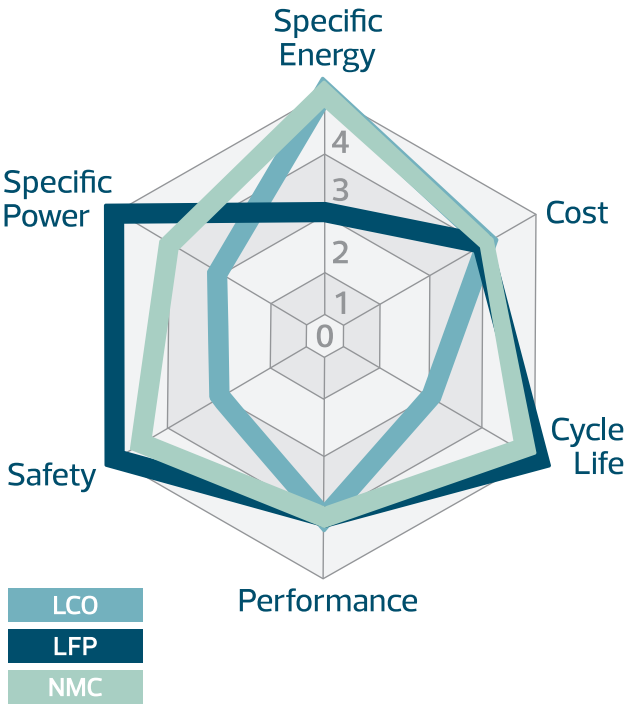
Incell Academy

Comparison Common Lithium Technologies

Conclusions

For Telecom applications high specific energy, high safety and high cycle life all at reasonable cost are important criterion when selecting your Lithium battery.

Incell believe the most suitable technology for Telecom applications in general is Lithium Nickel Manganese Cobalt Oxide due to its high energy density, long cycle life and low self-heating rate at a overall all attractive Total Cost of Ownership (TCO).



LCO

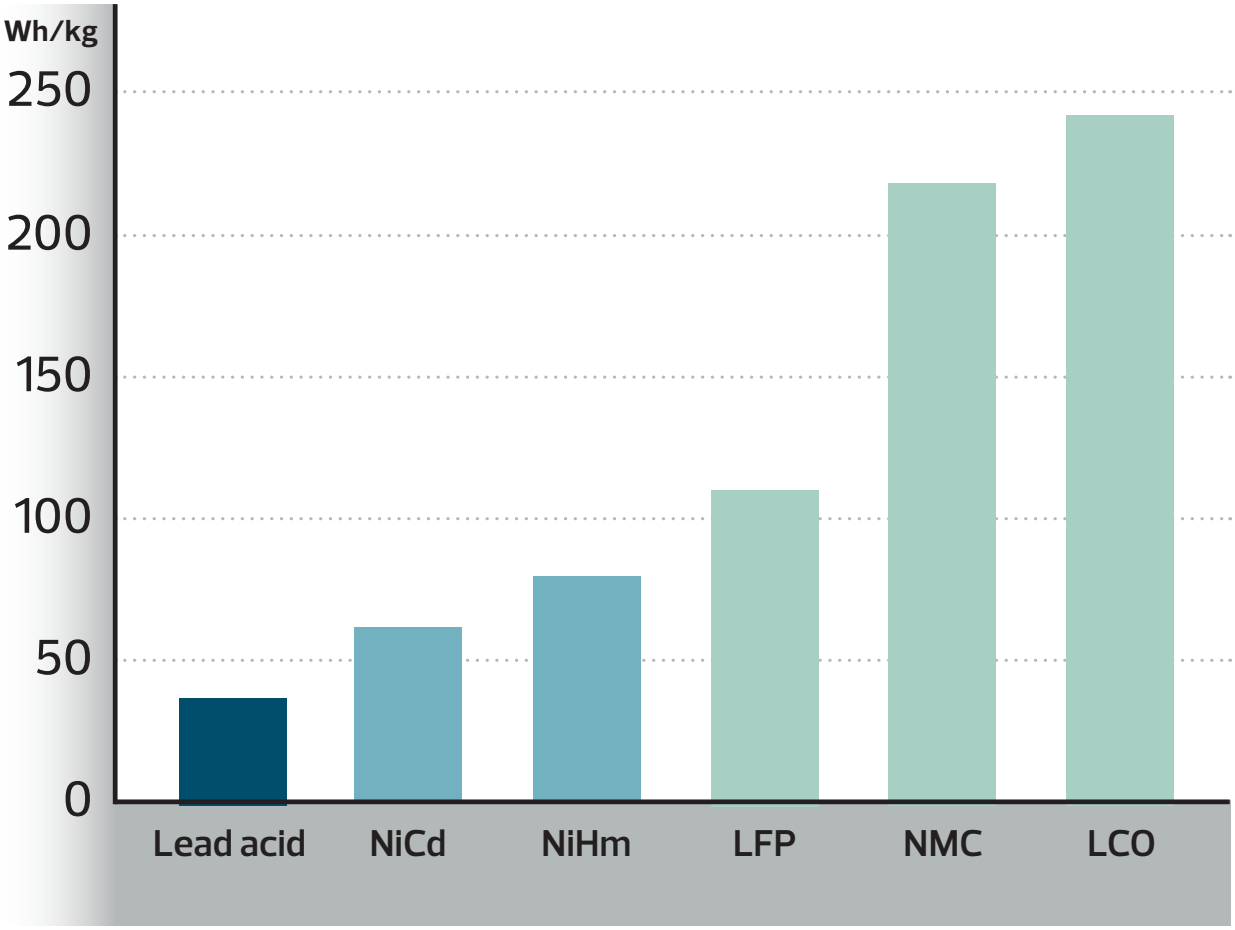
Lithium Cobalt Oxide ($LiCoO_2$ or LCO)
Li-cobalt excels on high specific energy but offers only moderate performance specific power, safety and life span.

