when converting your gas-powered equipment to battery power.

A Note From The Authors

"The Vanguard team is here to help OEMs walk through this process and work out all the technical details, but we will use this guide to give you the general direction and what is needed to be successful."

Nick Moore
Director of Product Management

"Our team is excited to dive into this topic and provide OEMs with the right tools for success. We know there is a big resistance to change out there, but our goal with this guide is to help educate and ease any anxieties along the way."

Stephen Avery
Manager of Battery Applications

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STEP 1:

UNDERSTAND THE NEED FOR CONVERSION

INDUSTRIAL BATTERIES MARKET WAS VALUED AT $18.1 BILLION USD IN 2022 AND IS PROJECTED TO REACH $28.1 BILLION USD BY 2027, GROWING AT A CAGR 9.2% FROM 2022 TO 2027.[1]

1.1 Market Demand for Sustainable Solutions

Let's face it, the market demand for sustainable solutions has been steadily increasing. This is driven by a combination of factors including environmental awareness, regulatory pressures, and consumer preferences.

1.2 Environmental Concerns and Regulations

This is what primarily drives the need for battery-powered equipment. Some of the key factors contributing to this trend include:

- Reducing emissions
- Air quality improvement
- Noise reduction
- Regulatory compliance
- Sustainability
- Technological advancements

1.3 Advantages of Battery-Powered Equipment

Once there is a good understanding of the demand for battery-powered equipment, start recognizing the many advantages battery power can give your machine.

The advantages of battery-powered equipment include:

REDUCED OPERATING COSTS (LOWER TCO)

DECREASED MAINTENANCE REQUIREMENTS

IMPROVED COMFORT AND USER EXPERIENCE

VERSATILITY AND ADAPTABILITY

REGULATORY COMPLIANCE

ENERGY EFFICIENCY

REDUCED DEPENDENCY ON FOSSIL FUELS

[1] "Industrial Batteries Market," MarketsandMarkets, April 2022

STEP 2:

ASSESS CURRENT GAS-POWERED EQUIPMENT AND ITS SUITABILITY

Not everything needs to be electrified. Sometimes a gas-powered machine is worth staying as-is. However, if certain factors are posing the question of taking on a conversion to electrification in a specific application or piece of equipment, consider it.

2.1 Performance Evaluation

Evaluate the feasibility of electrifying each piece of equipment in your fleet or product portfolio based on factors such as **size, power requirements, and usage patterns.**

2.2 Prioritize Suitable Equipment

Prioritize equipment that has high fuel consumption and operates in urban or enclosed environments where emissions are a concern. After an adequate list is developed, understand the outcome of what you'll see, and what end-users will benefit from, once completing a successful conversion.

Size: The conversion for a walk-behind trowel will look a lot different than a conversion for an excavator.

Power requirements: Many gas-powered machines are overpowered, so you need to determine what the actual needs are, both the peak and continuous power. Motors can be much more efficient in using the power from the battery than some mechanical systems with belts, so you likely don't need that same engine HP in an electrical system.

Usage patterns: Think duty cycles. How long is the machine usually on versus off? Does it drive uphill and if so for how long? Is it used every day? Once a week? You get the idea.

STEP 3:
RESEARCH COMPONENTS

Look for components designed specifically for your type of equipment. There are lots of different components out there – some that might not be necessary for your application and some that are critical.

3.1 Component Compatibility Analysis

Always consider factors such as compatibility with existing equipment, reliability, performance, and ease of installation.

> It's not as easy as taking an engine out and replacing it with a battery. You're replacing the fuel tank and the spinning shaft so you'll need a new energy storage system (the battery), motors, and motor controllers. If your application requires more than one motor, a vehicle control module (VCM) is needed. The VCM determines how you set priority in the machine's drive wheels and other capabilities it requires to do its work. For example, a skid steer loader not only drives but performs lifting and loading movements while a walk-behind machine has less complexity in how it operates. The person operating the walk-behind machine somewhat acts as the VCM.

3.2 Component and Supplier Research

Research reputable suppliers and consult with experts in the field to ensure you select the most suitable components for your needs.

> In most cases, the components you choose need to talk to each other to work properly. Be aware of the communication protocol being used between all the components to ensure you are getting the full benefits of an electrified system. Also, coming from the engine world to electrical components you will find that spec sheets and available information can vary widely from manufacturer to manufacturer, so ensure you are doing your homework and working with a company that can help you determine the proper parts for your needs.

STEP 4:

SELECTING BATTERY TECHNOLOGY

Once you've narrowed down an application type or piece of equipment you are considering converting, start thinking about the different types of rechargeable batteries you will use.

