

Shmuel De-Leon
Energy Ltd



Li-Ion NCA/NMC Cylindrical Hard Case Cells Market 2022

October 2022

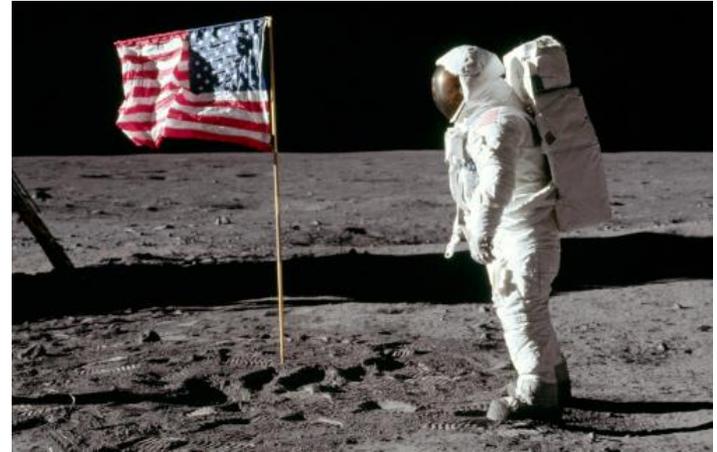
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www.sdle.co.il

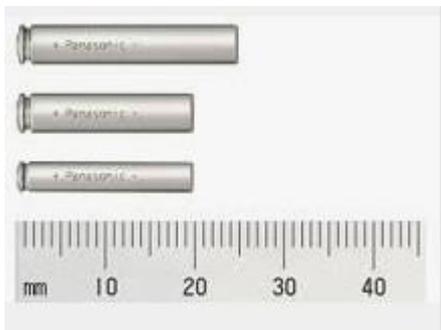
shmuel@sdle.co.il

NASA and Africa Bushmen tribe



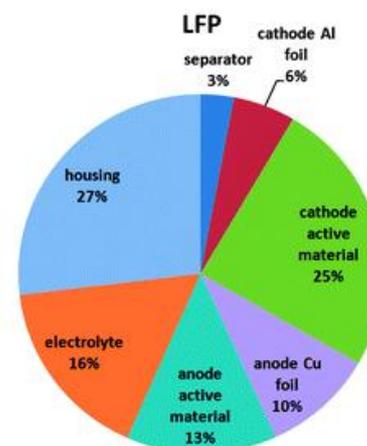
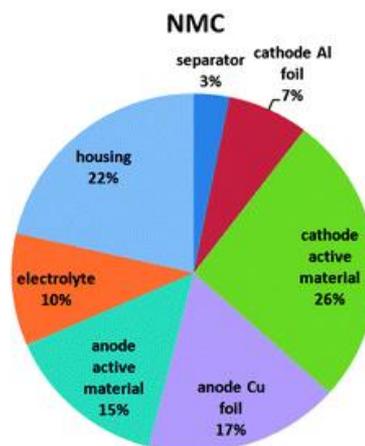
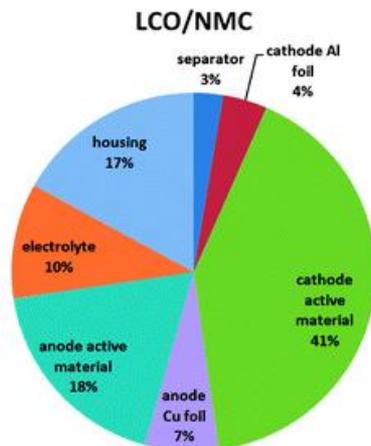
Li-Ion Cells Different Packaging But the Same Chemistry

1. Hard Case Cylindrical
2. Hard Case Prismatic
3. Hard Case Button/Coin
4. Hard Case Pin
5. Soft Case prismatic
6. Soft Case Special Shape
7. Soft Case Cylindrical
8. Soft Case Button



Li-Ion Rechargeable Systems

Technology	Anode	Cathode
Lithium Cobalt Oxide 3.6V	Graphite – Gr/Si	LCO
Lithium Manganese Oxide Spinel 3.8V	Graphite – Gr/Si	LMO
Lithium Nickel Manganese Cobalt 3.7-3.8V	Graphite – Gr/Si	NMC(111, 532, 622, 811)
Lithium Nickel Cobalt Aluminum 3.65V	Graphite – Gr/Si	NCA
Lithium Iron Phosphate 3.2V	Graphite	LFP
Lithium Titanate Oxide 2.3/2.4V	LTO	NMC, LMO, LFP



Cylindrical Hard Case Cells

Advantages

1. High energy density (up to 270Wh/kg, 740Wh/l).
2. Wide operating voltage range 4.35 – 3.0/2.5/2V.
3. Wide power density range (High energy, Medium Power, High Power).
4. Good cycle life ~500-1000 Cycles.
5. Low self-discharge ~ 1% per month.
6. Quick charge is possible ($\geq 2C$).
7. Include internal safety devices like vents, shut down separators, PTC, CID etc.
8. Standard sizes: 18650, 21700, 26650, 46800.
9. Automatic mass production lines ensure cost & quality.



