BENNING

World Class Charging Systems

Excellent Technology, Efficiency and Quality

New energy for the future

LIONIC®

Lithium-ion energy systems
for the materials handling industry

LIONIC® reduces the total cost of ownership (TCO) of your industrial truck operations

Fig. 1: Cost comparison 375 Ah lead-acid batteries vs. LIONIC® 240 Ah energy system based on 2-shift operation over a period of 5 years. (investment and operating costs)

LIONIC® – the highly efficient energy system for the materials handling industry

- Fast charging
- Opportunity charging
- Maintenance-free, no topping up with water
- Low operating costs
- Long life
  > 3000 cycles
- Reliable operation

Fig. 2: LIONIC® energy system 24 V / 6 kWh (240 Ah)

More energy and lower costs thanks to opportunity charging

Make better use of equipment, increase cost efficiency

- No second battery required
- Opportunity charging possible at any time (37.5 % charge in 0.5 h at $I_L = 0.75$ C)
- 100 % charge in 2.0 h, $I_L = 0.5$ C

LIONIC® energy systems are capable of fast charging and can also be opportunity charged. Charging is carried out at constant current. In 2-shift operation, a replacement battery is not required if opportunity charging is carried out during breaks (1x15 min and 1x30 min per shift).
As an example, Fig. 3 shows the capacity curve of a LIONIC® 24 V / 9 kWh (360 Ah) energy system for 2-shift operation with intermediate charging.

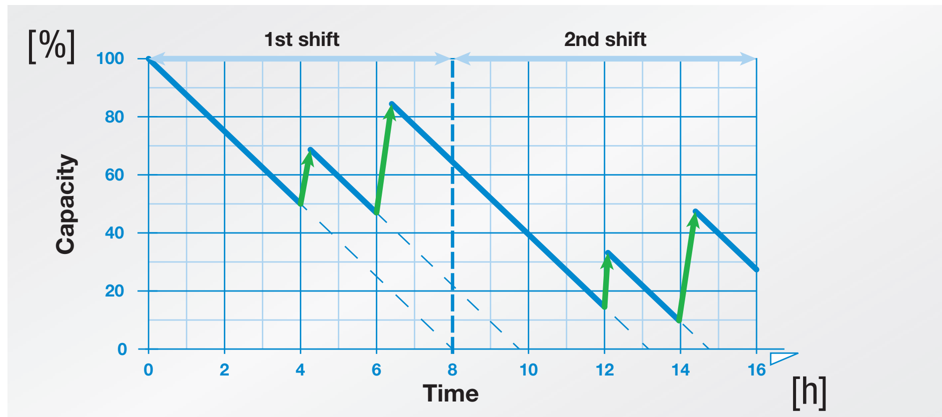


Fig. 3: Capacity curve of a LIONIC® 24 V / 9 kWh (360 Ah) energy system for 2-shift operation with opportunity charging