4.1 Lithium-Ion Versus Other Battery Types

You should always keep Lithium-Ion high on your list of considerations. Create a solid list of pros and cons or wants and needs to get your unit(s) ready for conversion.

WHAT ARE THE DIFFERENT BATTERY TYPES?

Lead Acid: This is one of the most common types used in industrial and commercial applications. There are two main types of lead acid; flooded which requires maintenance and sealed which does not. Lead acid batteries are inexpensive and widely available; however, they are heavier, have a shorter lifespan, and have limitations to discharge depth.

Nickel-Cadmium: This is an older type of rechargeable battery most commonly found in electronics. It has a high temperature tolerance, is relatively inexpensive, and recharges fast. The downside is that they are not as powerful as nickel-metal hydride batteries and do suffer from self-discharge issues.

Nickel-Metal Hydride: This is a newer type of rechargeable battery and is typically found in electronics and some automotive applications. These batteries have a higher capacity than nickel-cadmium and lead acid and are lighter in weight. The downside is that they are expensive and have high rates of self-discharge.

Lithium-Ion: This battery type is a very popular choice for many kinds of applications. Lithium-Ion has a much higher energy density than any other type of rechargeable battery. It has a lower self-discharge rate, a longer life, and is typically lighter in weight. However, it can be more expensive than its top competitor – lead acid.

OEM SPOTLIGHT

Club Car continues to transition more of their lead acid powered vehicles to Lithium-Ion with Vanguard Commercial Power. When Club Car was looking for a new battery supplier, it became clear that Vanguard's line of Lithium-Ion batteries would be the perfect fit for them to compete in the battery power market. With Club Car's Tempo® line of vehicles, they sought flexibility, adaptability, and speed – and Vanguard stepped up to the plate.

STEP 4: SELECTING BATTERY TECHNOLOGY

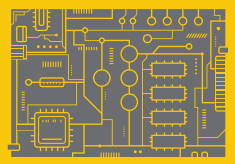
4.2 Capacity and Power Requirements

Capacity is how much energy is available. How fast you will use that capacity depends on your power requirements. People often refer to the C-rate a battery is capable of. 1C means that the power you're consuming will discharge a battery in one hour. 2C means you're using twice that power, which in turn means you'll run out the battery in a half hour, while 0.5C means you're using half the power and will use the battery in 2 hours. You need to work through the power needs to determine how much battery to put on your application to get to your desired run time. Also, the C-rate you run a battery at impacts its lifespan, so you want to understand what that means for the batteries you are considering.

4.3 Considerations for Battery Management Systems (BMS)

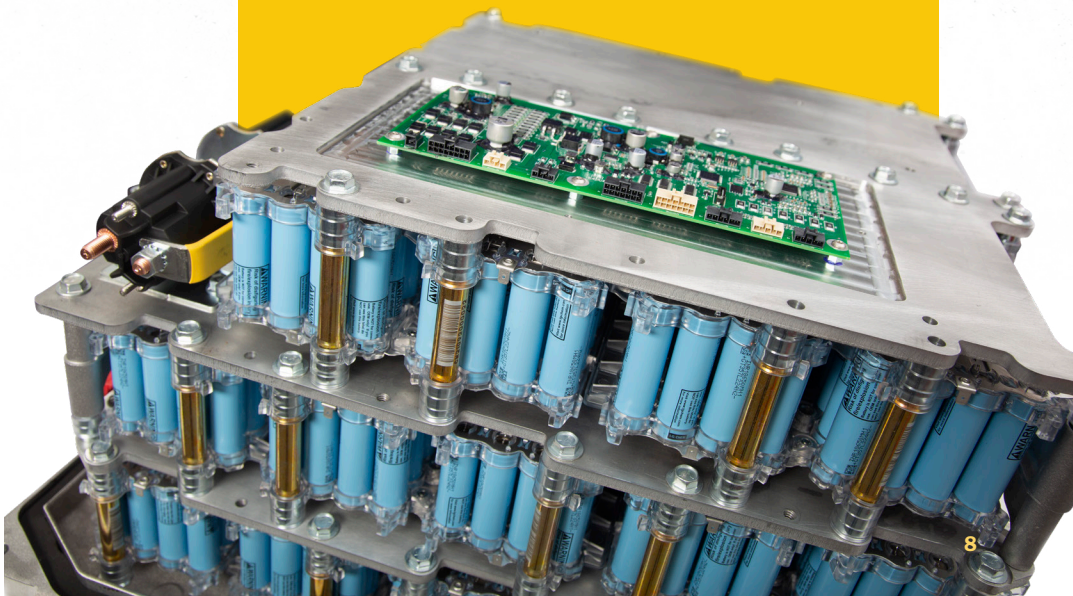
The BMS is the brain of the battery, so there is not much debate about the critical role it plays. Here are a few protection features to consider when selecting a battery with a BMS:

