

Choosing an electric forklift with lithium-ion battery



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Electric heavy-duty forklifts are now being introduced by many manufacturers. A lot of those are based on similar concepts and use a similar design. Does the technology you choose really matter, then? The clear answer is "Yes". Under the hood, the difference could be significant.

Logistics providers around the globe are paying more and more attention to their carbon footprint. There is a common concern for the environment and the well-being of coming generations. Today, a Sustainability Officer is often a part of management teams in organizations of all sizes.

Sustainability is quickly becoming a key performance indicator for many companies. This is because the environment is seen as a common responsibility, but it's also good for business when a company has a positive sustainability profile. Investors and customers alike often inspecting the environmental record of the companies they engage with.

Big transport buyers like retailers, car manufacturers and e-commerce companies have defined clear requirements on how to qualify logistics partners. For companies in the material handling and transportation industry, this means that they will be asked to present figures on their carbon footprint when they negotiate new contracts.

But the heart of the matter is the fact that buyers and users of forklift trucks are facing an increasing demand from their customers to present plans to reduce the use of fossil fuels in their operations.

The good news is that it is now possible to respond to these demands in a positive way which will benefit all of the parties involved.

Electric forklift trucks make up one part of the equation. Lift trucks with zero engine emissions open up a lot of possibilities, not only in terms of improved eco-efficiency, but better ergonomics and less technical complexity as well, with only minor requirements for preventive maintenance.



Why convert to an electric forklift?

The technology for diesel drivelines has evolved over more than a century and is today very sophisticated, particularly when it comes to fuel efficiency and reducing harmful tailpipe exhaust gas and particle emissions. Diesel engine technology is now so good that improving it has become quite difficult. It is impossible to reduce the CO₂ emissions of a diesel driveline to zero. The level of carbon dioxide in the exhaust depends on the amount of carbon in the fuel and on the diesel engine's fuel efficiency.

To reduce CO₂ and other exhaust gases still further, vehicle manufacturers have been turning to electric drives with energy storage primarily in lithium-ion (Li-ion) batteries. The process of electrification should aim to make the most of this new technical development and find ways to minimize the impact of the areas in which diesel still has a competitive advantage.

There are companies that decide on Li-ion electric forklifts for their efficiency or their intention to minimize their contribution to fossil fuel emissions in

the atmosphere. Others choose them because they see a zero-emission engine vehicle as the future, with better performance and a chance to save on operational costs. These forklifts guarantee a much smaller environmental impact, not only in terms of greenhouse gases or particulate emissions, but in noise, vibration and risk of contamination as well. They also offer valuable new features for everyday use.

Reduce your energy need

In terms of energy use, electric motors are significantly more efficient than diesel engines. About 90% of electrical energy is converted to usable work, whereas diesel energy barely achieves 40%. Storing and re-using regenerated energy from braking adds even more efficiency to the electric driveline.

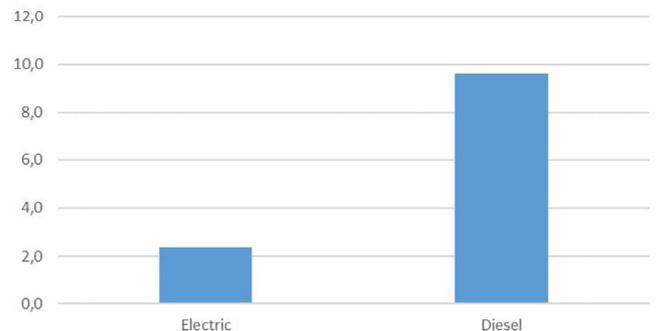


Fig. 1. Electric vs. diesel energy cost per hour for a 16-1200 forklift in regular operation, based on usage data in the following table.

	Diesel	Electric	
Energy	8 l/h	24 kWh/h	1.2 €/l 0.1 €/kWh
Interest rate			5%
Service Battery	As per Konecranes Lift Trucks recommendation		

Invest in the future

Li-ion batteries make up a significant part of the total cost of ownership an electric forklift, and are the main reason for the price difference when compared to a diesel truck. However, if manufacturer recommendations are followed, it should last longer than 3,000 charge cycles. In average conditions, this should be about 5 or 6 years of operation. So the forklift will probably require a new battery at some point during its lifetime.

In this way, it can be argued that battery costs can be considered an operational expense when looking at total cost of ownership.

