

Choosing Electric (AC) Lift Trucks Over Internal Combustion (IC)

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As the material handling industry has evolved over the past decade to address the rising cost of diesel and stricter emission standards, the 3-phase alternating current (AC) electric lift truck has come into its own and now offers many benefits to potential buyers. Tested and proven, the technology now provides increasing advantages to consider when buying an electric AC lift truck as opposed to an internal combustion (IC) forklift.

In the material handling industry, two broad families of lift trucks exist – electric alternating current (AC) and internal combustion (IC). IC models include forklifts running on technologies based on diesel, LPG (liquefied propane gas), liquid gasoline or petrol, and CNG (compressed natural gas). IC trucks are also sometimes confusingly referred to as “gas” forklifts, but the use of actual gasoline (petrol) vehicles is relatively uncommon in material handling – with the exception of very large trucks working in outdoor applications.

Features now favoring electric AC lift trucks are:

- Performance levels, productivity and cost-of-load handled that can match or exceed any IC truck available
- Potential for greater cost savings, including lower maintenance costs over the life of the lift truck
- Flexibility for both indoor and outdoor applications
- Enclosed motors and controllers for added protection
- Potential for up to two shifts’ work from a single battery charge
- Energy reclamation during braking
- Zero pollution from exhaust emissions

Following is an exploration of the concept of total cost of ownership (TCO), application trends for AC forklift technologies and the incentives and advantages inherent in an electric lift truck in today’s workplace.

The Concept Of Total Cost Of Ownership (TCO)

Equipment acquisition personnel often fail to understand the concept of TCO, instead looking only at the initial cost of the purchase in making their decision. In reality, TCO is far more relevant to the forklift purchasing decision process.

Perhaps the most striking selling point in favor of electric AC lift trucks is that the total cost of ownership (sometimes also called the total operating cost) over the life of the truck can be much less with an AC than an IC forklift.

Factors affecting operating costs of either electric or IC lift trucks include the following:

- Truck performance (pallets moved per hour)
- Energy efficiency (how long the truck can run on one battery charge or one tank of fuel)
- The cost of fuel or electricity to operate the lift truck
- Reliability (no work time lost due to lift truck down-time)
- Cost to maintain the lift truck, including such components as batteries (IC lift trucks also have batteries), fluids, tires and filters
- Cost of maintaining air quality in the warehouse
- Heating and/or cooling costs

TCO, as a monetary estimate, can help supply chain and warehouse managers evaluate the direct and indirect costs related to the purchase of a capital investment like a forklift.

When comparing the initial cost for one piece of equipment in comparison to another, you must take into consideration repair costs over the life of the forklift as well as other expenses such as upgrades. Looking at it this way, the magnitude of the initial price can be offset by the ensuing series of cost savings realized over the truck’s life. At the end of service life, the upfront purchase price of a forklift will be a fraction of the total cost of ownership.

Figure 1: Annual Fuel/Energy And Maintenance Cost Comparison

	LPG	Diesel/Gas	AC
Fuel or Energy Costs	\$8,225	\$15,000	\$2,020
Maintenance Cost	\$3,300	\$3,300	\$2,700

Note: Data assumes approximately 2,500 annual forklift operating hours.

To give a real world example, considering a five-year life cycle, the operation costs of an AC lift truck will be typically just one quarter of the costs of an internal combustion forklift. The return on investment for AC versus IC will usually become attractive between the first and second year of lift truck ownership – at some point in that time period, IC costs will surpass the costs of an AC forklift (See Fig. 2).

It is true, however, that the initial purchase price of an electric AC forklift will be either moderately higher or substantially higher than the alternative IC options, depending on whether the auxiliary equipment – the battery and charger – are included in the price (See Fig. 3). In fact, the biggest difference in the initial cost of an AC system versus other technologies is not so much due to the lift truck itself, but to the battery and charger. Electric forklift batteries, which are quite large and heavy, are expensive in large part due to the cost of lead in recent years.