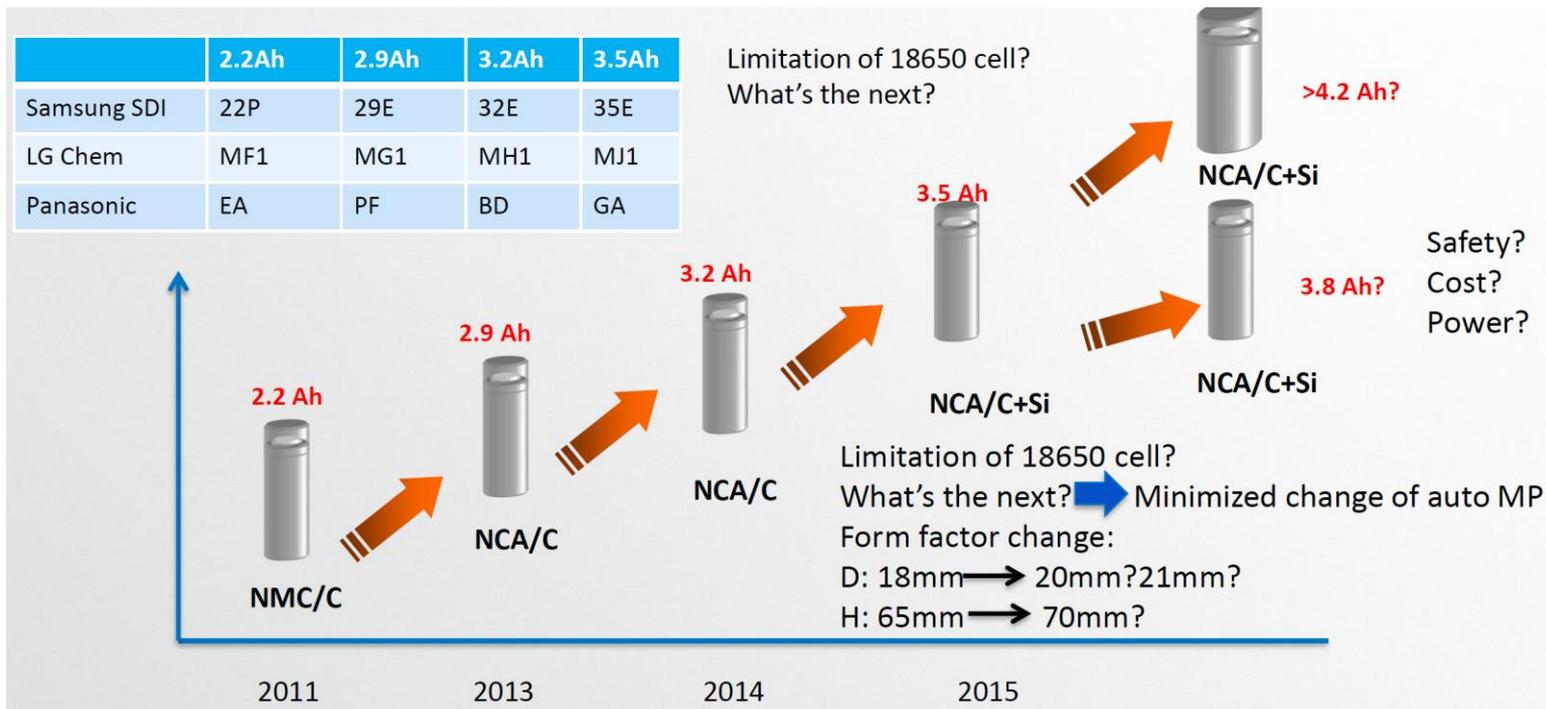
Cylindrical Hard Case Cells

Limitations

1. Low volumetric energy density pack level.
2. Max charging voltage of only 4.35V (4.45V in Pouch LCO).
3. Thicker than pouch cells.
4. Difficult to custom made special sizes.
5. Difficult to cool cylindrical cells due to lower external surface area (Pouch are much better).



18650 Cells – General Road Map



Samsung SDI INR18650- 35E

	Value
Nominal Capacity	3.45 Ah
Maximum Capacity	3.35Ah
Nominal voltage	3.6v
Standard Charge	1.5A
Max Charge Voltage	4.2v
STD Discharge	0.69A
Max Continiues Discharge Current	8A
Weight	50g
Dimensions	18.5 d, 65.25h mm

Panasonic NCR18650GA

	Value
Maximum Capacity	3.45Ah
Nominal Capacity	3.35Ah
Nominal Voltage	3.6v
Standard Charging Current	1.67A
Max Charging Voltage	4.2V
Std Discharge Current	0.2C
Maximum Discharge Current	8A
Weight	48 g
Dimensions	18.5x65.3mm
Cut Off Voltage	2.5V

LG Chem INR18650MJ1

- Nominal Capacity: 3500mAh
- Minimum Capacity: 3400mAh
- Nominal Voltage: 3.6V
- Standard Charge
 Constant current: 1700mA
 Constant voltage: 4.2V
 End condition(Cut off): 50mA
- Max. Charge Voltage: 4.2 ± 0.05V
- Max. Charge Current: 3400mA
- Standard Discharge
 Constant current: 680mA(0.2C)
 End voltage(Cut off): 2.5V
- Max.Continuous Discharge Current: 10A
- Weight: Max.49.0g
- Dimension: Max.(D)18.5*(H)65.2mm

New 3.5Ah 18650 Cells

1. Moli Energy start to manufacture new 18650 3.5Ah cells – INR-18650M35
2. Due to strong shortage with Samsung, LG, Panasonic, Moli 3.5Ah cells we see new Chinese cells arrival.
3. Lishen LR1865HC (R&D – M.P mid 2023).
4. Tenpower 18650-35HE (R&D – M.P mid 2023).
5. EVE 18650-35V (M.P – Q4/2022).
6. DMEGC INR18650-35E - (M.P – Q4/2022)
7. Cham 18650F9L (M.P – Q4/2022)

Model	50HE	35HE	32HE	28HE	26HE	22HE	32ME	48ME
Form Factor	21700	18650	18650	18650	18650	18650	18650	21700
Nominal Voltage (V)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Typical Capacity (mAh)	5,000	3,500	3,200	2,900	2,600	2,200	3,200	4,800
Continuous Discharge Current (A)	10	10	10	10	10	10	15	15
Continuous Charge Current (A)	0.5C							
Max. Weight (g)	69	47	47	46	47	45	47	69
Datasheet	📄							

