# How Hybrid Power Distribution can Make Gigafactories more Energy Efficient and Sustainable

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## Executive summary

Gigafactories are under increasing pressure to lower their environmental impact and reduce the cost of manufacturing battery cells. A novel approach to addressing these concerns is employing hybrid architectures that include both direct current (DC) and alternating current (AC) distribution systems. This paper explains some of the industry bottlenecks and describes hybrid architectures that could be used in gigafactories to facilitate improvements in sustainability efforts and reductions in manufacturing costs.

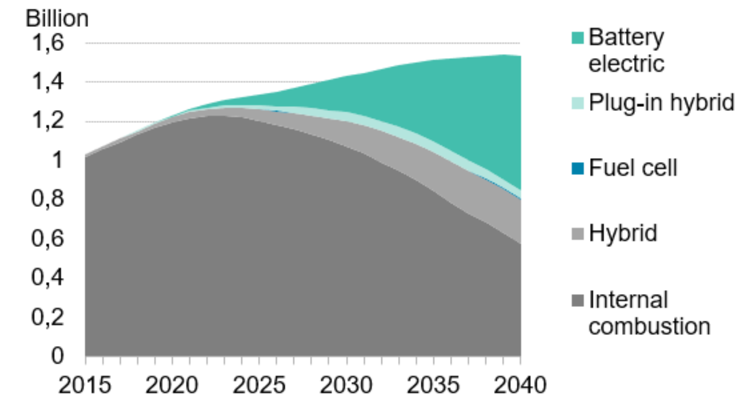
## Introduction

Today's businesses face a significant, yet seemingly conflicting choice between growth and the inherent increase in energy consumption and decarbonization. One way the automotive industry is addressing this challenge is by reducing its reliance on fossil fuels, transitioning away from internal combustion engines (ICEs) and moving toward battery electric vehicles (BEVs). The growing demand for BEVs necessitates **(Figure 1)**[1] an increase in battery production, which requires battery manufacturers to improve production efficiency and decrease manufacturing costs. Global EV sales shares reach 60% by 2040 and exceed 75% in several countries. [1]

**Figure 1**

*Electric Vehicle Outlook*

*Source: BloombergNEF*




## Battery Formation Process Requirements

Battery formation is the process of performing the initial charge/discharge operations on the battery cell. During this stage, special electrochemical solid electrolyte interphase (SEI) will be formed at the electrode, mainly on an anode. This layer is sensitive to many different factors and has major impacts on battery performance during its lifetime. Battery formation can take a number of days depending on the battery chemistry. Using a 0.1 C (C is the cell capacity) current during formation is the normal, taking up to 20 hours for a full charge and discharge cycle. This makes up 20-30% of the total battery cost. However, battery formation protocol is usually confidential and can vary from one application to another.

Electrical testing use currents of 1 C for charge and 0.5 C for discharge. Each cycle requires around 3 hours, with a typical test sequence requiring several cycles. Battery formation and other electrical testing usually have tight accuracy specifications with the current and voltage controlled to more than ±0.02% in the specified temperature range.

The formation process is one of the most energy consuming processes in a lithium-ion battery production's life cycle. It is also a critical process and cannot be eliminated without undermining cell quality[2] **(Figure 2).** Therefore, one of the better ways to improve energy efficiency is to bring innovative power distribution and energy monitoring technology to help a gigafactory be more efficient and produce cells in a more sustainable way.

[1] BloombergNEF: Electric Vehicle Outlook 2022: https://about.bnef.com/electric-vehicle-outlook