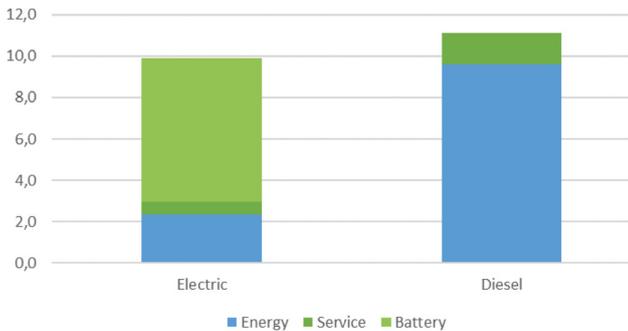


Fig. 2. Indicative battery costs included in operational costs for electric forklift. Energy efficiency measured according to EN 16796-1:2016, EN 16796-2:2016.

Assuming the same usage data as in Figure 1, Figure 2 shows that the hourly costs for operating a fossil fuel-free electric forklift are still lower than for the same truck running on diesel.

In addition to energy efficiency, an electric forklift gives off less heat and has less mechanical complexity, thereby reducing the need for maintenance while improving reliability.

Compact design, simplicity of construction and controllability, and the ability to recover braking energy, are all clear advantages of the electric forklift.

Include battery charging in daily operations

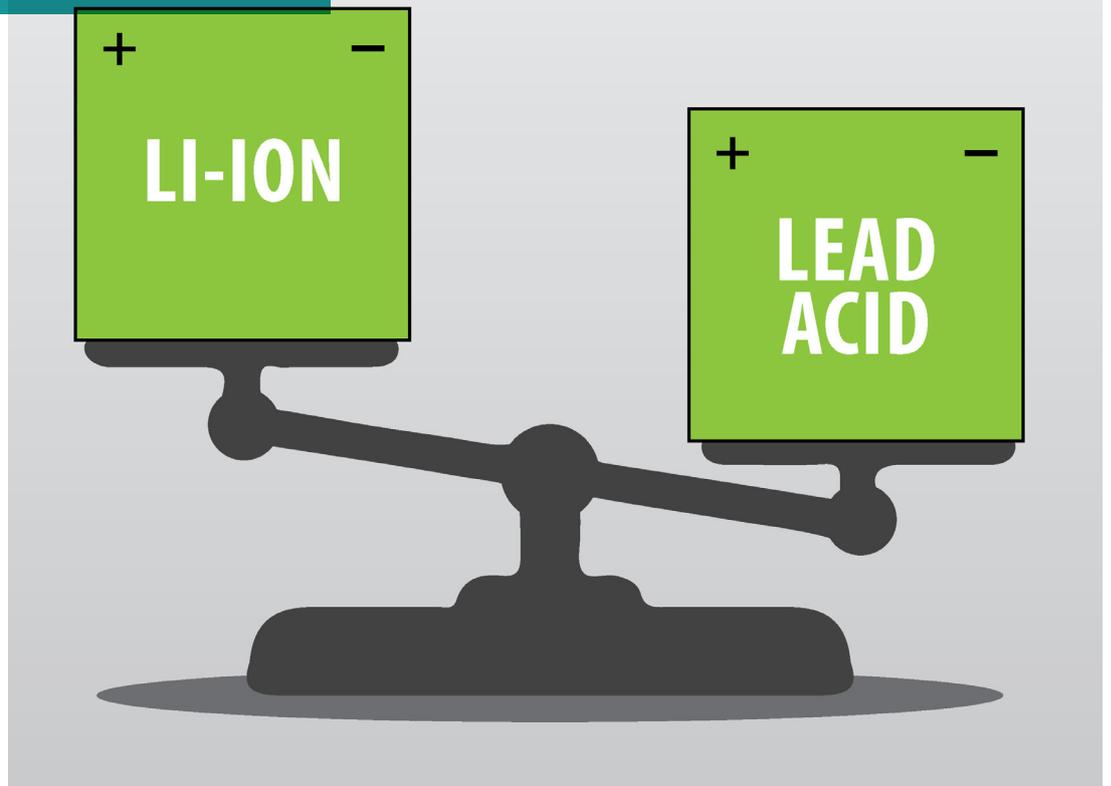
Charging a battery takes a lot longer than filling a fuel tank with diesel. However, once the charging cable has been connected, it is fully automatic, leaving the driver free to do other things. The effect of charging stops on operations can be minimized and easily synchronized with food breaks. A full battery fast charge takes approximately 45 minutes. Usually operating between 20% - 90% state of charge, the forklift does not have to be driven until the battery is empty. Opportunity charging (taking advantage of shorter breaks to top up the charge) will help extend the operating range without affecting the life of the battery, if it is given a slower charge at night. This is not like lead acid batteries, which suffer from reduced lifetime if they are not recharged in full every time.

How is productivity affected?

Drivers appreciate the dynamic behaviour of electric trucks. The vehicles deliver full torque even at low speed, making acceleration and lifting more immediate and improving measurable performance parameters beyond those of a diesel truck of the same capacity.