LIONIC® energy systems provide up to 30 % higher energy efficiency

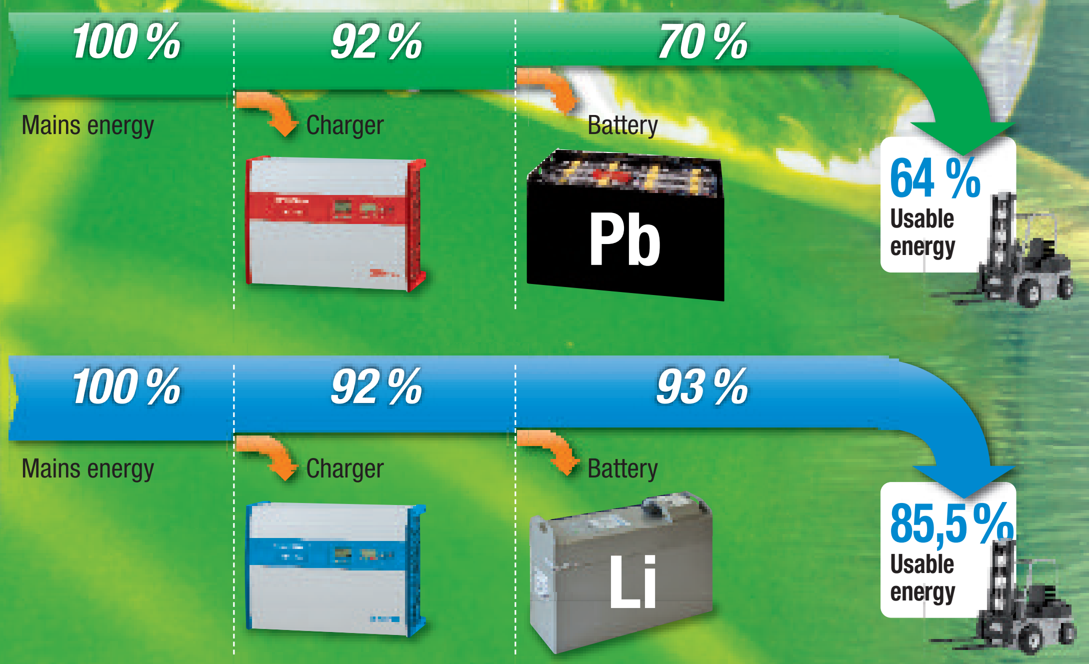


Fig. 4: Comparison of usable energy for lead-acid and lithium batteries

LIONIC® – Lower energy consumption, less CO_2

Economic and environmental advantages:

- Reduced energy costs
- High efficiency
- Emission-free
- Low self-discharge
- Energy recovery system e.g. during braking
- Stand-by mode
- Environmentally friendly
- Recyclable

Fig. 5: LIONIC® energy system 24 V / 6 kWh (240 Ah)

LIONIC® – Higher energy efficiency reduces your costs and protects the environment!

As Fig. 4 shows, the electrochemical conversion of the electrical energy in the lead-acid battery takes place with an efficiency of only 70 %.

The losses arise due to the charge factor, the large voltage swing between charge and discharge, and the temperature rise in the battery during the charging/discharging process.

Only 64 % of the full mains energy is available for the operation of electric vehicles powered by lead-acid batteries.

If LIONIC® energy systems are used instead of lead-acid batteries, the usable energy for the electric vehicle increases significantly to 85.5 %. This is because the efficiency of LIONIC® energy systems is approx. 93 % and therefore substantially higher than with lead-acid batteries.

This high efficiency is the result of a reduced charge factor, lower voltage swing and lower temperature rise when charging and discharging.

This gives rise to significantly better energy efficiency with LIONIC® energy systems.

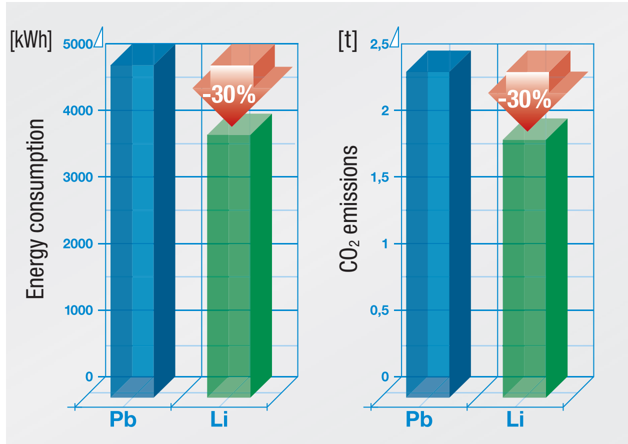


Fig. 6: Annual energy consumption and CO_2 emissions for charging traction batteries - lead-acid battery (Pb)/lithium-ion battery (Li)

Compared with lead-acid batteries, 30 % less electrical energy is required for every charging operation.
The costs for electrical energy and the figures for the relevant CO_2 emissions reduce equally as a result of using LIONIC® energy systems.