**Figure 2**

*Energy consumption for common battery manufacturing processes*

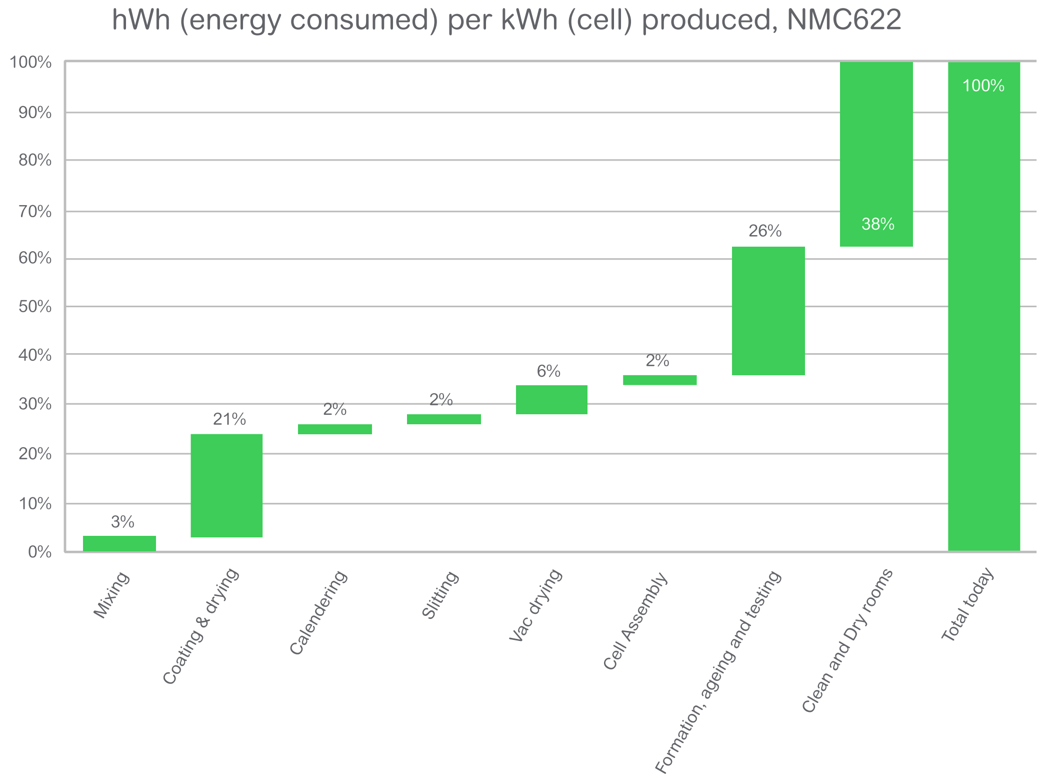



**Figure 3**

*Information on the formation process*

DID YOU KNOW? –
The formation process consumes 26% kWh per cell produced. It is one of the highest energy consuming processes -- alongside coating/drying and clean/dry rooms. [2]

[2] Strategies for Improving the Battery Manufacturing Process Dr. Ahmad Mikael Mohsseni

# Power Efficiency

Power efficiency is especially important as a factor in battery formation costs within the manufacturing process. It would be counterproductive for these environmentally friendly vehicles to use batteries manufactured in a way that wastes large amounts of energy.

