

→ Hydrogen as a fuel for forklift trucks

THE LINDE GROUP

Linde

Hydrogen for forklift trucks.

The eco-friendly recipe for
economical success.

Powered by sustainability. Hydrogen as a fuel for forklift trucks.

As a result of ongoing industrialisation, the global hunger for energy is constantly rising. This situation requires new solutions even today, because, now and in the future, the growing energy demand must be reliably met while at the same time ensuring maximum environmental protection. As an energy carrier, hydrogen covers both tasks: on the one hand, it is a sustainable and safe alternative to conventional fuels, and, on the other hand, it is especially eco-friendly. Moreover, if renewable energy sources are used for its production, hydrogen creates no CO₂ emissions at all, which in turn leads to a completely emission-free energy cycle. This is why it is also very attractive as a fuel for various automotive applications such as hydrogen cars, buses and forklift trucks (FLT).

A world-leading international gases and engineering company, Linde has years of experience in the successful development of cutting-edge hydrogen fuelling station technologies and is actively taking part in various initiatives that pursue the goal of creating a comprehensive market launch of hydrogen as a fuel. Moreover, Linde covers the entire hydrogen value chain – from various production processes to all sorts of application technologies.



Why using hydrogen as a fuel for FLT makes sense.

Up until recently, FLT have predominantly been operated either electrically, i.e. with rechargeable lead-acid batteries, or conventionally, i.e. with combustion engines. Both methods, however, have their issues in terms of costs and usability.

Using hydrogen as an alternative energy carrier is especially attractive for the operation of FLT because it not only means easy handling, greater efficiency, less downtime and a small CO₂ footprint but low costs as well, making this method both economically and ecologically worthwhile.

Instead of a combustion engine or a lead-acid battery, a hydrogen-powered FLT is based on an energy-efficient fuel cell which in turn activates an electric motor. Especially when compared to a battery-powered FLT, the efficiency of this innovative system starts even before the hydrogen-powered FLT is actually driven because the fuelling process takes only three minutes or even less, whereas replacing FLT batteries can take up to 20 minutes, during which the battery-based FLT is standing idle. The economical advantage is that the FLT remain in operation for longer periods of time. Consequently, the operator can reduce the number of FLT in his fleet.

Recharging FLT batteries can take several hours and necessitates the handling of harmful and environmentally hazardous substances such as lead and battery acid. All this and the high initial costs of spare rechargeable batteries can be eliminated by the use of state-of-the-art hydrogen fuel cells and the corresponding fuelling solution.

Another plus that comes with this technology is that driving hydrogen-powered FLT, in comparison to systems based on combustion engines, is practically noiseless. And even if the hydrogen required for their operation is produced by conventional means such as steam reforming or coal gasification, using conventional hydrogen already reduces CO₂ emissions by up to 80 % (with the potential of creating no emissions at all when produced from renewables) as compared to FLT powered by combustion engines.

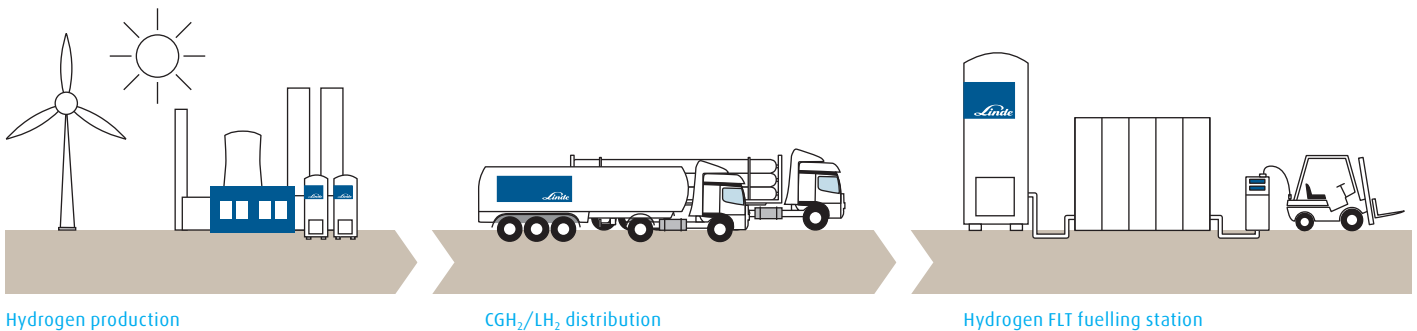
At a glance: Hydrogen-powered FLT have numerous advantages over conventional FLT which can turn into TCO advantages