What’s more, two batteries and a charger may be needed at the time of the initial lift truck purchase depending on the number of shifts in the application.

However, the adjusted price differential between the initial cost of an AC versus an IC lift truck (i.e., leaving out the cost of battery and charger for electric vehicles) is perhaps only a few thousand dollars.

Cat Lift Trucks has developed an online [Lift Truck Cost Comparison Tool](#) that allows the public to evaluate and compare the operation costs in dollars for fuel or electrical energy. While the cost of electricity differs from state to state, typically it is about one-tenth the cost of liquefied LP gas. The price of one 10-gallon tank of LPG varies from \$15 to \$35. By contrast, the energy cost to recharge the battery once for an electric lift truck may be as low as \$4.

Figure 2: Total Cost of Ownership Comparison: 2011

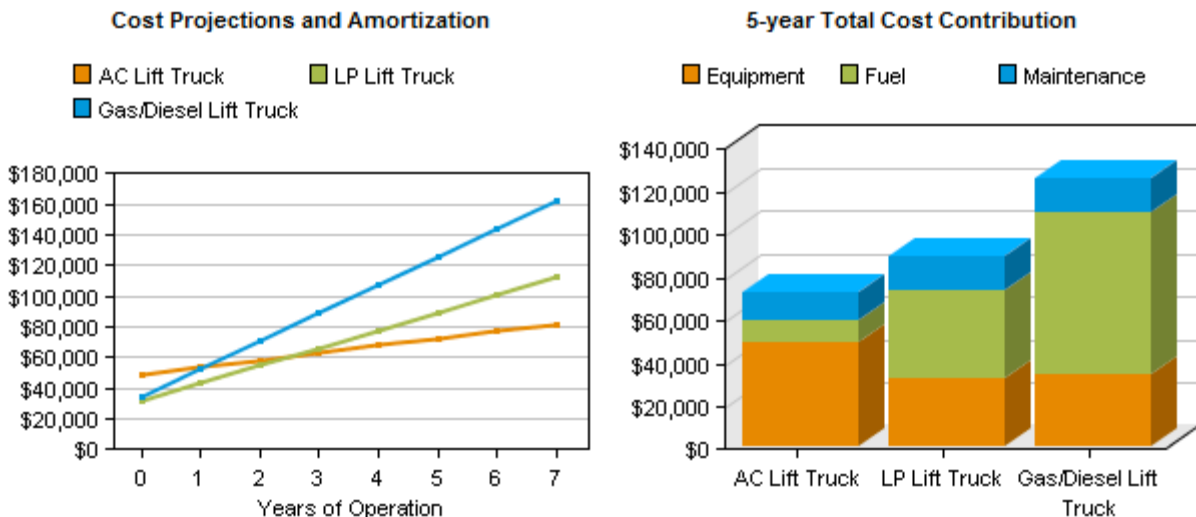


Figure 3: Lift Truck Total Cost Of Ownership Comparison: 2011

Equipment Data		Application Data	
AC Truck Model	EPC5000-EP5000	Number of Effective Hours per Shift	1
Number of Forklifts	1	Number of Shifts per Day	1
Number of Batteries per Truck	1	Number of Working Days per Year	1
Number of Chargers	1	Number of Hours per Year	2,500

		AC Lift Truck	LP Lift Truck	Gas / Diesel Lift Truck
Equipment Costs	Forklift Price	\$37,100.00	\$31,900.00	\$34,300.00
	Battery Price	\$8,750.00		
	Charger Price	\$3,250.00		
Fuel Costs	Electricity Cost per kWh	\$0.10		
	Electricity Cost per Hour per Lift Truck	\$1.01		
	LPG Fuel Cost per Gallon		\$2.50	
	Hours of Usage per Tank		6	
	Size of Tank, in Gallons (43# = 10.3 Gal, 33# = 7.9 Gal)		7.9	
	LPG Fuel Cost per Hour per Forklift		\$3.29	
	Diesel or Gasoline Fuel Cost per Gallon			\$4.00
	Hours of Usage per Tank			8
	Volume per Fill-Up, in Gallons			12
	Diesel or Gasoline Fuel Cost per Hour per Forklift			\$6.00
Maintenance Costs	Monthly Cost per Forklift	\$225.00	\$275.00	\$275.00