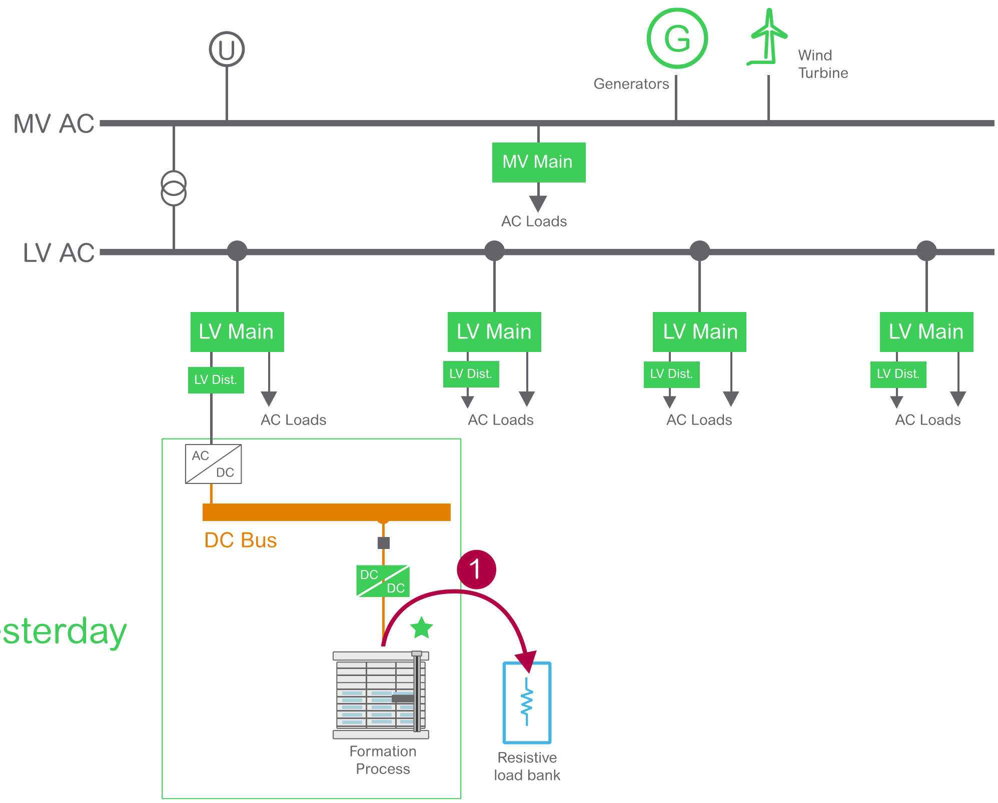
There is already research focused on optimizing some types of existing systems where batteries are discharged into resistive loads. Some battery manufacturers use this energy for building heat or to simply vent hot air outside.

Although discharging batteries into resistive loads **(point 1 in Figure 4)** is the simplest method of battery discharge, the costs quickly add up when large numbers of batteries are put through charge/discharge cycles. We call this “the method of yesterday” or ERA 1.

