

Energy Storage Specification

Market
Mobile
Transportation
Grid

Cost

- Capacity cost, \$/kWh**
 - \$1600 LiCoO2 Lithium Ion Polymer (C anode, LiCoO2 cathode)
 - \$1141 LiFePO4 Lithium Iron Phosphate (C anode, LiFePO4 cathode)
 - \$770 NiZn Nickel-zinc
 - \$668 NiCd Nickel-cadmium (flooded)
 - \$? AGM lead acid (low internal resistance)
 - \$236 AGM lead acid (high internal resistance)
 - \$327 Gel lead acid
 - \$115 Lead acid (flooded)
- Cost cent/Wh**
 - 30-50 cent/Wh NiZn Nickel-zinc, rechargeable used in portable cordless applications
 - 35-60 cent/Wh NiCd Nickel-cadmium, portable electronics and toys
 - 40-60 cent/Wh Ni-MH Nickel-metal hydride, higher capacity and less toxic than NiCd, used in GM, Honda EV plus, Ford Ranger, Toyota Prius, Honda Insight & Civic, Ford Escape Hybrid, Chevrolet Malibu

Lifetime wanted to EV

3-4 year initial battery life
10 years

Battery Type

- Lithium Ion**
 - 200 - 300 miles per charge
 - LiCoO2 - lithium cobalt oxide
 - LiFePO4 - lithium iron phosphate as cathode (LIFEPO4 technology)
 - LiMn2O4 - lithium manganese oxide
 - Li(NiCo)O2 - lithium iron phosphate
- Nickel Metal Hydride**
 - 120 miles per charge
- Lead Acid**
 - 80 miles per charge
- Sodium**
 - Grid Storage
 - Estimated 20 to 40 kilowatt hours of energy into a package about the size of a refrigerator, and operate below 90 degrees C

Specification

- Power Density W/Kg**
 - 900+ W/kg NiZn Nickel-zinc, rechargeable used in portable cordless applications
 - 900 W/kg NiCd Nickel-cadmium, portable electronics and toys
 - 800 W/kg LiCoO2 Lithium Ion Polymer (C anode, LiCoO2 cathode)
 - 600 W/kg Ni-MH Nickel-metal hydride
 - 420 W/kg AGM lead acid (low internal resistance)
 - 349 W/kg LiFePO4 Lithium Iron Phosphate (C anode, LiFePO4 cathode)
 - 1100 W/kg LiFePO4 (Graphite) Lithium Iron Phosphate (LFP)
 - 340 W/kg to 1700 W/kg lab Lithium ion battery
 - 900 W/kg Li(Ni1/3Co1/3Mn1/3)O2 (Graphite) Lithium Nickel Cobalt Manganese (NCM)
 - 700 W/kg LiMnO2 (LiTiO2) Lithium Titanium (LTO)
 - 250 W/Kg NiMH Nickel-Metal Hydride
 - 250 W/kg market 980 W/kg lab Nickel metal hydride
 - 248 W/kg AGM lead acid (high internal resistance)
 - 202 W/kg NiZn Nickel-zinc
 - 189 W/kg Gel lead acid
 - 180 W/kg Lead acid battery
 - 179 W/kg NaNiCl2 Sodium Nickel Chloride (ZEBRA)
 - 120 W/kg NiCD Nickel-cadmium (flooded)
 - 250 Wh/kg (for pack) NiMH Nickel-Metal Hydride
 - 140 Wh/kg Li(Ni1/3Co1/3Mn1/3)O2 (Graphite) Lithium Nickel Cobalt Manganese (NCM)
 - 137 Wh/kg LiCoO2 Lithium Ion Polymer (C anode, LiCoO2 cathode)
 - 115 Wh/kg NaNiCl2 Sodium Nickel Chloride (ZEBRA)
 - 90 Wh/kg LiFePO4 (Graphite) Lithium Iron Phosphate (LFP)
 - 81 Wh/kg LiFePO4 Lithium Iron Phosphate (C anode, LiFePO4 cathode)
 - 70 Wh/kg LiMnO2 (LiTiO2) Lithium Titanium (LTO)
 - 60 Wh/kg @ 12A NiZn Nickel-zinc, rechargeable used in portable cordless applications
 - 55 Wh/kg NiCD Nickel-cadmium (flooded)
 - 48 Wh/kg NiZn Nickel-zinc
 - 40 Wh/kg @ 12A NiCd Nickel-cadmium, portable electronics and toys
 - 38 Wh/kg @ 12A Ni-MH Nickel-metal hydride, higher capacity and less toxic than NiCd, used in GM, Honda EV plus, Ford Ranger, Toyota Prius, Honda Insight & Civic, Ford Escape Hybrid, Chevrolet Malibu
 - 30 Wh/kg Lead acid (flooded)
 - 24 Wh/kg Gel lead acid
 - 24 Wh/kg AGM lead acid (high internal resistance)
 - 19 Wh/kg AGM lead acid (low internal resistance)
- Energy Density Wh/kg**
 - Emerging chemistries offer a higher combination of energy and power density than previous batteries for EVs. Latest chemistries based on lithium manganese spinel, lithium titanate, and lithium iron-phosphate materials reduce or avoid the use of expensive cobalt in the electrodes. 5/13/09 Electric-drive-vehicle developments B. Williams - UC Berkeley.
 - LiCoO2 (Graphite) Lithium Cobalt Oxide (LCO)
 - Li(Ni0.85Co0.1Al0.05)O2 (Graphite) Lithium Nickel Cobalt Aluminum (NCA) JCS-Saft, GAIA, Matsushita and Toyota.
 - LiMnO2 or LiMn2O4 (Li4Ti5O12) Lithium Manganese Spinel (LMS) GS, Yuasa, Litcel, NEC and EnerDel.
 - LiMn1.5Ni0.5O4 (Li4Ti5O12) Manganese Titanium (MNS)
 - Li1.2Mn0.6Ni0.2O2 (Graphite) Manganese Titanium (MN) Limited peak power density for EV

Life Cycle

- 2750 NiCd Nickel-cadmium (flooded)
- 2000 LiFePO4 Lithium Iron Phosphate (C anode, LiFePO4 cathode)
- 800 Ni-MH Nickel-metal hydride
- 800 NiCd Nickel-cadmium, portable electronics and toys
- 800 LiCoO2 Lithium Ion Polymer (C anode, LiCoO2 cathode)
- 700 Lead acid (flooded)
- 600 Gel lead acid
- 600 AGM lead acid (high internal resistance)
- 500 NiZn Nickel-zinc, rechargeable used in portable cordless applications
- 500 NiZn Nickel-zinc

Safety

- Thermally stable, fuse recommended, Nickel cadmium, Nickel metal hydride
- Thermally stable, Lead acid sealed
- Protection circuit mandatory, stable to 150 C, Lithium ion cobalt
- Protection circuit mandatory, stable to 250 C, Lithium ion manganese, Lithium ion phosphate

Toxicity

- Highly toxic, harmful to environment, Nickel cadmium
- Relatively low toxicity, should be recycled, Nickel metal hydride
- Toxic lead and acids, harmful to environment, Lead acid sealed
- Low toxicity, Lithium ion cobalt, Lithium ion manganese, Lithium ion phosphate