Acquisition Cost	Lift Truck(s):	\$37,100.00	\$31,900.00	\$34,300.00
	Battery(ies):	\$8,750.00		
	Charger(s):	\$3,250.00		
TOTAL ACQUISITION COST:		\$49,100.00	\$31,900.00	\$34,300.00
Operating Cost	Fuel Cost (per year):	\$2,020.00	\$8,225.00	\$15,000.00
	Maintenance Cost (per year):	\$2,700.00	\$3,300.00	\$3,300.00
TOTAL YEARLY OPERATING COST:		\$4,720.00	\$11,525.00	\$18,300.00
Operating Cost per Lift Truck per Hour:		\$2.36	\$4.61	\$7.32

ROI and Savings	Lift Truck Cost Comparison Tool - ROI Time [years]:		2.5	1.1
	AC Truck: Savings after 3 years:		\$3,215.00	\$25,940.00
	AC Truck: Savings after 5 years:		\$16,825.00	\$53,100.00
	AC Truck: Savings after 7 years:		\$30,435.00	\$80,260.00
	AC Truck: Savings after 10 years:		\$50,850.00	\$121,000.00

Consider the following hypothetical analysis factors:

- A prospective purchase of ten 5,000 lb. lift trucks (an individual AC forklift truck may cost \$37,100 and an LPG lift truck may cost \$31,900).
- With AC, a \$8,750 battery and a \$3,250 charger are necessary. That adds another \$12,000 for the AC forklift. For AC, the initial purchase cost can rise to as much as \$49,100. Although buyers tend to focus far too much on the initial price of AC forklifts, the price of fuel for an IC over the life of the truck is roughly 4-7 times that of an AC, while maintenance is approximately 50 percent more, leading to a total cost per year that is 2-4 times that of an AC lift truck.

Trends, Niches And Market Shares

A trend to increasingly narrower aisles in warehouses and distribution centers reflects the need to store more goods in the same amount of space than in the past (“cube utilization”). In addition to aisles shrinking, storage racks are being raised higher, meaning a forklift working in these evolving environments must maneuver in smaller areas and lift loads higher.

Lift trucks also have to be able to turn within tight spaces like the inside of half-full trailers where stacked goods reduce maneuvering space. In response, forklift manufacturers are now making their products more compact. AC electric lift trucks designed specifically for narrow aisle applications are now serving areas where counterbalanced lift trucks cannot go.

Electric forklifts are most commonly used in indoor environments and regulated areas, such as refrigerators and freezers in grocery and food distribution centers. These are arenas where exhaust emissions in confined spaces would be a problem.

Therefore, electric forklifts excel in environments with medical and food products, which largely dominate the grocery industry, and in enclosed areas where toxic emissions like carbon monoxide would be a concern. Another strong niche for electric lift trucks is working around explosives and chemicals.

Evaluating only the market for 5,000-6,000 lb. capacity sit-down counterbalanced lift trucks, approximately 25 percent of the 80,000 of those forklifts currently being used are electric. The remainder of the total are internal combustion lift truck models (LPG, diesel, gasoline, etc.), with LPG forklifts owning the majority of that share.

Voltage Levels Used In Electric Forklifts Today

Electric warehousing forklifts are based on a range of voltages (e.g. 24V, 36V, 48V and 80V). Some applications don't require a great deal of power. For example, most Class III forklifts (walkies, walkie-stackers and walkie end-riders) operate on 24V power, considered a low voltage. Smaller lift trucks like these often (although not always) only have to transport lighter loads, have limited hydraulic functions requiring lower amperage and work in areas where top speeds are not important.