**Figure 4**

*Yesterday’s state-of-formation process without any regenerative features.*

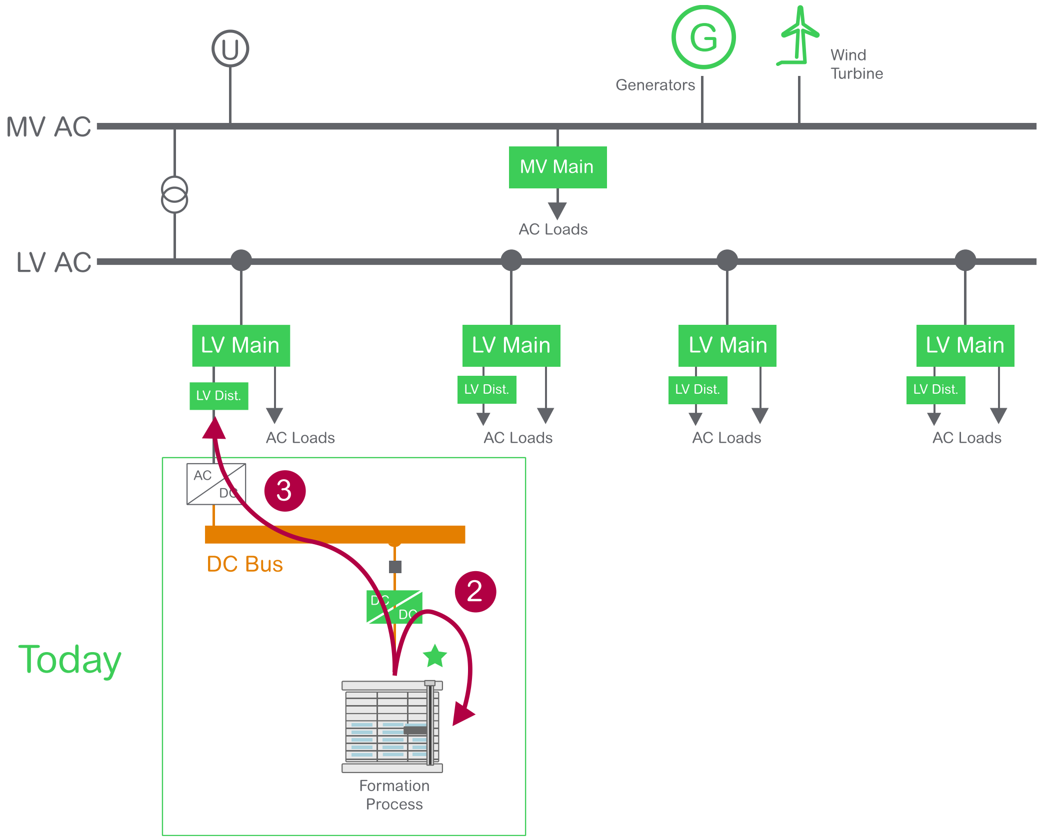
Yesterday




Today, many formation OEMs have a feature that repurposes the battery’s discharge to a set of additional batteries. This is better than “the method of yesterday” or ERA, but still has cost limitations and does not aid a flexible power distribution architecture **(point 2 on Figure 5)**. Instead, the discharge of the battery can be sent to the AC part of the gigafactory **(point 3 on Figure 5).** However, this also reduces operational efficiency as this energy had previously been converted from AC.

**Figure 5**

*Current state-of-formation process within gigafactories with regenerative features.*




# Hypothesis of Energy Availability

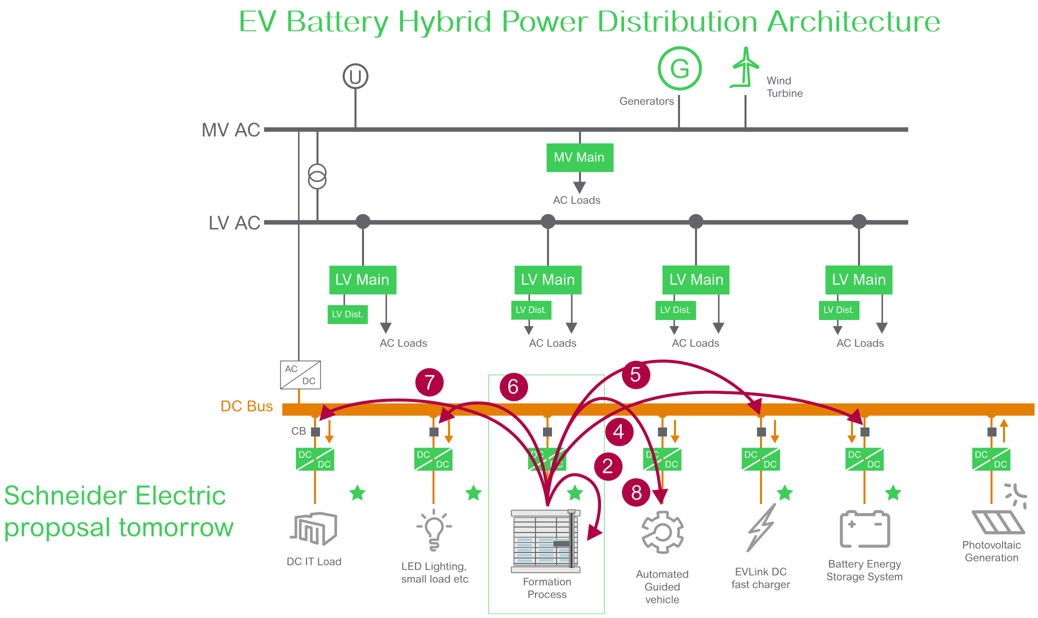
In this paper, we present an innovative solution that will offer gigafactories the flexibility to repurpose the discharge energy within the DC area of the factory (i.e., local energy first). This innovative and flexible power distribution system will help gigafactories better manage their energy efficiency and improve their carbon footprint.

With this system, we could repurpose the discharge energy into the DC main bus to keep the energy local and avoid the AC/DC gymnastics. For example, the formation process could act as a huge battery source that could inject the discharge power in the local DC bus **(Figure 6)**. This could then be used for DC loads within the gigafactory such as an on-site DC microgrid.

The discharge energy from the formation process could be used to store power in the local battery energy storage (BES) or any other DC load. There could be a potential use of the BES, by using it as backup energy instead of using fossil fuel generators. Such systems will enable gigafactories to scale and produce a higher volume of cells, discharge power coming from the formation process, as well as increase flexibility to create more renewable sources of energy.