- Very short fuelling time (between 2 and 3 minutes), thus hardly any downtime
- No additional battery changing facilities necessary
- No additional space needed for spare batteries
- No performance loss during operation
- Practically noiseless operation
- CO₂ emission-free
- Very low maintenance effort
- FLT remain in operation for longer periods of time, number of FLT can be reduced

Compared to conventional drive systems, using hydrogen as a fuel for FLT has many advantages – here they are, at a glance:

	Forklift trucks powered by:		
	Hydrogen fuel cells	Rechargeable batteries	Combustion engines
FLT classes	1, 2 and 3	1, 2 and 3	1 and 2
Location of use	Indoor and outdoor, in transition areas	Predominantly indoor	Outdoor use only
Power output	Constant	Performance loss during operation	Constant
Operating time	3-8 hours	6-7 hours	12-16 hours
Time needed for refuelling	2-3 minutes	20 minutes (for rechargeable battery replacement)	2-3 minutes

Production, distribution, application. Linde covers the entire hydrogen value chain.



Apart from extensive know-how for the implementation of hydrogen projects, Linde has many years of experience in developing, producing and installing hydrogen fuelling station technologies and provides customised services for reliable hydrogen station maintenance and efficient operation.

Hydrogen production

In spite of highly efficient processes, conventional hydrogen production methods such as steam reforming generate CO₂ emissions. In order to establish a hydrogen chain which is completely CO₂-free, Linde is developing various eco-friendly processes to produce hydrogen, e.g. from biomass. Another alternative is producing hydrogen on site through electrolysis. This method also allows for CO₂-free hydrogen production if the electricity required for on-site electrolysis is generated from renewable energy sources.

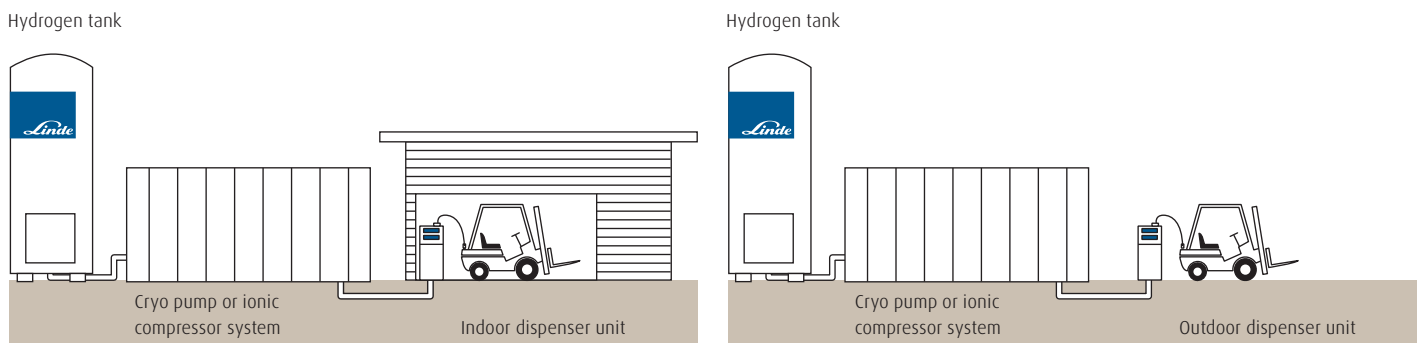
Hydrogen distribution

Once the hydrogen is produced, it can either be transported in trailers as a cryogenic liquid at -253 °C, or via pipeline or trailer as a compressed gas at ambient temperatures. The main advantage of liquid hydrogen (LH₂) is that the same quantity of hydrogen stored in this way takes up less space than compressed gaseous hydrogen (CGH₂). The cryogenic temperature needed for liquid hydrogen storage, however, has to be maintained by using specially insulated, double-walled cryogenic tanks.

Hydrogen FLT fuelling stations

For the application of hydrogen as a fuel for FLTs, Linde engineers and installs the fuelling technology for on-site hydrogen stations. Apart from storage tanks for liquid or gaseous hydrogen and the corresponding hydrogen dispensers, Linde's state-of-the-art hydrogen compression technology is at the core of each of our hydrogen fuelling stations.