Less noise and vibration inside the cabin provide a more relaxed work environment and a less fatigued driver at the end of a shift.

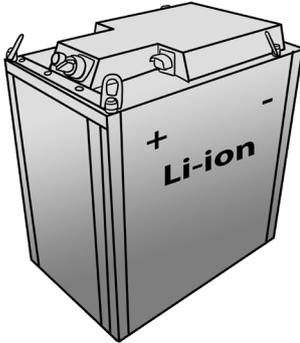
Lift truck battery technology: Li-ion vs. lead acid



When we compare battery technologies, we need to take **efficiency, safety, charging time, energy density storage, weight, maintenance, life cycle, temperature sensitivity** and **cost** into account.

At first glance, lithium-ion batteries might seem more expensive. However, if we check all the benefits, the Li-ion turns out to be more cost-effective.

Choosing the best solution



Operational requirements

- Lifetime: approx. 3,000 cycles
- Efficiency: > 96%
- Charging time: 45 mins for full recharge
- Estimated operating time: 2-3 hours equipped with one battery, 4-6 hours if with two. For a full 8-hour shift, opportunity charging plus an extended one over lunch break are needed.
- Maintenance needs: no specific maintenance requirements
- Extra battery: not necessary - in case of more than one shift, can be opportunity charged (e.g. during lunch breaks)

Infrastructure requirements

- Charging station: required
- Power: 75 /150 kW (single/double battery)
- Charging site: conveniently located on lift truck travel paths as needed
- Battery swap: not required - the battery is charged on the truck

Operational requirements

- Lifetime: 1,200-1,400 cycles
- Efficiency: 70%
- Charging time: 8 hours
- Estimated operating time: 8 hours or less - recharging cannot have the same power used for Li-ion batteries and it has more charging losses
- Maintenance needs: regular maintenance required (e.g. top-up water)
- Extra battery: required if more than 1 shift is needed

Infrastructure requirements

- Charging station: required
- Power: A 200 kWh battery needs approx. 30 kW charging power
- Charging site: needs a ventilation system due to hydrogen emissions or outdoor location (to avoid risk of explosion)
- Battery swap: necessary if the lift truck can't be out of operation for 8-10 hours needed for charging. Battery swap will obviously necessitate double set of batteries.

Charging a lead acid battery

Lead acid batteries have only 70% charging efficiency because it needs more energy for recharging than it delivers. Other problems with recharging include:

- Fast or partial charges ruin the battery;
- Charging times are long;
- Battery heats up during charging (due to low charging efficiency)
- The charger does not collect full information on the battery - it only checks the voltage, but changes in temperature affect the recharge profile as well, and if the temperature is not measured, the battery will never charge completely in winter and will gasify too much in summer;
- An incorrect charger or setting reduces battery life;
- Poor maintenance reduces battery life
- Chargers need to be installed outdoors or in a ventilated area to avoid risk of explosion due to hydrogen emissions while charging.

However, a charging infrastructure for lead acid batteries usually exists in most industrial environments (even tough for charging an heavy lift trucks, higher current is needed). Good recycling processes are also in place due to long experience with this type of battery.

Charging a lithium-ion battery

Theoretically, a lithium-ion battery can be "fast" charged to 100% capacity. It **cuts down on energy expenses, as it is at least 96% efficient.**

A Li-ion battery can load up to 50% of its charge capacity in only 30 minutes.

Because Li-ion batteries can be recharged repeatedly over a short space of time, lift trucks can be powered with a Li-ion battery with a lower installed capacity than that required for lead acid batteries.

The battery management system (BMS) controls the charger so it can deliver the exact current consistent with internal parameters (voltage, temperature, charging level, etc.). A malfunction stops the battery from connecting, so it is fully protected.

In addition, the Li-ion battery weighs three times less than a lead acid battery of the same capacity.

Maintenance and service life

A lead acid battery has high maintenance costs. With the physical battery, users must top up the electrolyte, service the filling system and remove oxide from the elements and terminals. Associated with these are three less obvious but still essential costs:

1. Infrastructure: dedicated area for charging, due to release of gas.
2. Gas disposal: special ventilation system to remove the gas.
3. Demineralized water: needed for battery top-up.

A lithium-ion battery has a charging infrastructure that costs nothing to maintain, it doesn't leak gas while charging, and it doesn't need water. It just works.

Moreover, lithium-ion batteries last approximately three times longer than lead acid batteries of the same utility capacity, without losing effectiveness over time. This is one of the most important factors behind for its higher initial cost.