Tenpower 18650-35HE

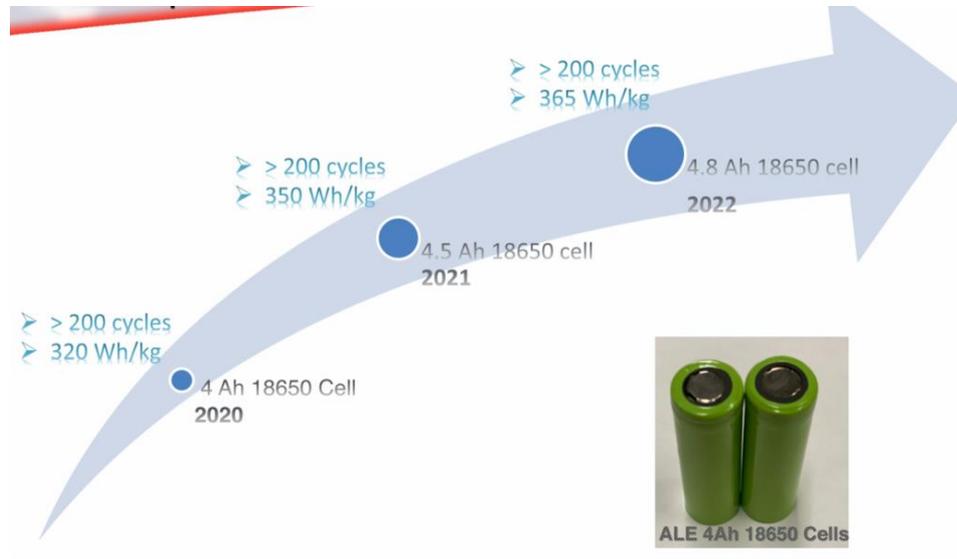
MOLICEL®
LITHIUM-ION RECHARGEABLE BATTERY

■ CELL CHARACTERISTICS

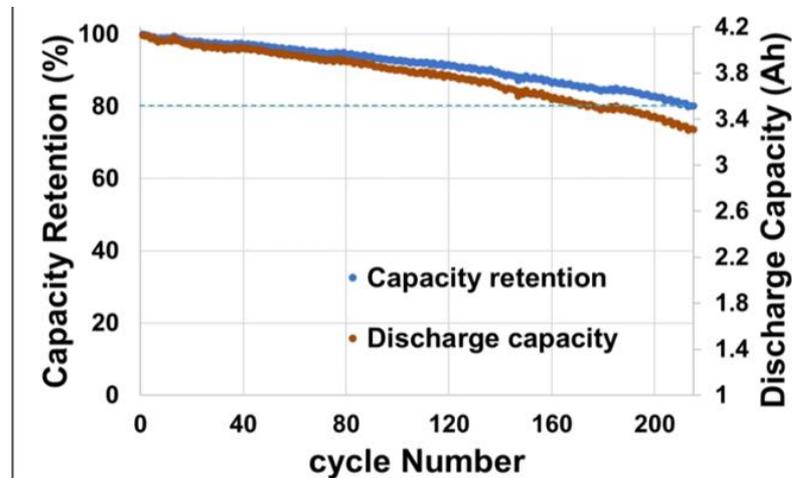
Capacity	Typical	3500 mAh 12.5 Wh
	Minimum	3350 mAh 11.9 Wh
Cell Voltage	Nominal	3.6 V
	Charge	4.2 V
	Discharge	2.5 V
Continuous Charge Current	Standard	1.7 A
	Maximum	1.7 A
Charge Time	Standard	2.5 hr
Continuous Discharge Current	Maximum	10 A
Ambient Temperature	Charge	0°C to 60°C
	Discharge	-40°C to 60°C
Energy Density	Volumetric	700 Wh/l
	Gravimetric	250 Wh/kg

Breakthrough Cells for Military Use

- Capacity: 4.0 Ah
- Specific energy: 320 Wh/kg
- 60 °C storage for one week at 100 % SOC
- ~ 95 % capacity retention and > 99 % capacity recovery



- Capacity: 4.0 Ah
- Specific energy: 320 Wh/kg
- > 92 % capacity retention at 1C discharge rate
- > 50 % capacity retention at -40 °C and 0.2 C discharge rate



- Cell Capacity: > 4.0 Ah
- 100 % DOD
- C/3 charge rate
- C/5 discharge rate

Introduction to ALE 4Ah Nano 18650 Cells



- High specific energy: ~330 Wh/kg
- High power: Up to 700 W/Kg
- Excellent low temperature performance
 - >60% capacity at -40°C and at 0.2C rate
- Meet the cycle requirement of the missions 1, 2 and 4 now per Space System Commend, the US Space Force. For other missions, the testing is still on going
- Meet UN 38.03 requirement
 - Pass impact, crush, overcharge and 130°C hot box tests per UN 38.03 standard

Nanograp^h

NanoGraf Enables Most Energy Dense Battery

3.8 Ah 18650 | 800 Wh/L

NanoGraf Reaches Energy-Density Milestone for its Lithium-Ion Battery Material

Record-setting breakthrough in energy density of silicon anode cells enable longer-lasting, lighter weight, and shortened charge cycles for consumer electronics, electric vehicles, military equipment and more.

CHICAGO – June 10, 2021 (9am CT) – To help us better embrace our electric future, NanoGraf, an advanced battery material company, today announced it has enabled the highest energy density 18650 cylindrical lithium-ion cell in the world – one that provides a 28 percent longer run time than traditional cell chemistries.

Aided by funding from the U.S. Department of Defense and others, NanoGraf's team of scientists, technologists, and engineers today unveiled an 800 watt-hour per liter (Wh/L) silicon-anode based cell that provides compelling benefits for virtually any application – from consumer electronics to electric vehicle batteries to the batteries that power the equipment soldiers use during operations.

"This is a breakthrough for the battery industry," said NanoGraf President, Dr. Kurt (Chip) Breitenkamp. "Energy density has plateaued, only increasing eight percent or so over the last decade. We just achieved a 10 percent increase in a little under a year. This is over a decade's worth of innovation in one technology."

