Solar panels are a cost effective and emissions-free source to recharge batteries. They have improved in efficiency and dropped in price, and today, they cost anywhere from just under $1 per watt to $1.50 per watt.

Building back better with batteries

BY **RICHARD CADENA** AND **NEEL VASAVADA**

WHETHER YOU'RE TRYING TO SAVE MONEY or trying to save the planet, it's time to reconsider how to power live event productions.

Most of the time we rely on the grid power or generator power without much thought given to the direct and indirect costs. Direct costs—the costs of electricity—are rising, and the indirect costs—the greenhouse gas emissions—are damaging the planet. Perhaps there's a better way.

Battery technology has come a long way in a short time, thanks to the research and development that has gone into electric vehicles, and they have reached the point where we should consider how to use them to our advantage to power events of all sizes. You are probably very familiar with lithium-ion (Li-ion) and lithium polymer (Li-Po) batteries. They have very high energy density and are used in portable devices like mobile phones, laptops, tablets, drones, and remote-controlled cars. You might be less familiar with lithium iron phosphate (LFP)

batteries, which are used in electric vehicles and whole-house battery systems. They also have high-energy density, but they are very stable and safer than Li-ion and Li-Po batteries. They don't pose the same fire and explosion hazard, nor do they have toxins such as cobalt.

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Battery lifecycles have also improved considerably. All batteries lose storage capability and fail over time. LFP batteries typically have 5,000 to 10,000 full charge/discharge cycles before their performance degrades significantly. If they are used daily, this means they will remain in service for at least 10 years. LFP batteries also charge faster than other lithium-based batteries, which allows for a quick turn-around. For live events that means, if solar recharging is not an option, a battery bank can be recharged from the grid overnight when demand costs are lower or by using a generator.

One of the best-known benefits of using batteries is that they can store energy from solar panels, which is cost-effective and free of emissions. Like batteries, solar panels have improved in efficiency and dropped in price, and today, they cost anywhere from just under $1 per watt to $1.50 per watt. There may also be governmental assistance in the form of tax credits or rebates for installing solar power.

Charging battery banks using solar, wind, or hydro is ideal because these energy sources have the smallest carbon footprint. Of course, batteries can also be recharged using grid or building power. A hybrid inverter can be used to connect a battery bank to both solar panels and the grid to better ensure reliability in areas where the photovoltaic power potential is low. (See Solar Resource Map at https://bit.ly/3IDnMP3.) Even though grid power is likely to be much higher in emissions than renewable energy—as of this writing, almost two-thirds of the world's electricity was generated by burning coal and natural gas (See *bp Statistical Review of World Energy 2022*, 71st edition at http://estalink.us/bpworldenergy2022)—there are opportunities to buy solar power through the grid by subscribing to a solar farm. As an example, see National Grid's community solar program at www.bit.ly/3YA3tHH.

On a remote location, such as an outdoor festival or stadium show where building power is unavailable, a battery bank with an inverter can be charged using solar panels and a portable power generator as a backup. When the batteries are unable to provide enough power, a generator can take over. This better ensures that the generator is operating at peak fuel efficiency because diesel generators burn fuel more efficiently when they are more heavily loaded. For example, a fully loaded Multiquip 125 diesel generator has an efficiency of about 17.6 kWh per gallon of fuel, but when it's only one-quarter loaded, the efficiency drops to about 12 kWh per gallon. With a battery/generator tandem team, the system can be optimized to supply battery power for periods when the load is lighter, such as during load in and set up when the main use is for chain motors and periodic testing of equipment. Once the system is up and running, then the generator can take over.

Battery power has other advantages as well. Diesel generators are loud, they spew noxious odors, and if left unattended, they can be hazardous. If a generator develops a fuel leak it becomes a fire hazard, and sparks from the exhaust can ignite dry leaves on a nearby tree or other vegetation. In addition to eliminating these hazards, batteries require much less maintenance than do diesel generators, they eliminate hazards and spills due to refueling, and they don't require fuel storage.