Flexible hydrogen fuelling solutions for FLTs



Hydrogen fuelling station technologies

Compression technology is crucial for hydrogen fuelling stations because hydrogen can only be fuelled with a pressure difference. Technologically, this pressure difference is created by means of a compressor. Depending on the individual fuelling requirements, Linde has developed compression technologies for compressed gaseous hydrogen as well as for cryogenic liquid hydrogen. The application of these technologies is subject to various different factors such as the number of FLT's and the required fuelling frequency, the way in which the hydrogen is delivered (CGH₂ or LH₂, on-site production, trailer or pipeline) as well as investment and operating costs. Our engineers are experts in assessing the required hydrogen parameters and finding the best-suited hydrogen production, distribution and fuelling technologies for your hydrogen-powered FLT's.

The cryo pump

Cryogenic liquid hydrogen can be compressed with Linde's patented cryo pump. The process benefits to a high degree from the direct compression of liquid hydrogen, reducing the energy demand at the hydrogen fuelling station to a minimum. Moreover, no additional cooling is needed during the compression process. A specially designed heat exchanger and a temperature conditioning system raise the temperature of the cryogenic gas to -40°C. Subsequently, hydrogen-powered FLT's can be fuelled with gaseous hydrogen through a standard hydrogen dispenser.

Advantages of the cryo pump at a glance:

- High throughput
- Very low energy consumption
- Hydrogen with highest purities
- No additional cooling system
- High reliability
- Little maintenance effort and low costs
- Low noise emission

The ionic compressor

For compressed gaseous hydrogen, Linde has developed and patented an innovative and unique compression technology: the ionic compressor. Instead of a metal piston, this solution is based on an ionic liquid which compresses the gas by its up-and-down motion. This liquid consists of tailor-made salt molecules with special physical and chemical properties which prevent them from mixing with the hydrogen gas. This is very important because, for application in fuel cells, hydrogen has to be very pure. The ionic compressor, contrary to conventional compressors, needs no lubricant (which could contaminate the hydrogen) and, unlike conventional lubricant-free compressors (which require more frequent maintenance intervals), it virtually eliminates mechanical wear. Moreover, the ionic compressor removes the compression heat directly from the cylinder, whereas with metal pistons, the heat must be removed by means of heat exchangers.

Advantages of the ionic compressor at a glance:

- Close to 100 percent energy conversion efficiency
- Low energy consumption
- Very small number of moving parts (due to use of ionic liquid as piston)
- Reduced wear and long service life
- Little maintenance effort and low costs
- Low material costs
- Low noise emission

Hydrogen forklift reference projects.

Hydrogen FLT fuelling station at BMW, Greer, SC, USA

For its vehicle manufacturing plant in Greer, South Carolina, Linde provided BMW with a hydrogen fuelling system for its material handling fleet. Linde engineered and installed a liquid hydrogen tank and six indoor hydrogen dispensers which are supplied by an ionic compressor fuelling system. After having their lead-acid batteries replaced with hydrogen fuel cells, fuelling BMW's FLTs with hydrogen now takes an operator less than three minutes.



Hydrogen FLT fuelling station at Coca-Cola (CCBCC), Charlotte, NC, USA

For its bottling plant in Charlotte, North Carolina, Linde engineered and installed a liquid hydrogen tank and three indoor hydrogen dispensers for its material handling fleet. The hydrogen fuelling system is an ionic compressor fuelling system which provides 100 to 125 kg of hydrogen per day. In total, 40 propane-powered FLTs were retrofitted with hydrogen fuel cells.



Hydrogen FLT fuelling station at Whole Foods, Landover, MD, USA

For its distribution centre in Landover, Maryland, Linde provided Whole Foods with a hydrogen fuelling system for its material handling fleet. Linde engineered and installed a liquid hydrogen tank and two indoor hydrogen dispensers which are supplied by an ionic compressor fuelling system. After having their 63 battery-powered FLTs upgraded to hydrogen fuel cells, fuelling Whole Food's FLTs with hydrogen now takes an operator less than three minutes.



Get in touch with our hydrogen experts

Are you planning to retrofit your forklift trucks with efficient, eco-friendly hydrogen drives? Or are you thinking about setting up a new, hydrogen-powered FLT fleet entirely? Then get in touch with our specialists for hydrogen FLT fuelling stations. They will help you find the best hydrogen technology solutions and support you and your project at any step along the way.

It's time to do H₂.



Getting ahead through innovation.

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages, and greater profitability. Each concept is tailored specifically to meet our customers' requirements – offering standardised as well as customised solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow's competition, you need a partner by your side for whom top quality, process optimisation, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde – ideas become solutions.

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