Lithium vs. lead-acid battery – saving in operating costs of a LIONIC® 24 V / 6 kWh (240 Ah) energy system

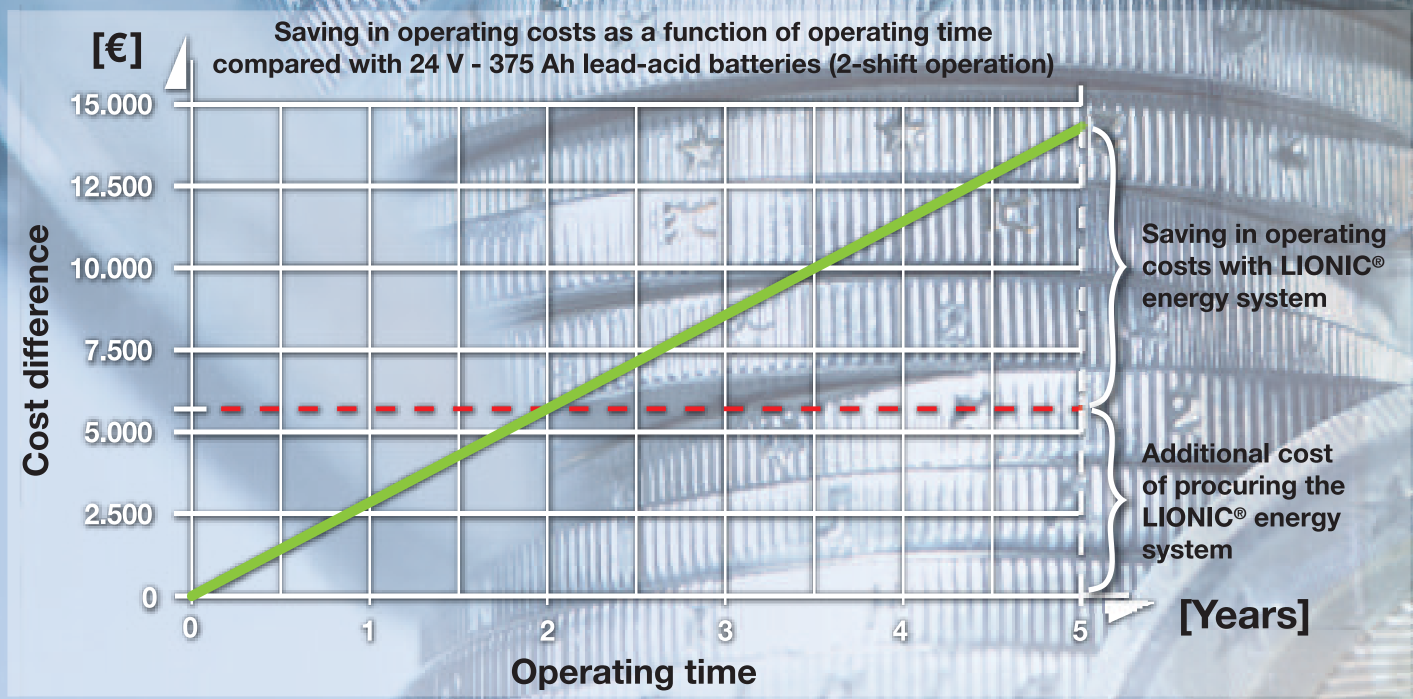


Fig. 7: The additional cost of investing in a LIONIC® energy system is compensated for by the savings in operating costs after just 2 years.

LIONIC® – The efficient energy system with the following cost advantages

- Approx. 30 % reduced energy costs
- Approx. 75 % lower maintenance costs
- Approx. 60 % lower battery handling costs

Fig. 8: LIONIC® energy system 24 V / 6 kWh (240 Ah), fitted in a conventional battery tray with counterweight

The diagrams (Fig. 7 and 9) show the large difference in maintenance and battery-handling costs for lead-acid and lithium-ion batteries. The cost comparison is based on 2-shift operation with two lead-acid batteries compared with one lithium-ion battery.

With lead-acid batteries, maintenance in the form of topping up the water is carried out once a week; with the LIONIC® energy system, inspection only has to be carried out once a year.