With a relatively low voltage and lower amperage, power output is low. On the other hand, a higher voltage in a truck's electrical system means the ability to achieve higher levels of performance. For example, an 80V system, as opposed to, say, a 36V system, permits higher levels of acceleration and torque.

In general, any current flow entails some heat radiating from conductors. Thus, the low current of a higher voltage system means relatively lower heat losses. In a lift truck, the single biggest enemy of energy efficient operation is buildup of heat that cannot be dissipated quickly. Heat buildup not only harms electronic components, it also creates greater electrical resistance in wiring and cables, making it more difficult for a battery to push current through the conductors – as the electrical resistance has been increased. A rising heat level in conductors means a greater current draw is needed to compensate for this increased resistance, which in turn creates even more heat.

Battery And Charging Systems

Forklift batteries come in all shapes and sizes. A typical battery's dimensions and weight can vary widely depending on the truck, but in the case of the 5,000 lb. electric sit-down counterbalanced lift truck, it's approximately 40 inches wide by 32 inches high by 34 inches front-to-back, and it weighs around 3,200 lbs. A forklift battery must continually provide power for vehicle systems (the three main system motors – drive, steering and load-lift), so its physical size and energy capacity must be large. Also, the heavy battery in a forklift contributes a substantial amount of the truck's counterweight.

How often a battery charge or change-out becomes necessary on an electric forklift depends on how it is used. In a three-shift operation, a battery will definitely need to be changed out during the three shifts of work – physically removed and replaced by a fully-charged one. With the lead-acid battery technology present in today's forklifts, if the energy in the battery becomes depleted, it takes a long time to put the energy back into it correctly. In fact, it's common in the material handling industry to refer to the “8-8-8 rule,” which means that it takes about 8 hours to deplete a battery working on the job, 8 hours to charge it back up and another 8 hours to allow the battery to sufficiently cool.

New and emergent battery technologies are shortening the 8-8-8 rule times. For example, new fast-charging technology allows multi-shift operations to charge batteries partially during breaks in a shift, and then at lunch or at shift's end to fully charge it up in approximately an hour and a half. However, although this fast-charging technology represents a significant improvement, there's a limit in how far this technology can be taken. For example, such fast charging technology still requires a weekly “equalizing charge.”

Electric Braking And Energy Regeneration

AC electric technology allows precise and aggressive electric braking in which mechanical friction from a physical brake is not used as the sole means of slowing or stopping the forklift. Because it reduces wear on the truck's conventional brake components, electric braking can lower operating costs over the life of the lift truck.

Cat Lift Trucks form of electric braking leads to more precise positioning. Lift truck speed precisely corresponds to the degree of travel of the accelerator pedal and won't vary unpredictably, even on ramps. There's no need for the operator to constantly switch a foot back and forth between accelerator and brake pedals in such situations.

Electrical braking occurs primarily with the release or easing up of the accelerator pedal and during changes of direction (e.g., going into reverse following a forward motion and vice versa). The controller senses a request to stop or slow down and creates a counter-electric force, or "back EMF," in the motor. Essentially, this turns the drive motor into a generator and sends current in the opposite direction back toward the battery for regeneration.

With these modes of regeneration working as the forklift carries out its normal tasks, a great deal of otherwise wasted potential energy can be, under ideal circumstances, fed back to the battery on a continual basis. Lift trucks can achieve more working cycles per charge, and users can sometimes even reduce the size of their charging stations or battery exchange areas. It is not out of the question to get two shifts of work from a lift truck with just one charge.

The process for energy regeneration in electric AC lift trucks serves to top off a battery "on the run" and extend the time between charges, though regeneration is not intended to be an outright substitute for a full battery charge. The characteristics of an electric AC system allow for potent regeneration with a large amount of energy transferred back to the battery.

An AC lift truck can electrically brake and regenerate battery charge all the way down to zero mph, giving it essentially "infinite" speed control. The ability of an AC forklift to regenerate down to zero mph allows for very smooth direction changes, which become evident in a smoother operation and more productive shuttling overall. In addition, the use of aggressive regenerative braking allows for a more level battery discharge rate during peak battery draw periods, resulting in longer battery run-times.