One of the biggest opportunities for more energy-dense batteries lies with electric vehicles, where "range anxiety" is a major impediment to mainstream adoption. NanoGraf's new cell technology could immediately provide a boost to electric vehicles, such as the Tesla Model S, which would last approximately 28 percent longer on a single charge compared to similar vehicles on the road today.

In addition to commercial applications, the NanoGraf-enabled battery also dramatically improves the performance of soldier-carried military electronics and equipment. U.S. soldiers on patrol carry upwards of twenty pounds of lithium ion batteries, often the second heaviest category of equipment after body armor. NanoGraf's batteries improve run time on U.S. soldiers' equipment and can reduce their battery pack weights by over 15 percent.

<https://www.nanograp.com/18650-press-release>

21700

1. High demand for more energy and cost reduction lead to larger cells.
2. Assembling battery packs with 18650 cells become less efficient, require complicate BMS and costly.
3. 21700 cells increase pack energy density, reduce number of cells in battery packs and increase pack efficiency (Max of 5Ah capacity of today),
4. 46800 under design and soon in production.

Coverage of 21700

Standardizing next form factor 21700 for major application and setting up MP line



Mid rate

E-Bike
E-Scooter



EV
ESS



High rate

P/Tool
G/Tool



Power Tool



Motor-assisted bicycle



Energy Storage System



Automatic Guided Vehicle



Garden Tool



E-Scooter / Engine starter



Cordless Vacuum Cleaner



Golf Cart

LG 21700 Cells >5Ah

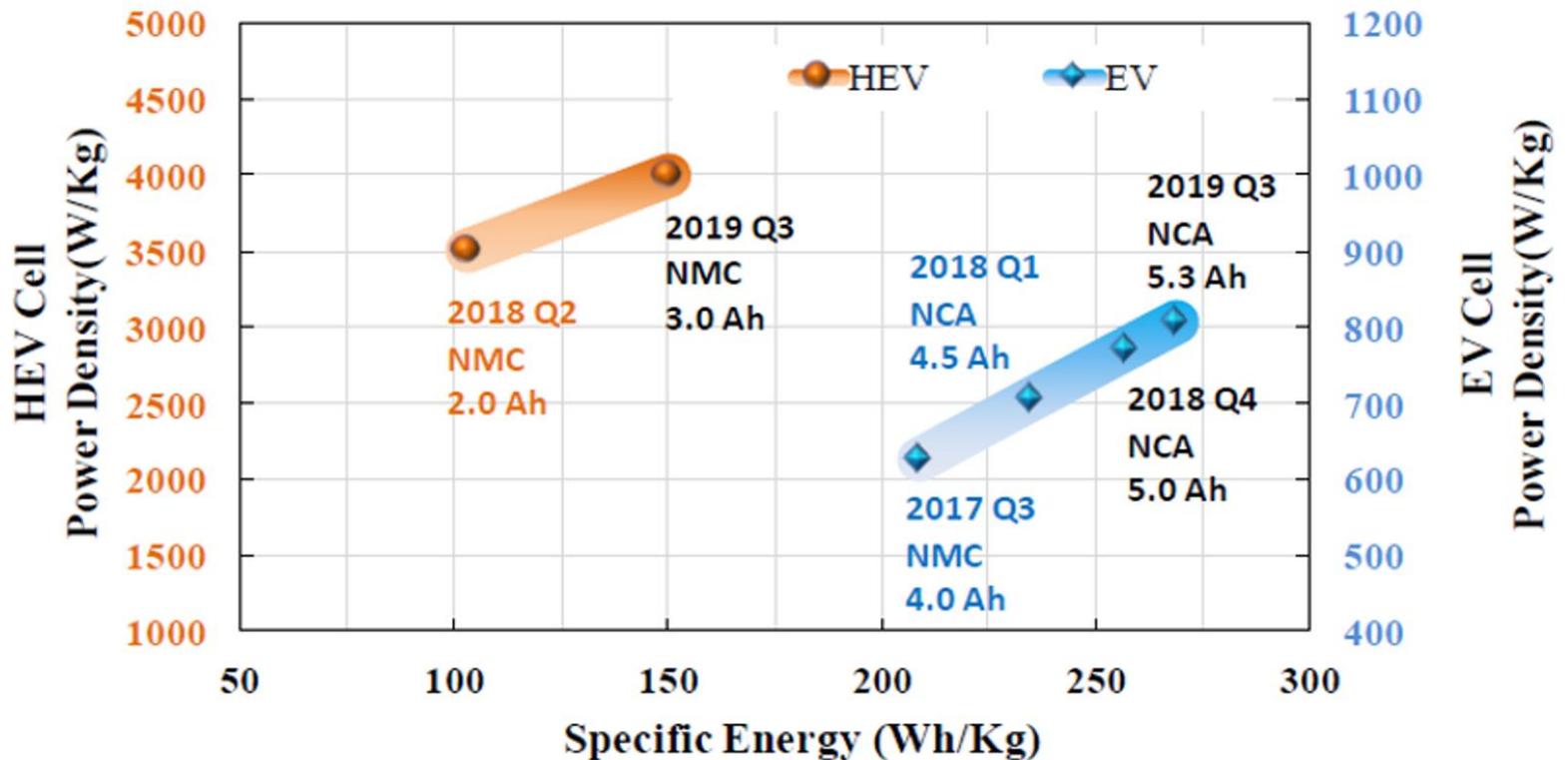
**LG should start mass production of M52VP
5.2Ah cell on Q3/2022**