- **Overvoltage protection**
- **Undervoltage protection**
- **Overcurrent protection**
- **Short circuit protection**
- **Temperature monitoring**



INTELLIGENT BY DESIGN

With Vanguard commercial batteries, the BMS is a part of the package. Our onboard BMS monitors, controls, and protects the battery to help prevent misuse and abuse, safeguarding your investment.



STEP 5:

DESIGNING BATTERY INTEGRATION

When designing for battery integration into various systems or products, a few key factors need to be considered to ensure optimal performance, safety, and efficiency.

5.1 Compatibility With Existing Equipment

As an OEM, you need to determine how much work there will be to convert an existing piece of equipment to electric, versus designing something purpose built. Many engine-powered applications do lend themselves to a simple conversion, but complex, embedded systems can be more difficult. Battery selection can also play a big role, as you need to understand the robustness and IP rating of the battery to know if you need to build extra protections around it, or if it can be mounted just like the engine was.

5.2 Weight and Balance Considerations

Converting from an engine to a battery will very likely impact where the weight is on the machine. In mobile equipment, you need to ensure your design keeps an appropriate center of gravity and tilt angles. Lithium-Ion batteries can weigh much less than lead acid, which can be a benefit in some cases, and a detriment in others where weight is needed. Sometimes multiple smaller batteries may be needed rather than a single larger one if you need to disperse the weight to specific places on the equipment.

STEP 6:

PLAN CHARGING INFRASTRUCTURE (IF YOU NEED TO)

Charging infrastructure is crucial for battery-powered equipment for a handful of reasons such as **availability and accessibility, range anxiety mitigation, and supporting the growth of electric equipment.**

6.1 Options For Charging Stations

Assess your site's electrical infrastructure and determine the requirements for installing charging stations. You can build equipment with onboard charging or off-board. Onboard typically makes it easier to connect, often just needing to bring an extension cord from an outlet to the unit. On higher power applications, you may need access to a 240V outlet if you want to charge faster.

6.2 Fixed Versus Removable Batteries

With a fixed battery permanently mounted to the equipment, you need to determine the onboard or off-board charging mentioned above. There is a third option now, though, with a swappable battery like the Vanguard Si1.5, you can have a charger off the machine to which you move the discharged battery to charge and can have another pack ready to go to keep the equipment running.

6.3 Integration With Existing Infrastructure

Consider factors such as voltage, amperage, and location of charging points to optimize convenience and efficiency. Consult with electricians or infrastructure specialists to ensure compliance with safety regulations and efficient charging setup.

3 REASONS TO HAVE A WELL-ESTABLISHED CHARGING INFRASTRUCTURE

1. Availability & Accessibility
Having a robust charging infrastructure ensures that users have access to charging stations wherever their work takes them. Portable charging stations, where users can transport their chargers in easy and efficient ways, will ensure the work can still get done. There is a big opportunity for this with removable batteries.

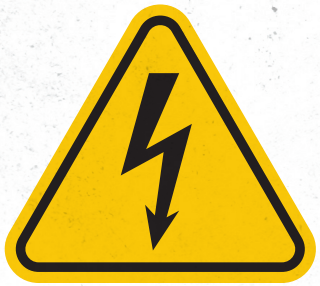
2. Range Anxiety Mitigation
For electric equipment, range anxiety – the fear of running out of battery charge before the job can get finished – can be a significant concern. A well-developed plan for users can help alleviate this anxiety by integrating the charging features. Manufacturers can partner with a battery supplier that will help them integrate these capabilities directly into their products, like built-in charging ports.

3. Supporting Growth of Electric Equipment
Simply having a charging plan and integrating it with your equipment will increase more widespread adoption of electrified equipment. Without adequate charging solutions, users may hesitate to switch from traditional gas-powered equipment.

STEP 7:

ADDRESSING SAFETY

Properly handling and maintaining Lithium-Ion batteries are crucial to ensure their longevity, safety, and optimal performance, so educating your customers on this is important.