With lead-acid batteries, costs are incurred at every battery changeover due to the 2-shift operation (7 battery changes/week). With the LIONIC® energy system, short-term opportunity charging eliminates the costs for changing batteries. (see also Fig. 3, Page 3)

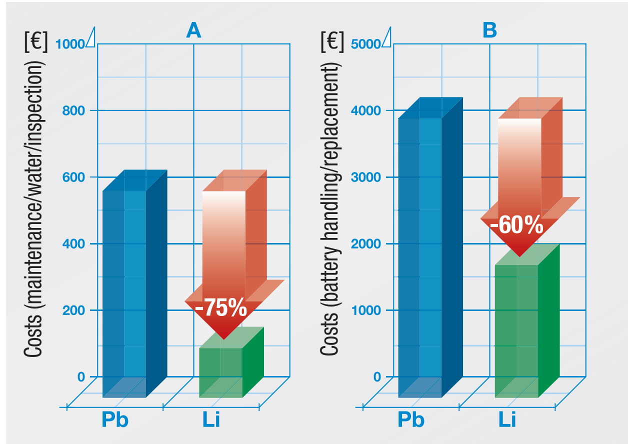


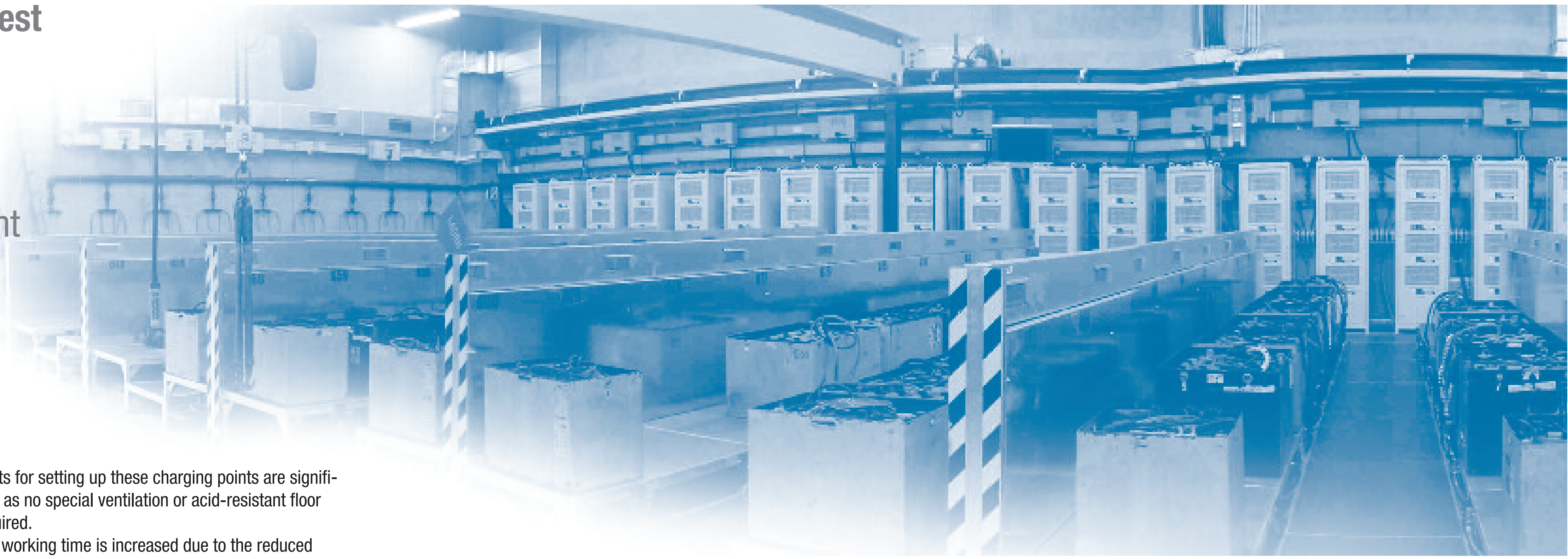
Fig. 9: Lead-acid battery (Pb) vs. LIONIC® energy system (Li), annual cost comparison for:
A) Maintenance and water or inspection (for 2-shift operation)
B) Battery handling/battery changeover or charging (for 2-shift operation)