Safety and emissions for lift trucks

Lead acid batteries are not sealed, have no integrated electronics that would allow the system to avoid safety risks, and release hydrogen during charging. As Li-ion batteries do not release any emissions, they are suitable for all applications (including IP67).

In addition, electric forklifts feature 3 different control systems that protect the battery:

1. Automatic disconnection: battery disconnects when the truck is charging.
2. Battery cell balancing and management system maximizes battery efficiency.
3. Remote control automatic warnings when issues arise.

Circularity of lithium-ion

Used batteries should be disposed of responsibly. Besides traditional recycling, some expired Li-ion batteries can be used for other purposes at the end of their lifetimes.

When a lead acid battery has only 80% state of health (SOH), it is no longer suitable for heavy duty work and should be recycled. However, a Li-ion battery that can no longer provide the charge required by an electric forklift can be used for other things that don't need as much power. For example, they can serve as stationary energy storage for an uninterruptible power supply (UPS) or installed in wind or solar plants for backup power if regular sources fail.

The old battery can also be used as a power reserve for Li-ion charging stations. When charging is needed for multiple trucks at the same time, one way to reduce strain on the power grid is to store grid energy in used Li-ion batteries during the day, and use this energy when fast charging the vehicles, reducing the power output requirements of the grid during peak times. This can be discussed with the charging infrastructure provider.



Meet Konecranes' strongest newcomer



Konecranes has more than six decades of experience in designing and building forklift trucks for your world. In all that time, technology has come a long way, and now the first electric Konecranes forklift **E-VER 16-1200 C** is here.

It combines the long-lasting, heavy-duty Konecranes machinery you know with the latest eco-efficient features to enhance your productivity, reduce energy consumption, and prevent exhaust emissions.

What makes Konecranes electric forklift trucks so special?

KONECRANES[®]

Li-ion battery: new but well-proven technology

The Konecranes E-VER electric forklift is powered by one or two Li-ion battery packs. Starting with a single battery, the second battery is easy to retrofit thanks to full design modularity. The main advantages of the Li-ion battery are its high energy density in terms of kWh per kg and its ability to be fast-charged.

Even though battery powered drivelines are relatively new in medium-sized forklifts, the technology has already been used in high-performance applications (e.g. electric cars and buses) for many years. But Li-ion batteries also have some features that make them well-suited for use in lift truck applications.

How is a Li-ion battery different?

- **Fast charge option**
- **Significantly longer life**
- **Almost flat discharge curve, with full power available until the battery is empty**
- **Virtually no maintenance**
- **Charge stations can be outside**

Operating range and battery duration*

The operating range of an electric truck is related to the intensity of the work performed. An average drive cycle, if starting with a fully charged battery can last:

- 2 – 3 hours with one battery
- 4 - 6 hours with two batteries

The range can be extended by opportunity charging (e.g. during coffee or lunch breaks).

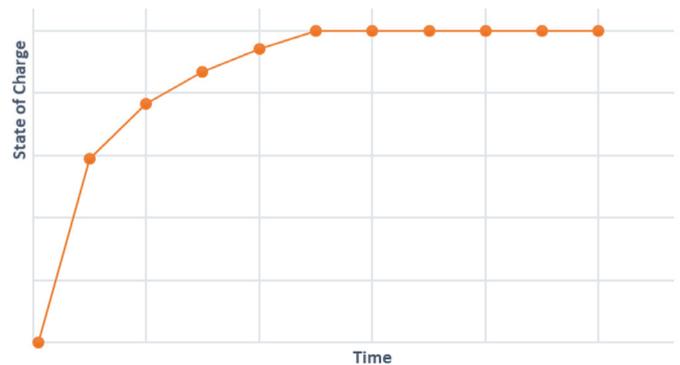


Fig. 3. Example of logarithmic charging sequence for Li-ion battery (does not show actual charge cycle for manufacturer)

Rapid charging is a key advantage of Li-ion battery technology. The graph shows that the battery charge increases very quickly at the beginning of the charging cycle. So, if it takes 45-50 min from empty to full capacity, it reaches 50% capacity in less than half the time. When the battery is fully charged, charging will stop automatically.

Each Li-ion electric forklift battery has a cycle life rate of around 3,000 charge cycles. Under average conditions, this should correspond to somewhere between 5 and 6 years of operation. Opportunity charging reduces the need for a full charge and extends battery life.

The main factors that affect battery life are charging rate and temperature. The BMS on the forklift monitors the state of charge, keeping the cell within safe operating limits and estimating its residual life. As long as charging follows manufacturer guidelines, the longer the battery will last.

*indicative numbers only - if any intended usage should be verified by simulation/calculation in order to confirm validity

Battery production

The production of batteries is as important to consider as any emissions it may produce.