7.1 Battery Handling and Maintenance

Put proper guidelines in place that are easy for future users of your equipment to follow. Take a look at a handful of things we think you should cover in your handling and maintenance plan:

- Know if your battery has live terminals or internal disconnects to know how best to handle it
- Avoid extreme temperatures
- Follow proper charging techniques
- Properly store batteries
- Avoid physical damage
- Regularly inspect and clean the battery with something dry if needed
- Update firmware
- Avoid overloading
- Avoid constant over-discharge

7.2 Thermal Runaway Prevention Measures

The best thing an OEM can do here is to work with a battery supplier who leads with safety in everything they do. Ask potential suppliers a set of questions that address the following topics:

Quality assurance and testing: Ensure that batteries used in your equipment follow industry standards and undergo rigorous quality control measures.

Battery Management System (BMS): Make sure any Lithium-Ion battery you're considering has a robust BMS in place to monitor and manage battery parameters such as voltage, current, and temperature.

Passive propagation resistance (PPR): One method of thermal management you may discover is PPR which Vanguard battery engineers leverage. In PPR, cells in the Lithium-Ion battery are properly spaced and compartmentalized so that if one has a failure, it is unlikely to spread to any neighboring cells.

Physical protection: The main protection here is the battery's enclosure and how durable it is. This helps prevent mechanical or electrical damage that could lead to short circuits or other failures.

Cell selection and configuration: Choose battery cells from reputable manufacturers and select cell chemistries suitable for the intended application.

STEP 8:

TESTING AND PROTOTYPING

Test, test, test. You'll want a professional, experienced team helping you at this stage. They should be able to identify and perform the appropriate application tests, select and test the power source for your application, and troubleshoot issues that may arise in the field.

8.1 Performance Testing

In many cases, the best way to determine what you need is to build a prototype and test it. Smart batteries with a BMS allow you to capture data while testing so that you can see exactly what kind of loads you encounter and can design the system with the appropriate battery to handle that load and give you the ideal run time.

8.2 Durability and Reliability Testing

Ensuring the components you choose are built to be used in the conditions your equipment operates in is critical. Work with the manufacturer to understand what testing they've done, then create your test plan to supplement that. You don't want a system that is too fragile to handle the use case your customers are going to put the machine through.

8.3 User Feedback and Iterative Design

Performance can be tweaked, in many cases via software changes which are easy and unobtrusive to the machine design. Make sure you understand the parameters that can be adjusted and have a partner that enables you to give your equipment the feel and performance that your customers are looking for.

Early prototyping of our first-generation battery provided valuable insights on battery power output, weight, shape, dock configurations, and motors for integration with OEM units.

THE VANGUARD ADVANTAGE

The biggest advantage you get from Vanguard Battery Systems is that a fully integrated system is provided. This includes the Lithium-Ion battery with an integrated BMS, motors, motor controllers, and chargers. Vanguard Battery Systems is truly a one-stop shop to alleviate the amount of work an OEM has to do.

When it comes to safety, it's our top priority. Vanguard battery engineers have designed many features into our battery packs that keep them safe and you confident:

- We monitor every cell module assembly (CMA) within the battery which allows us to react to issues quickly.
- The design of our battery packs is heavily focused on passive propagation resistance (see page 11 section 7.2).
- We use wire bonding to connect the cells so that if one cell fails, it is electrically disconnected from the rest of the pack and does not impact the performance of the battery.
- All Vanguard batteries have a physical disconnect, controlled by the BMS to keep the battery safe.
- We have tier plates separating the cell layers so that if a cell has an issue, it is separated from the tiers above it.
- Beyond using properly thermal-rated materials throughout the packs construction, the packs unique die cast aluminum structure and enclosure provide additional resistance to high temperatures in the event of an issue.

Last but not least, Vanguard's Power Application Center (PAC) teams around the world identify and perform the appropriate application tests, select and test power sources for the application, and troubleshoot issues that may arise in the field. The top-tier knowledge of in-house Vanguard battery experts is next to none and makes for a great partnership between OEMs and Vanguard.

INTEGRATED SYSTEMS + SAFETY + EXPERTISE

PARTNER WITH VANGUARD BATTERY SYSTEMS

Contact us today if you've been thinking about making the switch to electrification. Our well-rounded team will guide you through a process like this one and ensure your electrification goals are met with success.

EMBRACE ELECTRIFICATION

Converting gas-powered equipment to battery-power represents a significant step toward a zero-emissions future and efficiency gains in many industries.
By understanding the steps outlined in this guide and leveraging the expertise of professionals in the field, you can successfully transition to battery-powered equipment while reaping the benefits of reduced emissions, lower operating costs, and enhanced performance. Embrace the opportunity to lead the way in changing how the world gets work done.

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