LFP

Lithium Iron Phospahte ($LiFePO_4$ or LFP)
Li-phosphate has excellent safety and long life span but moderate specific energy and a lower voltage than other lithium-based batteries. LFP also has higher self-discharge compared to other lithium-ion systems.

NMC

Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$ or NMC)
NMC has good overall performance and excels on specific energy. This battery is the preferred candidate for the electric vehicle and has the lowest self-heating rate.



Graph comparing Wh/kg for different battery technologies.

Lithium Cobalt Oxide ($LiCoO_2$ or LCO)

Its high specific energy makes Li-cobalt the popular choice for cell phones, laptops and digital cameras.

The battery consists of a cobalt oxide cathode and a graphite carbon anode. The cathode has a layered structure and during discharge lithium ions move from the anode to the cathode. The flow reverses on charge.

The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities

Li-cobalt cannot be charged and discharged at a current higher than its rating. This means that an 18650 cell with 2,400mAh can only be charged and discharged at 2,400mA. Forcing a fast charge or applying a load higher than 2,400mA causes overheating and undue stress. For optimal fast charge, the manufacturer recommends a C-rate of 0.8C or 1920mA. The mandatory battery protection circuit limits the charge and discharge rate to a safe level of about 1C.

Lithium Cobalt Oxide: LiCoO2 (~60% Co), Graphite anode, Since 1991 Short form: LCO or Li-cobalt	
Voltage, nominal	3.60V
Specific energy (capacity)	**150–250Wh/kg**
Charge (C-rate)	0.8C, 1C maximum, 4.20V peak (most cells); 3h charge typical
Discharge (C-rate)	1C; 2.50V cut off
Cycle life	**500–1000**, related to depth of discharge, load, temperature
Thermal runaway	**150°C** (302°F). Full charge promotes thermal runaway
Applications	Mobile phones, tablets, laptops, cameras
Comments	**Very high specific energy**, limited specific power. Cobalt is expensive. Serves as Energy Cell.

Lithium Iron Phosphate($LiFePO_4$ or LFP)

In 1996, the University of Texas (and other contributors) discovered phosphate as cathode material for rechargeable lithium batteries. Li-phosphate offers good electro-chemical performance with **low resistance**. This is made possible with nano-scale phosphate cathode material. The key benefits are **high current rating and long cycle life, besides good thermal stability, enhanced safety and tolerance if abused.**

Li-phosphate is more tolerant to full charge conditions and is less stressed than other lithium-ion systems if kept a high voltage for a pronged time. As trade-off, **the lower voltage of 3.2V/cell reduces the specific energy**. In addition, cold temperature reduces performance, and **elevated storage temperature shortens the service life but is still better than lead acid, NiCd or NiMH**. Li-phosphate has a higher self-discharge than other Li-ion batteries, which can cause balancing issues with aging.