The Konecranes battery supplier is committed to value chain sustainability, with a minimal carbon footprint and recycling wherever possible.

The Li-ion batteries we use are produced using 100% hydroelectricity, so all the energy used to manufacture them comes from renewable sources.

Charging infrastructure

Electric forklifts require a charging infrastructure. Charging stations should be equipped with CCS2 charge plugs and 75/150 kW DC (single/double battery) for fast charging capacity. This is an established standard for charging electric cars.



Fig. 4. Charging stations possible solution

Where should chargers be?

Charging stations do not need a specific location with adequate ventilation like lift trucks powered by lead acid batteries do. Li-ion battery chargers can be anywhere convenient along the traveling paths and working areas of the electric forklifts.

Charging mode

The Konecranes E-VER electric forklift will alert the driver well before charging is necessary. Charging should proceed as follows:

1. Drive to a charging station, stop the forklift within reach of the charging cable and apply the parking brake.
2. Connect the CCS2 charger. Both the charger and the truck will automatically check electrical safety and battery status to ensure conditions are right for charging. If they are, charging will start automatically.
3. Remaining charging time is shown and the driver can leave the machine.

For a full charge of the battery, the fastest recommended time is 45 minutes. If the truck has a two-battery pack, the batteries charge in parallel.

To optimize battery usage and lifetime, opportunity charging is best during work hours in the daytime and a slower charge more appropriate at night.

If the yard has Smart Connected Lift Trucks, battery information is also available on TRUCONNECT.

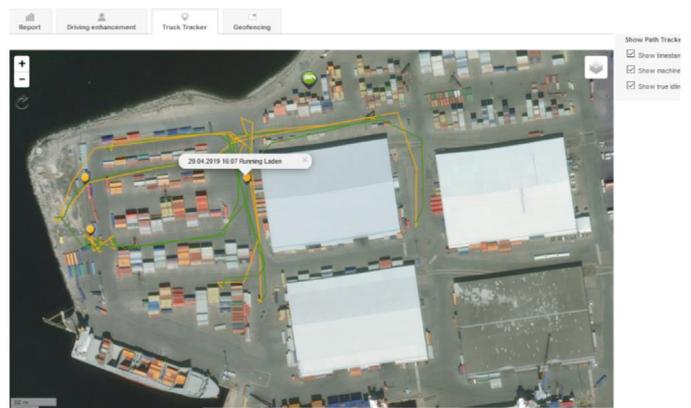


Fig. 5. The Konecranes Path Tracker function, available through TRUCONNECT Remote Monitoring in the yourKONECRANES.com customer portal can help to plan the most efficient charging locations.



Safety

Lithium-ion batteries are quickly becoming the industry standard for the electrification of all kinds of vehicles, from cars to cargo handling equipment. Safety is the highest priority, and thanks to an increasing market presence, international safety standards are already in place. Safety always starts with the manufacturer.

In electric vehicles, safety should be observed:

- in the electrical system;
- for system functions;
- while charging batteries;
- during maintenance, operation and training.

All of these aspects have been considered during forklift design, with all possible requirements met to minimize the possibility of any hazards. Some of the key safety measures are described below.

Battery control system

Li-ion battery packs must operate within specific parameters of temperature and electric current. A Battery Management System (BMS) constantly monitors cell voltage, electric current and battery temperature so that any movement outside of normal range disconnects the cell or the entire battery.

The temperature of the battery pack is controlled by a Thermal Management System (TMS). Exposure of the battery pack to temperatures outside optimal operating range activates heating or cooling as necessary.

Preventing damage

Mechanical damage to the battery pack must be avoided. Battery cells that are dented can cause a short circuit and generate heat, or in extreme cases, overheating. These battery packs are mounted in a well-protected position at the centre of the chassis. They are surrounded by a protective frame to minimize the risk of physical impact on the battery inside the truck.

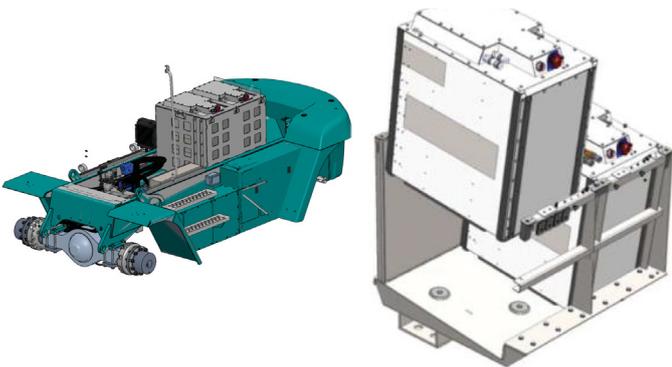


Fig. 6. Battery position in the chassis

The specially designed electric driveline contains high voltage and should only be serviced by trained personnel.