Also, batteries are completely silent, making them ideal for supplying power on movie sets, classical concerts, and other noise-critical events. Since they have zero emissions, they can be located much closer to people without affecting the air quality. This contributes to the cost savings since it requires less infrastructure, and it also improves the quality of the power since it can drastically reduce voltage drop, and that can improve the quality of a sound system.

Battery technology has come a long way. Lithium iron phosphate (LFP) batteries have high energy density but are very stable and safe. They pose no hazard and have no cobalt.

Using battery power also can help mitigate transient voltage spikes and surges that come from the electrical grid. Transient spikes are typically very short in duration, and they can be very high in voltage. If you are unaware of them, it's probably because your meter is too slow to detect transient spikes, but they are there. They can be caused by lightning strikes, arcing, the switching of large loads on the grid (especially inductive loads), and other events. Transients can damage sensitive

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electronics like circuit boards and integrated circuit chips by creating excessive heat. They also can damage transformers and stress the insulation of conductors, which can lead to breakdown, arcing, and further damage. If a battery bank is isolated from the grid, then it is also isolated from all of those transients, and that can help extend the life of the connected devices.

Surge protectors are often employed to guard against transient surges and spikes, and they are primarily a battery and inverter combination. Many inverter units already have transfer switches designed for computer equipment built into them, which means they easily can be used as a backup/uninterruptable power supply from a battery bank.

Additionally, inverters and battery systems respond to surging demand much better than generators do. Generator power comes from the prime mover, which in live event production is typically a diesel generator. In response to high current peaks, the engine has to increase its mechanical power output to supply the alternator and keep up with the load. It takes time for it to ramp up the horsepower, and in an audio or lighting system, often those peak demands are so fast that the demand has passed before the generator can respond. That means the audio system doesn't respond to certain transients, like a booming kick drum or a musical accent, the same way a battery/inverter system can. Since the energy is already stored and an inverter can respond very quickly, it can respond to an audio system much better than a generator. Tests have shown that an arena-sized line array that draws about 35 to 50 A on average can peak at 150 or 200 A in extremely short bursts.

One of the unexpected benefits of using battery power for live events is that they can be less susceptible to induced noise, since they are a separately derived system. In a sense, they can act like an isolated ground system for audio, video, or lighting. Trials with audio systems are showing promise in terms of sound quality. One audio engineer said, "I noticed the bottom end transient response to be noticeably tighter and faster, with less fatigue in the high frequencies." Trial runs are also planned for a well-known guitar player who is extremely selective about his tone. The authors believe that locating the source closer to the load and reducing voltage drop and induced noise could provide a reliable portable power package that can easily tour with the artist, making the sound quality independent of the local power.

But battery power is not without its downside. First, the upfront cost is higher than using grid power, and the return on your investment could take as long as five to ten years, depending on the circumstances. Although the up-front cost for battery systems can be three to five times more than a generator, over the life of the system batteries start to save money and then pay dividends. But to completely replace one or more 400 A 3-phase switches with battery power will require a large system. If it's a portable system, the weight will be considerable, although it's comparable to a similar sized generator. And in extremely cold conditions, a battery system may be troublesome. LFPs have a rated operating temperature from -4° F (-20° C) to 140° F (60° C); charging them in freezing temperatures (32° F or 0° C and below) can damage them.