Lishen 21700 >5Ah

Lishen should start mass production of LR2170SH 5.8Ah cell on Q3/2024

Roadmap of 21700 Cells



BAK 21700 >5Ah

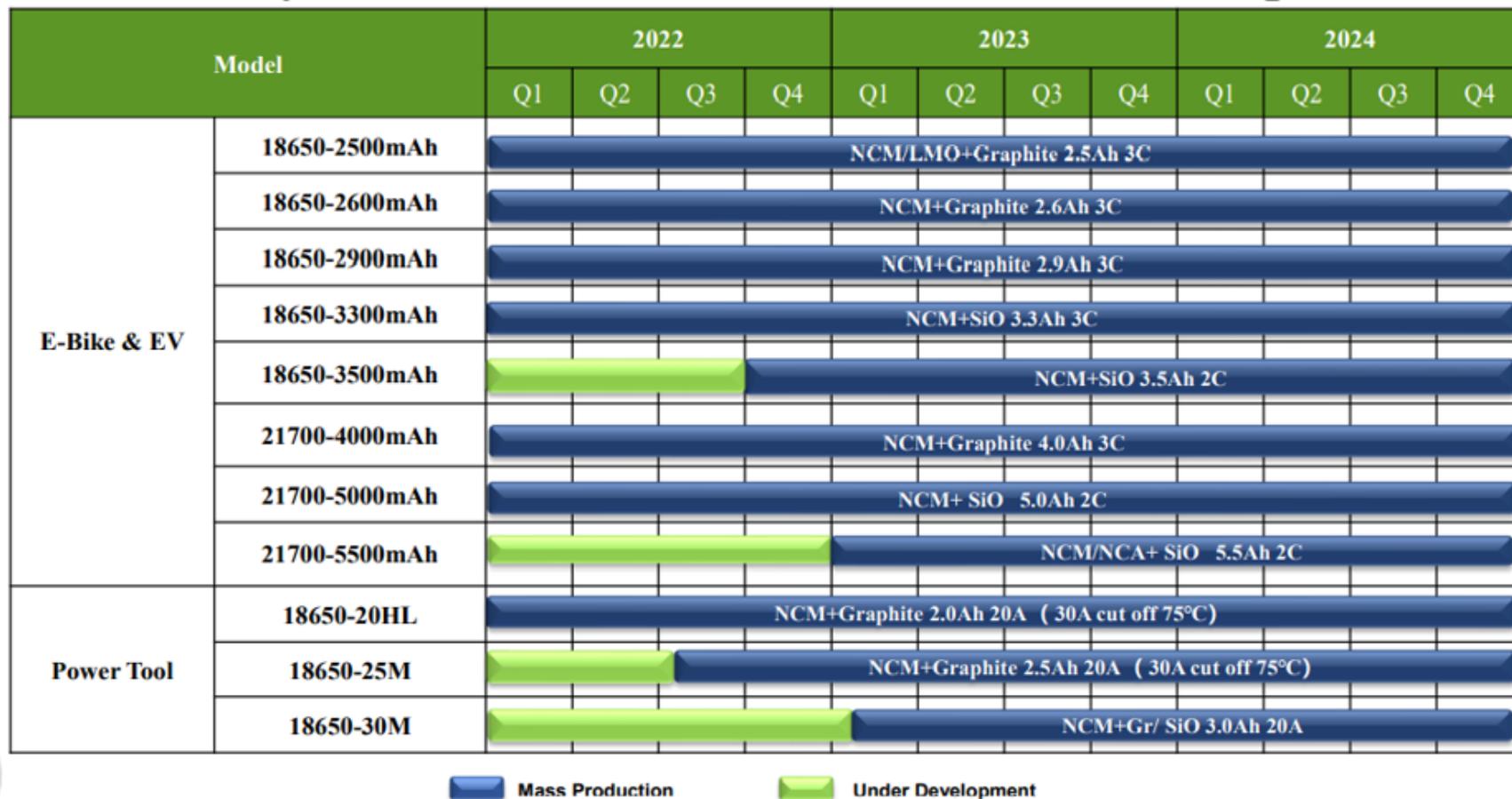
BAK should start mass production of 5.3Ah cell on Q4/2022, N21700CH, 6Ah cell is under development

N21700CD					
CATHODE	HI-NI	ANODE	SIC	NOMINAL CAPACITY (AH)(0.2C)	5.3
DIMENSION (MM)	HEIGHT: 70.50±0.25 DIAMETER: 21.25±0.15	NOMINAL VOLTAGE (V)	3.6	WEIGHT (KG)	≤0.072
IR (MΩ)	≤30	MAX DISCHARGE RATE	1.5C	MAX CHARGE RATE	1C
CYCLE LIFE (100% DOD 25°C)	800 CYCLES≥80% (RT 0.5C/1C)	OPERATION RANGE	CHARGE: 0~45 °C DISCHARGE: -20~60 °C		