Li-ion batteries do not need to be swapped or even touched most of the time. The manufacturer provides guidance and training on the safe handling and service of the electric forklift.

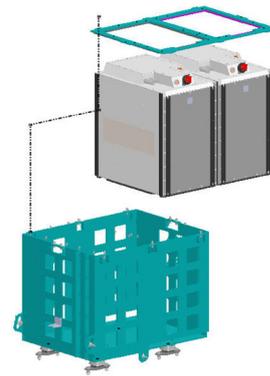


Fig. 7. Battery secured cage

Fire protection

From the reports of electric car manufacturers, it is clear that vehicles powered by Li-ion batteries are less likely to be involved in fires than similar vehicles using fossil fuels. The most common cause of fires in electric cars is a collision that mechanically damages the battery. This is almost impossible to happen with the Konecranes electric forklift, as something sharp would need to pierce the battery cage.

In the very unlikely event of a fire, it can be extinguished with large amounts of water, and the battery can also be cooled down with water to prevent further ignition. It is advisable to contact the local fire department before starting to operate lifting equipment powered by Li-ion batteries.



Digitalization

There is much more data to monitor in an electric forklift truck than a diesel model. So Konecranes has developed a new state-of-the-art IoT platform based on the latest technologies.

Konecranes can now:

- Provide the latest available cyber security level under ISO 27001;
- Increase performance significantly by collecting data from the truck and transferring it hourly;
- Collect data from the truck and the battery, to be sent to the cloud in < 1 sec;

- Retrieve battery data analytics and monitor the parameters to optimize the BMS and extend battery lifetime;
- Integrate with customer systems;
- Send data from suppliers' subsystems directly to cloud services;
- Automatic software updates just like on a mobile phone.

A new 4G modem on the trucks, specifically designed for mobile applications, brings GPS accuracy from 10/15 meters to 2/3 meters, which helps to define operating areas using Geofencing.

What's on the display

The main display in the forklift cabin shows key information about the battery, such as charge level, temperature and energy consumption. HVAC can also be controlled by the same user interface.

The second level display shows power required by traction, Power Take Off (PTO), the Thermal Management System (TMS), and DC/DC converters that supply auxiliary systems.

Dedicated counters are available for energy consumption rate, average power, time elapsed and total energy used. There is also a maintenance page for the status of HV parts and switching connections.

Battery information

Residual capacity shows clearly on the main display like the fuel gauge in a car, to avoid running out of power away from a charging station.

Before the battery runs out of charge, the truck alerts the driver in the following ways:

- At 30% remaining energy, the display shows an alert and the lifting and driving functions of the truck are noticeably reduced.
- At 25% remaining energy, another alert appears and the truck enters "limp home mode", with further reductions in performance.
- Future electric forklifts will combine remaining battery energy with the location of the truck and the nearest charging station using the Work Zone function.

Konecranes TRUCONNECT Remote Services uses the new modem to collect vehicle data, including battery analytics and other truck information, for an accurate picture of all lift trucks in the yourKONECRANES customer portal.