LIONIC® – operationally reliable and emission-free ideal for the food trade and refrigerated warehouses

LIONIC® energy system – no need to invest in central battery rooms

Charging is carried out on site

- No central charging station
- No need for battery changing equipment
- No ventilation and extraction systems
- No central water filling
- Short distances to charging point



LIONIC® energy systems can be charged at decentralised charging points. As no gassing occurs during charging and LIONIC® energy systems do not contain liquid electrolyte, the special regulations for central battery charging stations (e.g. DIN 50272-3, BGHW, ZVEI datasheet) do not apply in many respects to the charging of LIONIC® energy systems.

Investment costs for setting up these charging points are significantly reduced, as no special ventilation or acid-resistant floor material is required.
In many cases, working time is increased due to the reduced distance travelled to reach the decentralised charging station.

Fig. 10: In the future the investment in central battery charging rooms with costly extraction and handling systems can be dispensed with

E/PzS lead-acid batteries vs. LiFePO$_4$ lithium-ion batteries

Lead-acid batteries	Characteristics	Lithium-ion batteries
40 Wh/kg	Energy density	95 – 140 Wh/kg
Up to 70 %	Charging efficiency [%]	Up to 95 %
1200 cycles	Charge/discharge cycles	> 3000 cycles
Gassing and water loss occurs when charging	Emissions	Emission-free (zero gassing)
Required	Maintenance	Not required
Charging: 50 % in approx. 3 h, 90 % in approx. 6 – 7 h	Fast charging capability	Charging: 90 % in approx. 1.5 - 2 h
Negative effect on service life	Opportunity charging	No negative effect on service life

Fig. 11: Comparison of main characteristics

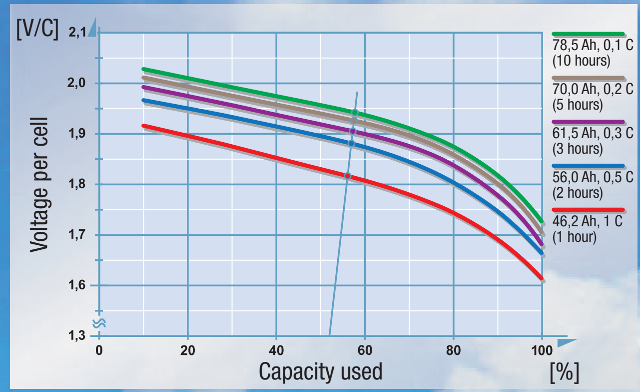


Fig. 12: Discharge curves for an E/PzS lead-acid cell (70 Ah, 5 hours) as a function of the capacity used

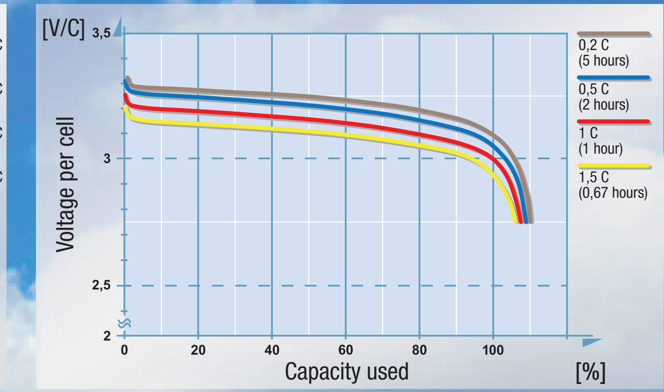


Fig. 14: Discharge curves for a lithium-ion cell (LiFePO$_4$) as a function of the capacity used