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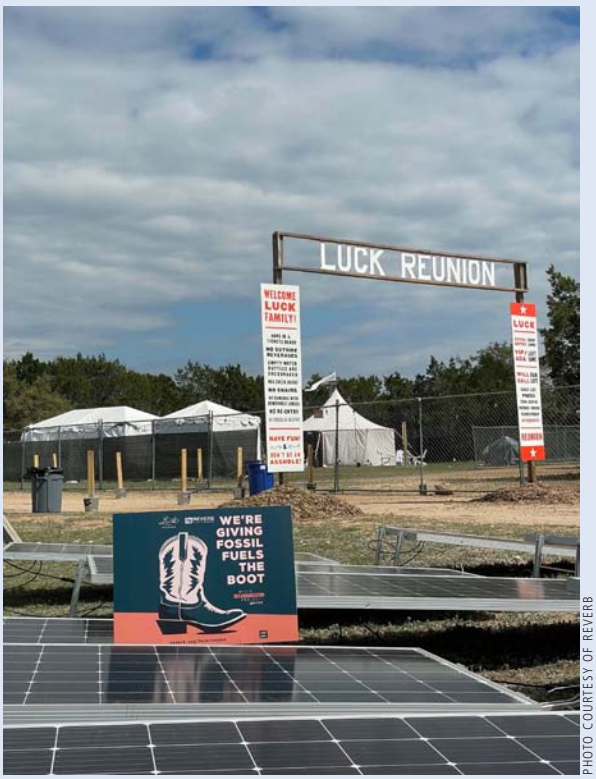
That said, there are already advancements to offset this. First of all, 3-phase inverter systems can be charged by single-phase or split-phase services. This means that as long as the battery capacity is matched to your overall daily requirements, you can bring 3-phase or split-phase anywhere there's an outlet, saving considerable money over a dedicated outlet. When you have loads, such as 3-phase amplifiers, that might run six hours a day, the 18 remaining hours to replenish that capacity is plenty. Finally,

REVERB partners to green concerts and engage fans

Environmentalist Lauren Sullivan recognized the power that musicians brought to environmental campaigns when she was working at the Rainforest Action Network. At the same time, her musician husband, Adam Gardner, of the band Guster, was concerned about the size of his band's environmental footprint when they were on tour. After speaking to a number of other touring musicians who felt the same way, they decided to form REVERB, a 501(c)(3) nonprofit, in 2004. Lauren reached out to Bonnie Raitt's manager, Kathy Kane, after seeing Bonnie's *Green Highway* tour which was an earth-friendly tour that educated fans at shows. REVERB was initially a project of Kathy and Bonnie's ARIA Foundation until it grew into its own 501(c)(3) organization.

Early on, REVERB partnered with Dave Matthews Band, Jack Johnson, Maroon 5, John Mayer, and Barenaked Ladies, and they continue to work with all of these bands to this day. Their mission is to partner with musicians, festivals, and venues to green their concert events and engage fans at shows to take environmental and social action. Most recently REVERB partnered with Luck Presents to replace diesel-powered generators with solar panels and intelligent battery systems to power the stages and other areas of the Luck Reunion festival in Austin, TX. Their goal was to reduce at least 75% of emissions related to fossil fuel power in these areas and demonstrate that clean energy options are a viable and affordable solution for large-scale music events. REVERB brought in Overdrive Energy Solutions to provide and manage power generation use and distribution.



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battery systems generate some heat while being used, and the latest generations have heaters built in. Although this takes some energy at first, the problem of charging in sub-freezing temperatures is easily solved.

Lithium-ion batteries have also been vilified, rightly or wrongly, by some high-profile accidents, like the exploding hoverboards. But lithium iron phosphate battery technology is much safer. LFPs are chemically stable, and they are non-toxic. Portable battery banks are also typically packaged in steel enclosures, making them explosion-proof and virtually immune to catching fire.

All of this is not just theory, it's already a reality. For the Birmingham 2022 Commonwealth Games, James Eade helped to deploy three-million volt-amps of battery power to reduce the run time of the generators they used. During set up, the generators ran for two hours each day to charge the battery banks. "The fleet of 122 generators (26 MVA)," he wrote, "ran on HVO [hydrotreated vegetable oil] which reduced our carbon footprint by over 1,000 tonnes." They also used 120 kW of solar panels to supply about one-third of the total electricity required for the event. To be sure, there were some challenges, but in the end they triumphed. (See *Light & Sound International*, October 2022, page 26.) ■

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In 2003, Neel founded Apex Speed Technology, a provider of control systems and engineering consulting for prototype, research and development, and motorsports vehicle projects. Neel has also led business development for capital equipment suppliers and tech companies in live events since 2012. He led eps America llc, one of North America's fastest growing production equipment suppliers of the last decade. Neel has constantly been a "go to guy" for growing live event companies. He can be reached at neel@overdrive.rocks.