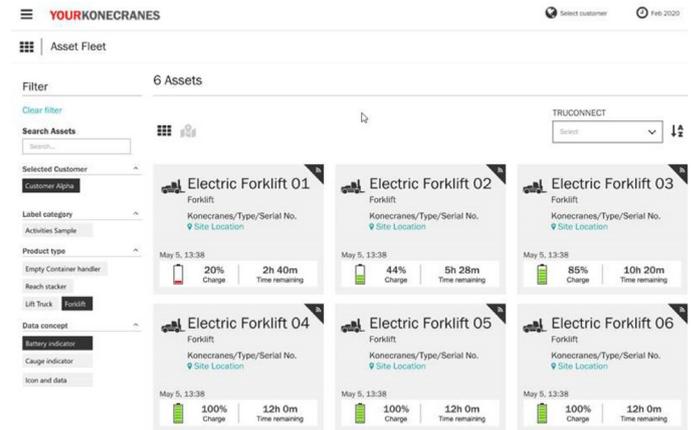


Fig. 8. yourKONECRANES.com Customer portal "Asset fleet" interface

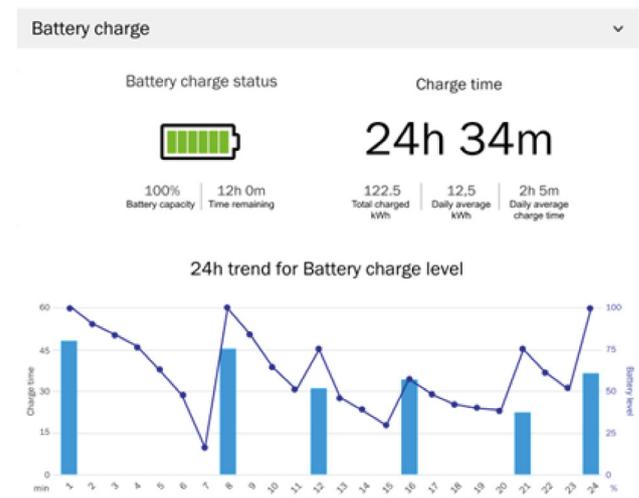


Fig. 9. Battery charge status from yourKONECRANES.com Customer portal

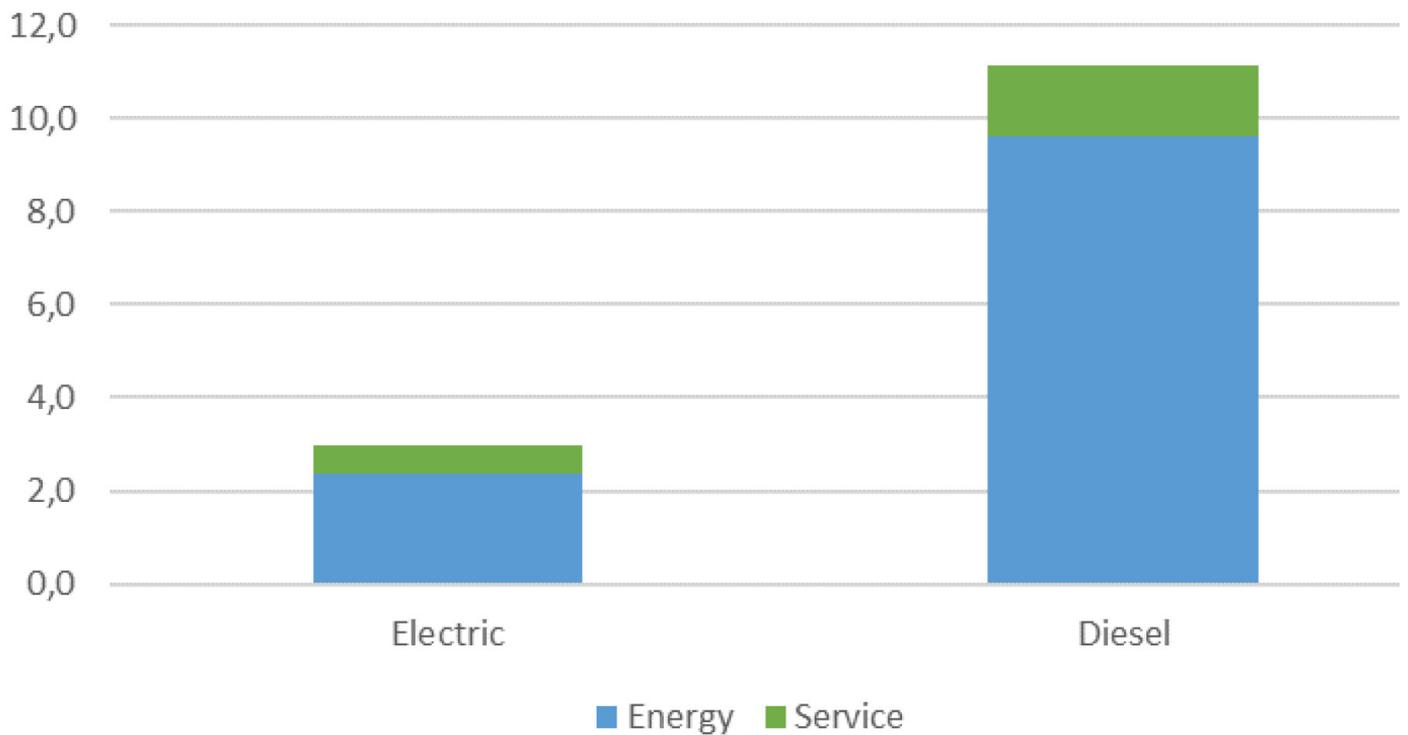


Fig. 10. Service costs added to the energy costs as presented in Fig. 1.

Spare parts and maintenance

A less complex driveline means the cost of servicing a Li-ion electric truck is much cheaper.

Diesel trucks require service to the engine, transmission, oil and filters. With only an engine and transmission to take care of, there is around 23% less maintenance on an electric truck, but the simpler design reduces the overall cost of servicing an electric forklift by more than half.