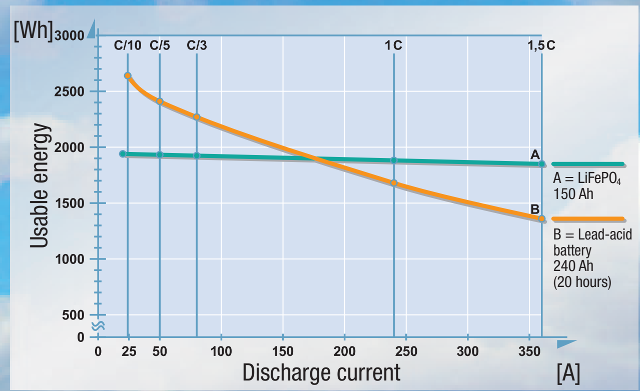


Fig. 13: Usable energy at increasing discharge currents

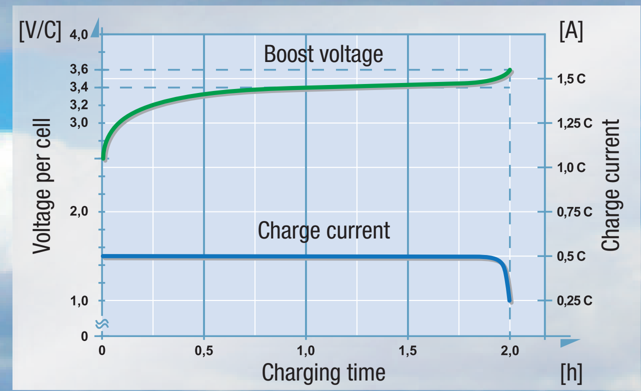


Fig. 15: Boost voltage as a function of the charging time, charge current 0.5 C

Comparison of the main characteristics of lead-acid and lithium-ion batteries

From the point of view of the user of battery-powered industrial trucks, the current method of propulsion with lead-acid batteries has several significant disadvantages, in spite of good reliability overall. With today's knowledge, no satisfactory solutions to these problems are likely to be available in the future.

Significant improvements can be achieved here by the use of lithium-ion batteries, e.g. higher energy efficiency (lower operating costs), very short charging times (effective opportunity charging), freedom from maintenance, emission-free recharging, lower weight and volume and longer service life.
(See Fig. 11)

Lithium iron phosphate (LiFePO$_4$) traction batteries have been used in various parts of the materials handling industry for some time.

Previous practical results from more than 500,000 h operational experience are very positive and confirm the superior system-specific characteristics of lithium iron phosphate (LiFePO$_4$) batteries compared with lead-acid batteries.

These energy systems are very robust and are distinguished by an extremely long service life.

From current results, a service life of more than 3000 charge/discharge cycles can be expected. This is at least 2.5 times the average life of E/PzS batteries.

As a pioneer of these new energy systems, the BENNING LIONIC® range now offers energy systems with capacities of 120 Ah, 240 Ah, 360 Ah and 480 Ah to replace the E/PzS lead-acid batteries previously used in 24 V industrial trucks.

The usable energy of lead-acid and lithium-ion traction batteries

The energy contained in a traction battery is the product of the rated capacity (Ah) and the rated voltage (V). A fully-charged 24 V lead-acid battery with a capacity of 375 Ah (5 hours) has an energy content of 24 V x 375 Ah = 9.0 kWh.

A 24 V - 240 Ah lithium-ion battery comprising 2 x 8 cells, each with a cell voltage of 3.2 V, has a rated voltage of 25.6 V and an energy content of 6.1 kWh.

The cell voltage of an E/PzS lead-acid battery drops significantly during the discharge process. This voltage drop is further increased at higher rates of discharge (see Fig. 12).
In contrast, the discharge voltages of lithium-ion batteries are very constant up to discharge times of 1 hour, so that nearly 100 % of the initial energy is available over the whole discharge range. (See Fig. 14)

When determining the nominal capacity of the E/PzS traction battery for a particular industrial truck and load profile, the reducing energy values during the discharge process must be compensated for by selecting a larger rated capacity (Ah).
This is to ensure that the truck is supplied with sufficient energy at all points of the load profile as the battery discharge state increases.

