



Draft Regulatory Guidance

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Low Carbon Fuel Standard Regulatory Guidance 17-02

Methodology for Determining Electricity Consumption of Electric Forklifts

Under the Low Carbon Fuel Standard (LCFS) regulation¹, the LCFS credits generated from electric forklift charging can be claimed by either the Electrical Distribution Utility (EDU), or the electric forklift operators. In the case of an EDU claiming the credits, ARB staff calculates the forklift electricity use in the EDU's service territory. In the case of an electric forklift fleet operator claiming credits, the following methodology may be used to calculate the electricity use in forklifts through a combination of measurements, industry standards, and ratings on charging equipment.

It is important to understand the difference between forklift operation and battery charging/recharging. Consider that a typical facility tracks the use of three batteries: one battery is actively charged in the charging equipment, a second battery is being used in an operational forklift, and a third battery is waiting to be charged. In most facilities the batteries and the forklifts each have a dedicated function during a work shift. Furthermore, the batteries are not interchangeable amongst forklift types.

Based on a survey of fleet operators conducted by ICF International, an electric forklift is usually on a one charge cycle per shift routine. A forklift is operated for the duration of a shift (6-12 hours, depending on the facility and forklift type). Although the number of shifts varies among different businesses, typically there are two shifts per day. At the conclusion of the shift, the battery that was in the charger is swapped into the forklift. The battery that was waiting to be charged is loaded into the charger, and the recently depleted/discharged battery is put in the on-deck circle for charging.

The table below includes the parameters considered in the calculation methodology.

¹ Pursuant to California Code of Regulations, Title 17, section 95491(a)(3)(D)(7).
<http://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf>

Variable / Parameter	Unit	Description
Depth_of_discharge	%	The amount of energy, as a percentage of the battery's capacity that was discharged during forklift operation.
Battery_capacity_rating	kWh	The capacity of the battery in kWh.
Charger_efficiency_rating	%	The charger efficiency rating varies depending on the charger technologies and the age of the charger.
Charge_return_factor	%	Charging equipment delivers a higher number of ampere hours (Ah) to the battery during the charge cycle than were discharged, which is referred to over-charge or equalization. This is a measure of how well the charger tailors its charge profile to the battery's depth of discharge. The charge return factor varies as a function of charger type.
kWh per charge cycle	kWh	This is a measure of the kWh per charge cycle.
kWh per charger per quarter	kWh	This is a measure of the quarterly kWh per charger.
Shifts per day	Unitless	Shifts per day are a measure of the number of charge cycles of a forklift, assuming that there is one charge cycle per shift.

The combination of the Battery Capacity Rating, the Depth of Discharge, Charger Efficiency Rating, and the Charge Return Factor yield kWh per charge cycle, which is then multiplied by the number of shifts per day and by the number of work days per quarter to determine kWh per charger per quarter.

The formulas to calculate kWh consumption of electric forklift are outlined below:

$$\begin{aligned}
 & \text{kWh per charge cycle} \\
 & = \text{Depth_of_discharge} \times \text{Battery_capacity_rating} \\
 & \quad \times \text{Charger_efficiency_rating} \times \text{Charge_return_factor}
 \end{aligned}$$

$$\begin{aligned}
 & \text{kWh per charger per quarter} \\
 & = \text{kWh per charge cycle} \times \text{Shifts per day} \times \text{Number of work days per quarter}
 \end{aligned}$$

$$\text{Quarterly Total Electricity Use} = \sum_{i=1}^n \text{kWh per charger per quarter}(i)$$

n = number of chargers

The quarterly total electricity use is the sum of the kWhs of all the chargers of the fleet.

The Methodology can be summarized in the following steps:

Step 1. Identify Battery Capacity Rating. Forklift operators should refer to *Battery Selector Guide*² to identify the battery capacity rating. This rating is based on 100% depth of discharge.

Step 2. Adjust for Depth of Discharge. Battery is nominally discharged during forklift operation (generally to around 80%). The fleet operator should adjust the capacity rating of the battery to reflect the amount of power that needs to be returned to recharge the battery.

Step 3. Adjust for Charger Efficiency Rating. The charger efficiency rating varies depending on the charger technology and the age of the charger. *Ferro-resonant* chargers typically run in the 82% to 86% efficiency range while *Silicon Controlled Rectified* (SCR) chargers run in the 78% to 82% range. *High Frequency* chargers typically run in the 90% to 96% range. With all of these technologies, the older chargers tend to run toward the lower end of the range, and the newer chargers tend to run on the higher end of the range. The fleet operator should adjust the charger efficiency rating based on the charger technology and the age of each charger used by the fleet.

Step 4. Adjust for Charge Return Factor (over-charge). Each charger type has a corresponding percentage of over-charge. Ferro-resonant chargers and High Frequency chargers are typically designed to provide a 15% over-charge or 115% total. SCR chargers are typically closer to an 18% over-charge or 118% total. The fleet operators need to adjust the corresponding charge return factor for each charger.

Step 5. Determine the number of work days per quarter. Based on their daily business operations, the fleet operators need to determine how many days the forklifts were in operation during the quarter in question.

Step 6. Calculate the total electricity use per quarter. Using the formulas given above, the fleet operators should calculate the electricity use per charger per quarter and sum up the kWhs of all the chargers of the fleet to calculate the total quarterly electricity use to be reported in their LCFS Reporting and Credit Bank & Transfer System (LRT-CBTS) accounts.

² <http://mptools.enersys.com/oem/>

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