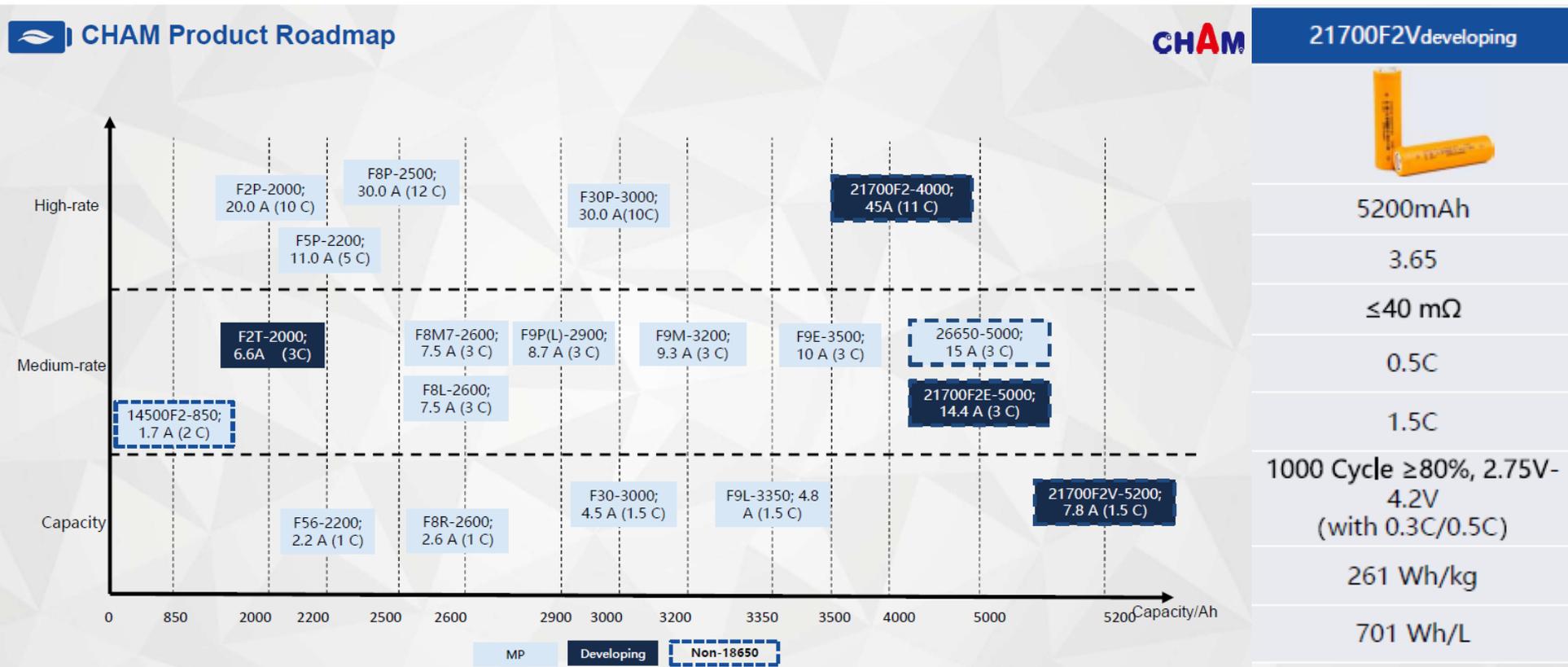
Jiangxi Far East 21700 > 5Ah



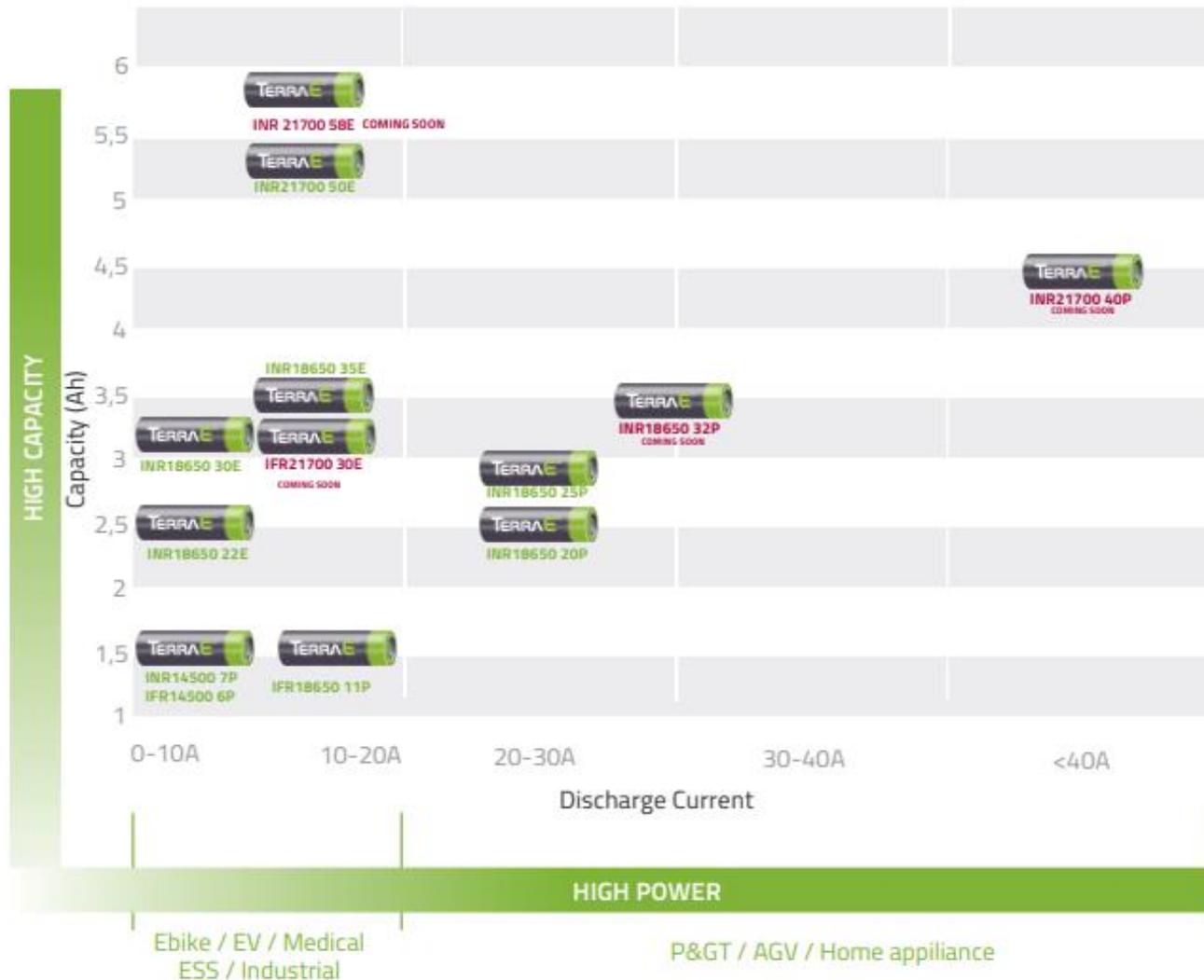
Cylindrical Cell 18650 & 21700 Roadmap



Cham 21700 >5Ah

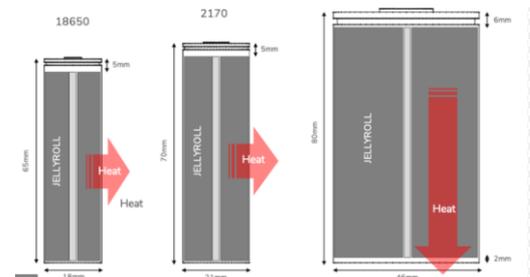
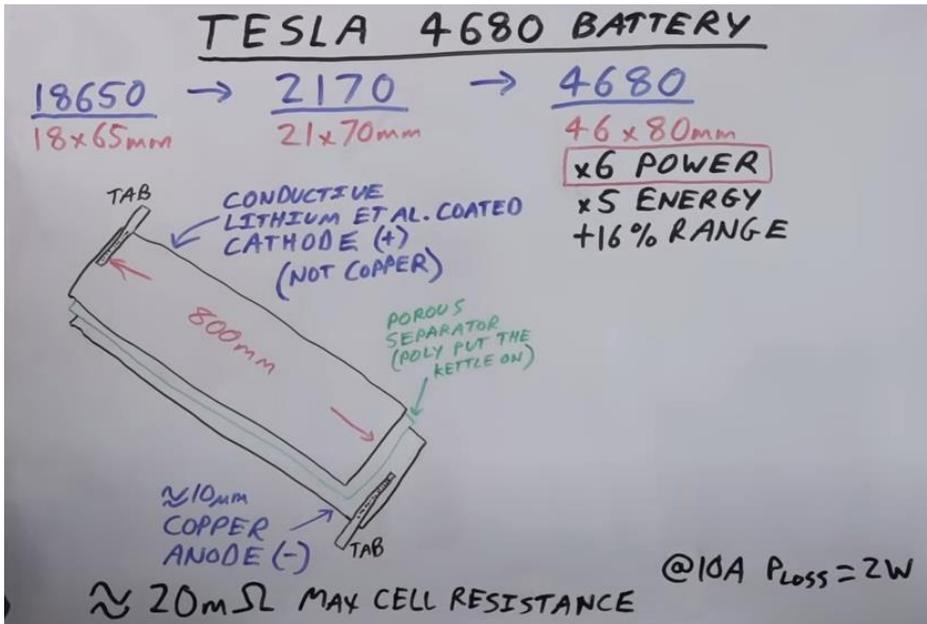
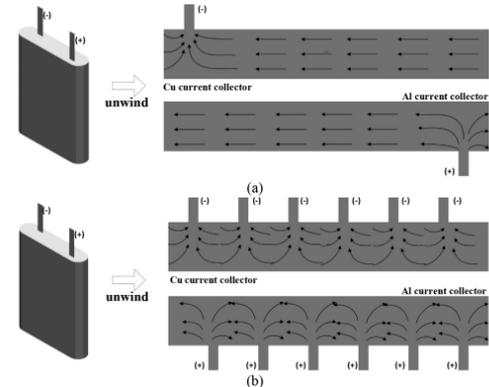


Terra-E (BMZ) 21700 > 5Ah



Tesla 46800 New Cell Size

1. Tab`s less technology.
2. Lower internal impedence.
3. Better thermal heat flow.
4. 16% better energy density.
5. Less cells in battery pack – Saving assembly cost.



Tesla 4680 Performance Estimation

- 4680-type cylindrical lithium-ion battery (46 mm in diameter and 80 mm tall)
 - cathode: NCM 811 (81.6% nickel)
 - anode: graphite (no silicon), dry battery electrode technology
 - tabless design
 - estimated total capacity: 26.136 Ah
 - estimated total energy: 96-99 Wh (assuming at 3.7-3.8 V)
 - estimated energy density: 272-296 Wh/kg
 - weight: 355 g
-
- 1st gen: 276 Wh/kg
 - 2nd gen: 305 Wh/kg
 - 3rd gen: 333 Wh/kg