Lithium Iron Phosphate: $LiFePO_4$, Graphite anode, Since 1996 Short form: LFP or Li-phosphate	
Voltage, nominal	3.20V, 3.20V
Specific energy (capacity)	**90–120Wh/kg**
Charge (C-rate)	1C typical; 3.65V peak; 3h charge time
Discharge (C-rate)	**25–30C continuous**, 2V cut-off (lower that 2V causes damage)
Cycle life	**1000–2000 (related to depth of discharge, temperature)**
Thermal runaway	**270°C** (518°F) Very safe battery even if fully charged
Applications	Portable and stationary needing high load currents and endurance
Comments	Very flat voltage discharge curve but low capacity. One of safest Li-Ions. **Elevated self-discharge**

Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$ or NMC)

Leading battery manufacturers focus on a cathode combination of nickel-manganese-cobalt (NMC). Similar to Li-manganese, these systems **can be tailored for high specific energy or high specific power**, but not both. For example, NMC in an 18650 cell for moderate load condition has a capacity of about 2,800mAh and can deliver 4–5A; NMC in the same cell optimized for specific power has a capacity of only about 2,000mWh but delivers a continuous discharge current of 20A. A silicon-based anode will go to 4,000mAh but at reduced loading and shorter cycle life.

The secret of NMC lies in combining nickel and manganese. An analogy of this is table salt, in which the main ingredients of sodium and chloride are toxic on their own but mixing them serves as seasoning salt and food preserver. Nickel is known for its **high specific energy** but poor stability; manganese has the benefit of forming a spinel structure to achieve **low internal resistance** but offers a low specific energy. **Combining the metals enhances each other strengths**.

NMC is the battery of choice for power tools, e-bikes and other electric powertrains. The cathode combination of typically one-third nickel, one-third manganese and one-third cobalt offers a unique blend that also lowers raw material cost due to reduced cobalt content. Other combinations, such as NCM, CMN, CNM, MNC and MCN are also being offered in which the metal content of the cathode deviates from the 1/3 – 1/3 – 1/3 formula. Manufacturers keep the exact ratio a well-guarded secret.

Lithium Nickel Manganese Cobalt Oxide: $LiNiMnCoO_2$, Graphite anode, Since 2008 Short form: NMC (NCM, CMN, CNM, MNC, MCN are similar with different medal combination)	
Voltage, nominal	3.60V, 3.70V
Specific energy (capacity)	**150–220Wh/kg**
Charge (C-rate)	1C, 4.20V peak; 3h charge time
Discharge (C-rate)	2C continuous; 2.50V cut-off
Cycle life	**1000–2000** (related to depth of discharge, temperature)
Thermal runaway	**210°C** (410°F) typical. High charge promotes thermal runaway
Applications	E-bikes, medical devices, EVs, industrial
Comments	Provides high capacity and high power. Serves as Hybrid Cell. This chemistry is often used to enhance Li-manganese.

Summary comparison

	LCO	LFP	NMC
Voltage, nominal:	3.60V	3.60V	3.60V
Specific energy (capacity):	150–250Wh/kg	150–250Wh/kg	150–220Wh/kg
Charge (C-rate):	0.8C, 1C maximum, 4.20V peak (most cells); 3h charge typical	1C typical; 3.65V peak; 3h charge time	1C, 4.20V peak; 3h charge time
Discharge (C-rate):	1C; 2.50V cut off	25-30C continuous, 2V cut-off (lower than 2V causes damage)	2C continuous; 2.50V cut-off
Cycle life:	500–1000, related to depth of discharge, load, temperature	1000–2000 (related to depth of discharge, temperature)	1000–2000 (related to depth of discharge, temperature)
Thermal runaway:	150°C (302°F). Full charge promotes thermal runaway	270°C (518°F) Very safe battery even if fully charged	210°C (410°F) typical. High charge promotes thermal runaway
Applications:	Mobile phones, tablets, laptops, cameras	Portable and stationary needing high load currents and endurance	E-bikes, medical devices, EVs, industrial
Comments:	Very high specific energy, limited specific power. Cobalt is expensive. Serves as Energy Cell.	Very flat voltage discharge curve but low capacity. One of safest Li-Ions. Elevated self-discharge	Provides high capacity and high power. Serves as Hybrid Cell. This chemistry is often used to enhance Li-manganese.

Data and info: www.batteryuniversity.com