From previous experience, lithium-ion batteries with a 35 % smaller capacity than E/PzS lead-acid batteries can be chosen for the same application thanks to their excellent voltage stability.
For example, a 240 Ah E/PzS lead-acid battery can be replaced by a 150 Ah lithium-ion battery. (See Fig. 13)

Fig. 15 shows the charge voltage and charge current characteristics when charging a lithium-ion cell with a charge current of 0.5 C.
With this charge current, the charging time of a fully discharged LIONIC® energy system is 2 h.

LIONIC® energy systems achieve 2.5 to 3 times more charge cycles

BELATRON Li+ charging systems ensure fastest possible availability of the energy system

Fig. 16: External charge state and status indicator

Fig. 17: 24 Volt LIONIC® energy systems with different capacities

Fig. 19: Housing WT 120 Housing WT 60

Technical data

Type		24 V / 3 kWh	24 V / 6 kWh	24 V / 6 kWh "long"	24 V / 9 kWh	24 V / 12 kWh
Energy	[kWh]	3.1	6.1	6.1	9.2	12.3
Capacity	[Ah]	120	240	240	360	480
Charging time	[h]	1.5	2	2	3 (<2)*	4 (2)*
Charge current	[A]	80	120	120	120 (200)*	120 (240)*
Operating temperatures	[°C]	-20 to +60 (discharging) / 0 to +50 (charging)				
Storage temperatures	[°C]	-20 to +35 (6 months) / -40 to +45 (1 month)				
Dimensions						
Height x Width x Depth	[mm]	455 x 608 x 138	455 x 608 x 202	455 x 772 x 160	455 x 608 x 296	455 x 772 x 306
Weight (+/- 5 %)	[kg]	56	86	86	125	165
Protection class		IP54 / IP67**				

** Charge current "plus" option*
*** Optional*

LIONIC® energy systems

BENNING LIONIC® 24 V energy systems consist of 8 lithium iron phosphate ($LiFePO_4$) cells connected in series and are available with capacities of 120 Ah, 240 Ah, 360 Ah and 480 Ah. LIONIC® energy systems are suitable for the majority of industrial trucks powered by 24 V batteries.

LIONIC® energy systems are about 50 % lighter and about 30 % smaller than comparable lead-acid batteries.
Every 24 V energy system is fitted in a robust housing together with a Battery Management System (BMS) and can be integrated into standard battery trays.

The Battery Management System (BMS) ensures that voltage and temperature limits are maintained during the charging/discharging process. The individual cells are also monitored and are equalised in the event of potential deviations.

Fig. 18: Charge state indicator for LIONIC® energy systems

Technical data

Output voltage 24 V						
Rated current	[A]	80	100	120	200	240
Mains voltage	[V]	1 x 230	1 x 230	3 x 400	3 x 400	3 x 400
Mains current	[A]	11.2	14	6.7	9.8	13.4
Dimensions						
Height x Width x Depth	[mm]	405 x 564 x 318	405 x 564 x 318	405 x 564 x 318	405 x 564 x 318	405 x 564 x 318
Weight	[kg]	27	27	30	38	38
Housing		WT 60	WT 60	WT 60	WT 60	WT 60

BELATRON Li+ charger

BELATRON Li+ units are highly efficient charging systems with an efficiency of ≥ 92 % and have been specially developed for charging LIONIC® energy systems.

The charging process follows an IU-characteristic and is monitored and controlled by the Battery Management System (BMS) incorporated in the LIONIC® energy system.

With high-efficiency chargers, the electrical energy consumed when charging LIONIC® energy systems is approx. 30 % less than when charging E/PzS lead-acid batteries.

30 % less electrical energy means 30 % lower energy costs and 30 % lower CO_2 emissions.