AC Technically Compared To Internal Combustion

When compared to internal combustion systems, the performance of AC lift trucks in parameters such as acceleration, ability to negotiate a ramp, speed control on ramps, load-lift ability and braking are today quite competitive.

AC technology has demonstrated a proven ability in recent years to match the performance of IC forklifts in these criteria, and in some cases, even surpass them.

Emissions: A Major Problem For IC Forklift Trucks

A serious drawback to the use of internal combustion lift trucks in indoor material handling environments is the presence of polluting engine emissions: carbon monoxide (CO), various compounds of nitrogen and oxygen that contribute to creation of smog (lumped under the umbrella term NOx), hydrocarbons of various kinds (HCs), as well as particulates, soot and odors (See Fig. 4).

Carbon monoxide (CO) is poisonous to humans. Nitrogen oxide (NOx) emissions are undesirable since they are considered greenhouse gases and thought to harm the ozone layer, contribute to the formation of acid rain and even to aggravate asthmatic conditions. Produced primarily from the combustion of fossil fuels, at least six oxides of nitrogen exist. Many of the emissions reduction initiatives today are directed at reducing NOx compounds, because of their impact on the environment.

The main approach to suppressing pollutants on IC forklift trucks is the use of a catalytic converter. However, often-times a fix to the problems of modern technology does not come cheap, and catalytic converters are no exception. They are an expensive add-on to a forklift and take up valuable space inside the lift truck chassis.

What's more, although LPG lift trucks equipped with a three-way catalytic converter do have lower NOx emissions, the problem is never eliminated completely unless electric forklifts are used instead. Also, three-way catalytic converters only work effectively to reduce NOx emissions from LPG and fuel-gas engines; they offer no benefit with diesel engines. In fact, diesel forklifts are dying out in popularity because it's so difficult to economically eliminate NOx emissions from them, or bring their emissions to an acceptable and compliant level.

If the engine emissions of a forklift running on LPG are measured, the carbon monoxide (CO) content will be found to be only about 10 percent of that for automobiles or fuel-gas vehicles – including lift trucks. For that reason, internal combustion forklift trucks used indoors are generally LPG trucks, not diesels.

Even if an IC lift truck meets or exceeds the exhaust emissions regulations in force, it will still pollute the air to some degree, even if only a small one. "Excluding gasoline vehicles, the IC lift trucks considered the worst polluters when not fitted with a catalytic converter are those based on LPG technology. However, that is no longer true once a three-way catalytic converter is used. Running at full power (as opposed to idle engine speeds), an LPG forklift truck with a three-way converter gives off less CO than diesel.

Figure 4: General Comparison Of Three Technologies

	LPG/Gas	Diesel	AC
Carbon Monoxide (CO)	100%	Lower	0%
Hydrocarbons	100%	Lower	0%
Nitrogen Oxide (NOx)	100%	Higher	0%
Particulates	0%	Higher	0%
Odor	100%	Higher	0%
Life Cycle	100%	150-200%	150-200% (Battery 50%)
Engine Efficiency	100%	135%	200-300%
Initial Investment Costs	100%	105%	156% (w/ battery and charger)
Fuel / Energy Costs	100%	90-110%	10-20%
Indoor Use	Limited	Limited	Unlimited

In the above table, fuel gas/LPG has been used as a baseline. For LPG, the figures are always shown as 100% since it's essentially being compared to itself. All other figures represent a percentage of the expected value for an LPG truck. For example, CO emissions are somewhat lower and engine efficiency somewhat higher on a diesel truck than on an LPG, but the electric efficiency is substantially higher and CO emissions are zero percent of the LPG figure, i.e. electric runs "clean."

Notes:

- With all of the emissions reduction initiatives on IC trucks, vehicles of this type need even more complicated diagnostics and sensing components.
- This table uses fuel gas/LPG as the basis for comparison.