**Figure 6**

*Tomorrow's state-of-the-formation process by Schneider Electric that could repurpose the energy within the DC bus, providing flexibility and reducing carbon footprints.*




More specifically, at Schneider Electric, we are developing an intelligent and automated forming system, including flexible hardware and AI based software to manage the forming process. This includes the scheduled production volume and actual input of fresh cells, the measured characteristics of each cell, available space at each step of the forming / ageing process and the available renewable electricity or grid peak shaving request.

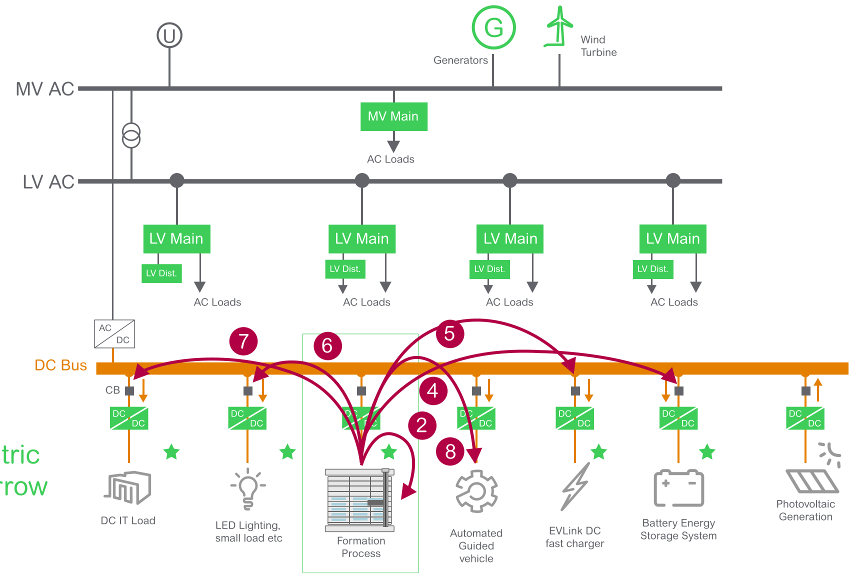
# Solution

**Figure 7**

*Tomorrow's state-of-the-formation process by Schneider Electric that could repurpose the energy within the DC bus, providing flexibility and reducing carbon footprints.*

EV Battery Hybrid Power Distribution Architecture

Schneider Electric proposal tomorrow




That system is a hybrid AC/DC Microgrid system encompassing several elements:

- A bidirectional AC/DC converter
- Solid state protection devices
- PV with DC/DC converters
- DC/DC bus converters for providing bi-directional connection from the main DC bus to the cells
- DC/DC converters for cycling the battery cells
- DC/DC converters for various DC load applications
- DC/AC converts for drives in factory

Energy from the formation process can be sent to power other DC loads in the gigafactory's DC microgrid and it can also be used to store energy in the local battery storage systems. This could contribute to the DC microgrid system. The battery storage system's advantage is that the factory can rely on non-fossil fuel backup energy instead of diesel generators.

The gigafactories can also make use of load shedding with smart AI. This enables cell charging when the electricity is cheap and discharging to the main DC bus for other DC loads to reuse, instead of converting back to AC. This would help to increase efficiency and reduce costs.

Similarly, photovoltaic (PV) systems can be used to inject energy into the main DC bus.

## Hypothesis of energy availability:

Based on this simplified hypothesis we have made below, 25,600 cells (Cell*number of trays*formation machines) can contribute 11.5MWh of energy to the DC microgrid.

