Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2) — NMC

One of the most successful Li-ion systems is a cathode combination of nickel-manganese-cobalt (NMC). Similar to Li-manganese, these systems can be tailored to serve as Energy Cells or Power Cells. For example, NMC in an 18650 cell for moderate load condition has a capacity of about 2,800mAh and can deliver 4A to 5A; NMC in the same cell optimized for specific power has a capacity of only about 2,000mAh but delivers a continuous discharge current of 20A. A silicon-based anode will go to 4,000mAh and higher but at reduced loading capability and shorter cycle life. Silicon added to graphite has the drawback that the anode grows and shrinks with charge and discharge, making the cell mechanically unstable.

The secret of NMC lies in combining nickel and manganese. An analogy of this is table salt in which the main ingredients, 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 is typically one-third nickel, one-third manganese and one-third cobalt, also known as 1-1-1. This offers a unique blend that also lowers the raw material cost due to reduced cobalt content. Another successful combination is NCM with 5 parts nickel, 3 parts cobalt and 2 parts manganese (5-3-2). Other combinations using various amounts of cathode materials are possible.

Battery manufacturers move away from cobalt systems toward nickel cathodes because of the high cost of cobalt. Nickel-based systems have higher energy density, lower cost, and longer cycle life than the cobalt-based cells but they have a slightly lower voltage.

New electrolytes and additives enable charging to 4.4V/cell and higher to boost capacity. Figure 7 demonstrates the characteristics of the NMC.

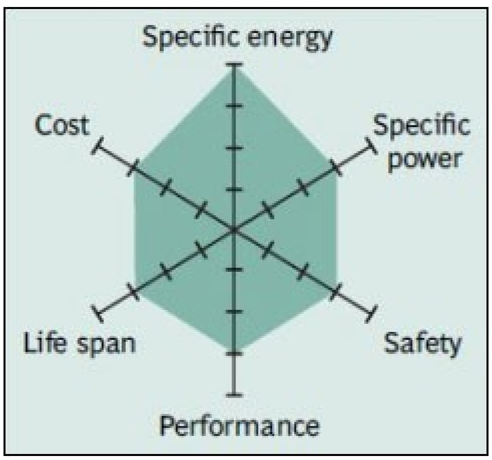

Figure 7: Snapshot of NMC.
NMC has good overall performance and excels on specific energy. This battery is the preferred candidate for the electric vehicle and has the lowest self-heating rate.
Source: Boston Consulting Group

There is a move towards NMC-blended Li-ion as the system can be built economically and it achieves a good performance. The three active materials of nickel, manganese and cobalt can easily be blended to suit a wide range of applications for automotive and energy storage systems (EES) that need frequent cycling. The NMC family is growing in its diversity.

Lithium Nickel Manganese Cobalt Oxide: $LiNiMnCoO_2$. cathode, graphite anode Short form: NMC (NCM, CMN, CNM, MNC, MCN similar with different metal combinations) Since 2008	
Voltages	3.60V, 3.70V nominal; typical operating range 3.0–4.2V/cell, or higher
Specific energy (capacity)	150–220Wh/kg
Charge (C-rate)	0.7–1C, charges to 4.20V, some go to 4.30V; 3h charge typical. Charge current above 1C shortens battery life.
Discharge (C-rate)	1C; 2C possible on some cells; 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
Cost	~$420 per kWh (Source: RWTH, Aachen)
Applications	E-bikes, medical devices, EVs, industrial
Comments	Provides high capacity and high power. Serves as Hybrid Cell. Favorite chemistry for many uses; market share is increasing.
2019 update:	Leading system; dominant cathode chemistry.