LIONIC® energy systems – easily integrated into your industrial trucks

Easy opportunity charging using externally accessible plug-in charging connector

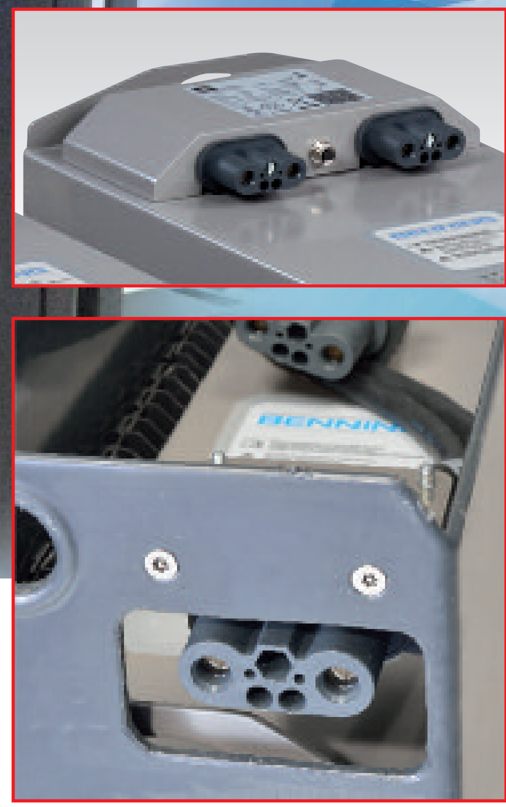


Fig. 22: An externally accessible plug-in charging connector enables fast opportunity charging without lifting the battery cover. (Option)

Options

Type	24 V/3 kWh	24 V/6 kWh	24 V/6 kWh "long"	24 V/9 kWh	24 V/12 kWh
Easy opportunity charging (2 power sockets etc.)	available	available	available	available	available
Charge current "plus"	–	–	–	200 A (< 2 h)	240 A (2 h)

"–" = unavailable

Fig. 20: Integral metal plates are used as a counterweight for use in counterbalance trucks.

Fig. 21: Examples of LIONIC® energy systems in conventional battery trays

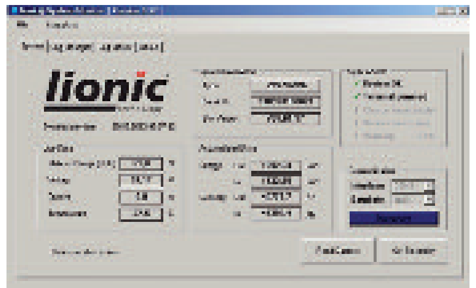


Fig. 23: System overview

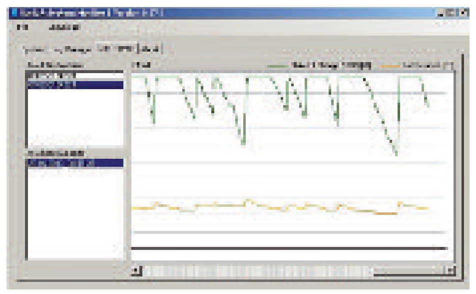
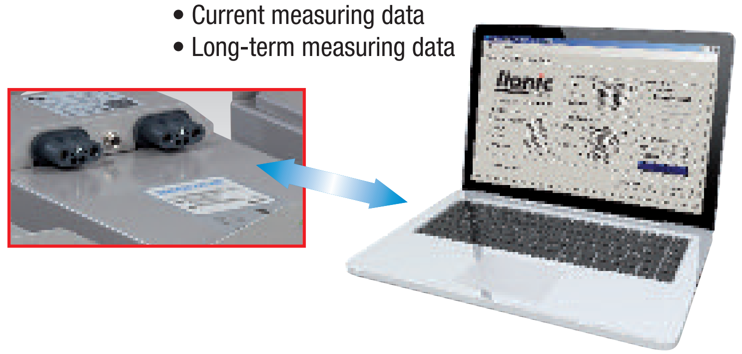


Fig. 24: Opportunity charging overview

LIONIC® Monitoring Software

- Data transmission to laptop using infrared interface
- Current measuring data
- Long-term measuring data



These days, it is essential for battery-powered industrial trucks to have a high availability and to operate reliably and efficiently. The control of the charging/discharging process for the traction batteries and the monitoring of battery temperatures are important measures for ensuring the maximum availability of the truck fleet at all times.