**Table 1**

*Table showing our hypothesis of energy availability*

**ASSUMPTIONS:**

- **The cell's energy capacity is 100Wh**
- **The cell goes through 5 cycles from 0% to 100% to 0% SOC,**
- **The efficiency of energy transfer during the charge and discharge (DC-DC) is 90%**
- **The efficiency of energy transfer from formation back to the AC distribution (DC-DC, DC-AC) is 85%**
- **1 cell requires 100Wh/90% = ~110Wh of energy for charging.**
- **1 cell delivers 100Wh*90% = ~90Wh of energy during discharging.**
- **1 formation machine has 10 trays.**
- **1 tray has the capacity for 256 cells.**
- **A gigafactory has 10 formation machines.**
- **Total cell energy capacity is 100Wh256*10*10 = 2560kWh = ~2.6MWh**

**FOR CHARGING:**
**1 tray will consume roughly 110Wh*256 = ~28kWh of energy.**
**1 formation machine will consume 28kWh*10 = ~280kWh of energy.**
**The total potential energy requirement is 280kWh*10 = ~2.8MWh.**

**FOR DISCHARGING:**
**1 tray will produce roughly 90Wh*256 = ~23kWh of energy.**
**1 formation machine will produce 23kWh*10 = ~230kWh of energy.**
**The total potential energy production is 230kWh*10 = ~2.3MWh.**

**In a production setting where energy from discharging is not diverted back into the DC bus to be recovered, the total energy requirement for the formation process is:**
**5*2.8MWh = 14MWh.**

**In a production setting, where the energy from discharging is diverted back into the DC bus for recovery, the total energy re-purposed from the formation process is:**
**5*2.3MWh = 11.5MWh.**

**In a production setting, where the energy from discharging is diverted back into the AC distribution for recovery, the total energy re-purposed from the formation process is:**
**5*25600Cells*100Whr/cell*0.85 = 10.9MWh.**

This is a significant amount of energy that can be reused within a gigafactory's DC microgrid system to improve energy efficiency. For example, this energy can be reused:

- Within the formation process
- To charge the onsite battery storage system which then could be used as a backup power instead of a fossil fuel generator
- In the locally hosted datacenter where there are many dc loads
- For non-critical loads like LED lighting in the building and cafeteria
- At the EV car charging stations

These are just a few examples of where the energy output from the formation process can be repurposed within the factory.

## Conclusion

Incorporating DC microgrid in gigafactories is a paradigm shift. It paves the way for more sustainable EV battery plants. Simply using renewable sources does not necessarily make a gigafactory sustainable. However, by repurposing the discharged electricity from the formation process of the LIB (Lithium-ion Battery), a gigafactory will become more energy efficient and sustainable. The demonstration in this paper shows that there is potential for double digit energy savings by repurposing the energy within a DC microgrid system.

In the next white paper, we will deep dive into the architecture of the DC power distribution along with the traditional AC distribution as one whole system.

## About the authors

**Ali Jaferri** is a Solution Architect at Schneider Electric. He has proven record of global accomplishments in various technical roles over the last 16+ years within the company. He has a master's degree in Digital Signal Processing from Newcastle Upon Tyne and second master's in Business Information Technology from Kingston Business school, UK. He uses his extensive knowledge and expertise in supporting EV battery manufacturers in troubleshooting challenges in the areas of energy efficiency, sustainability, process optimization and cell production.

**Marina Lisnyak, Ph.D.** is responsible for the technical integration of DC Systems in the Power Product division. She received her MSc in Applied Mathematics and Physics from Saint Petersburg State University, Russia (2010) and her PhD in Plasma Physics from Orléans, France (2018). In 2010, she started working as a research engineer in Russia and then in Germany in the field of vacuum arc research for medium voltage switchgear and made a significant contribution to the field of electric arcs. Later, her doctoral work has focused on the numerical and experimental investigation of electric arcs in aviation applications.
Marina joined Schneider Electric in 2018 as an expert in numerical arc modeling. In this role, she developed a tool that allowed the calculation of electrodes heating and optimization of the current LVCB design.
Since 2021, Marina is involved in the integration of DC Systems, a startup acquired by Schneider Electric in 2020. Currently, Marina is actively developing solutions in which DC brings value and new benefits to users.

**Stewart Harding P.Eng.** is a Principal Architect for the Power Products Division of Schneider Electric. He graduated from University of Victoria with a Bachelors of Mechanical Engineering with Distinction in 1999, and is a Professional Engineer. He began his career with Power Measurement in 1998 which was acquired by Schneider Electric in 2006. He has held various engineering positions related to the development of Schneider's Basic, Advanced, and Utility Metering Products.