There is normally no need to remove the Li-ion battery or have a spare one handy. Technicians only replace parts that suffer wear and tear. Modular design makes this a simple process without special training or licenses.

Total cost of ownership

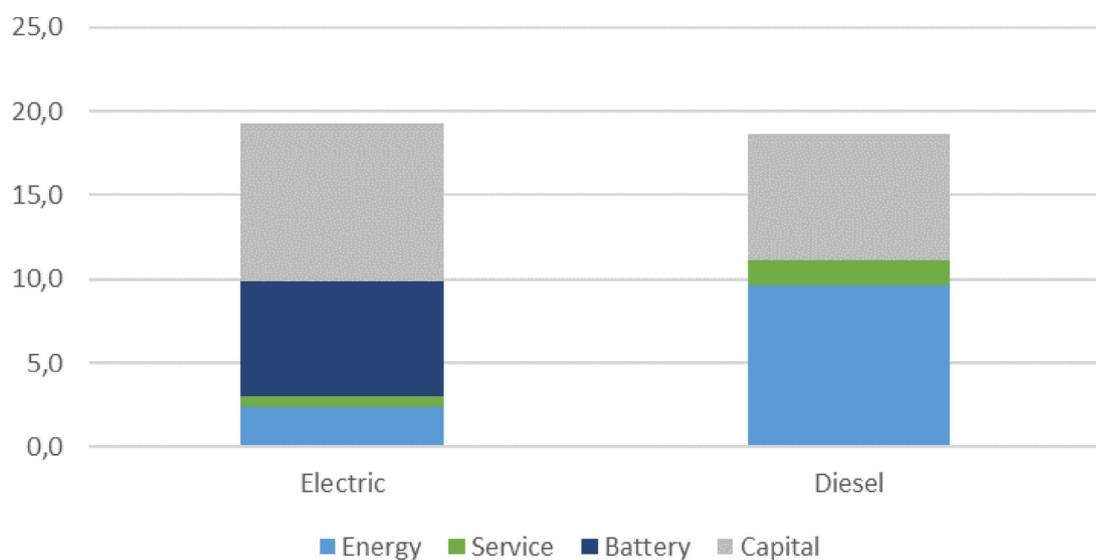


Fig. 11. Amortization and interest costs based on ten years' operational lifetime added to get to TCO (total cost of ownership).

When calculating the total cost of ownership, capital investments and interest are also added to the equation.

Taking into account normal equipment lifetime, the electric forklift is a very good option when compared to a diesel forklift truck.

Why Konecranes?

Focus on operation

Knowing the development and technical background of the electric forklift can make the truck seem very advanced, but that doesn't mean that operators need focus on these details. On the contrary, the truck has been designed specifically to make using it easier, so that your operators can focus on the most important thing - lifting your business.

Electrify your business

Electrification is not new to Konecranes. We're a leading company in the lifting business, with extensive experience in electrically powered lifting and mobile solutions like no others in the industry. The knowledge of Konecranes Group companies such as Gottwald in electric mobile cranes and terminal AGVs, Noell in electric straddle carriers, Motronica and Technical HUB in control systems and electrification solutions, and Konecranes in industrial lifting and port logistics, have been combined to develop a new range of quality, high-tech products that give you outstanding performance.

We didn't invent electrification, but we're ready to take it to the next level. We want to set the standard for electrification as we go forward, moving in a direction that the market is clearly telling us.

We provide our experience, expertise and guidance to you, as our customer, as we continue to build lift trucks for your world.

As we do this, we also do our best to reduce our carbon footprint, while extending our reach all over the world. The electric forklift will help you to increase your own reach and succeed in your business.



In 2013, Konecranes Lift Trucks was the first company in the world to sell hybrid reach stackers. Now, in 2020, years of development have finally brought you an electric forklift.



Familiar feeling – sustainable technology

Over the years, customers have come to appreciate Konecranes Lift Trucks for their dependability and the quality of their workmanship. Drivers like the ergonomics and extra power that help them to go the extra mile and manage busy schedules around the year. All these familiar values are found in the same way in the new range of electric forklifts.

The electric driveline has also added possibilities to further refine the familiar feeling:

- More power for driving and lifting – plus peak power when accelerating and lifting.
- An almost silent truck with minimal vibration for a further improved driving experience.

- No local air pollution – good for the environment, outdoors and indoors.

Driving electric

The driver will get to know the electric driveline through additional information in the main display. The charge status of the battery appears as a coloured bar and as a percentage of full capacity.

Ready to test-drive?

We're ready when you are. The range of medium-sized electric forklifts from Konecranes Lift Trucks is expanding quarter by quarter from now on!

Contact us at ever@konecranes.com to discuss how we can help you to lift your business.