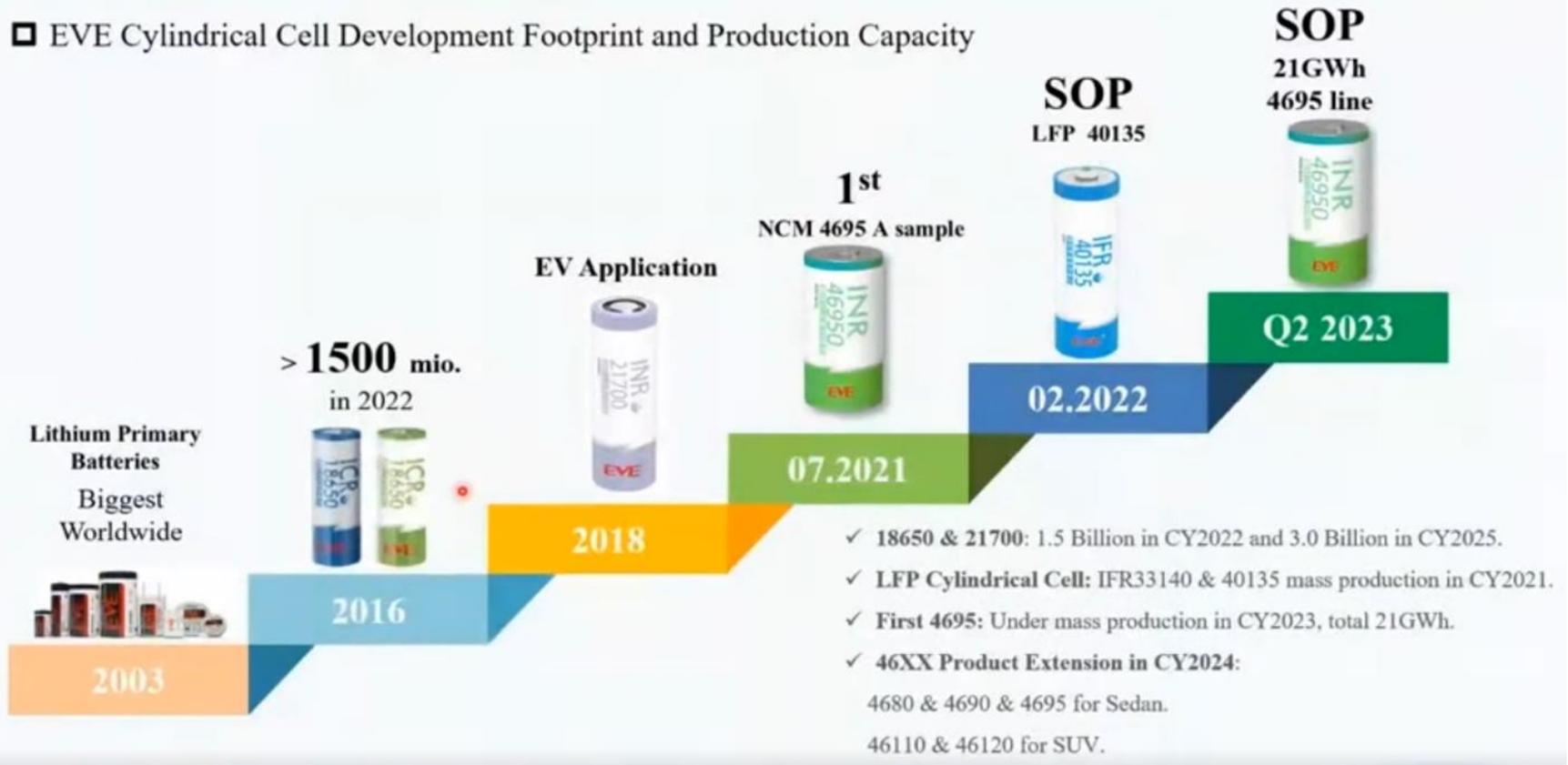
Mass Production not
before 2023

EVE 46XX New Cells

2. Cylindrical Cell R&D Progress

EVE 亿纬动力

□ EVE Cylindrical Cell Development Footprint and Production Capacity



Panasonic, Samsung, LG also developing 46800 cells

Cham Wide Temperature Cell – (-40 to 90 Deg C operation)

 Wide Temperature Cell 18650F2T - 2.0Ah (New Product – Samples Available)



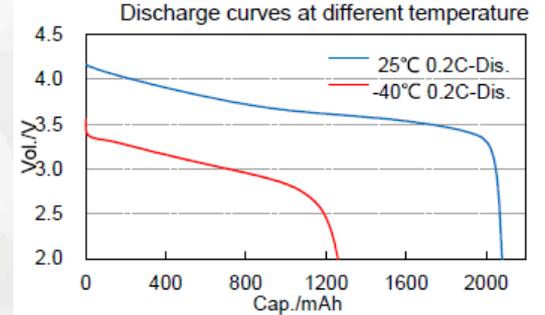
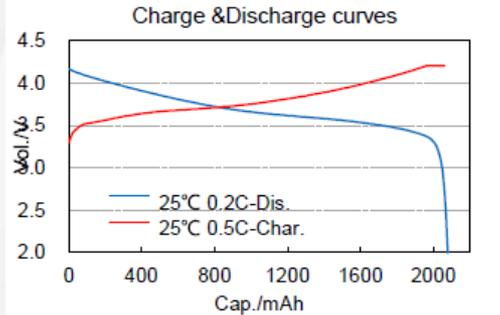
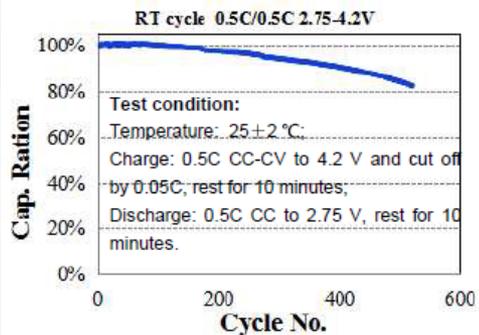
Features

- Wide Operating Temperature Range:
 - Charge -30°C~ 90°C
 - Discharge -40°C~90°C
- Excellent safety: Pass Heavy Impact Test
- Able to meet UL1642, GBT31241, GBT31485 standard
- Long cycle life: 500cycle > 60% (with 0.5C/0.5C)

Technology advantages :

- Unique Safety Structure Design
- Unique Polymer Functional Additive containing Hydroxyl groups to inhibit internal short circuit
- Wide Temperature Application

Model		18650F2T
Picture		
Nominal Capacity		2000 mAh
Nominal Voltage		3.65 V
Impedance		≤40mΩ
Max. Continuous Charge Current		1C(2000mA)
Max. Continuous Discharge Current		3C(6000mA)
Low Temperature Discharge(-40°C)		0.4A Discharge Capacity ≥ 1000mAh, (4.2-2.0V)
Standard RT Cycle Life		400 Cycle ≥ 60% (1.0C/1.5C)
Energy Density	Mass Energy Density	168 Wh/kg
	Volume Energy Density	427 Wh/L



Leading 13 Li-Ion Cylindrical Cells Manufacturers by Production Capacity

Companies	18650	21700	Web Site	UL Certification File
Panasonic - (Japan)	✓	✓	https://industrial.panasonic.com/	MH12210
Samsung SDI - (Korea)	✓	✓	https://www.samsungsdi.com/	MH21015
LG Energy Solution - (Korea)	✓	✓	https://www.lgensol.com/	MH19896
Murata Manufacturing - (Japan)	✓	✓	https://www.murata.com/en-global/products/batteries/cylindrical	MH12566
E-One Moli - (Taiwan)	✓	✓	http://www.molicel.com/	MH27672
Tianjin Lishen Battery Joint-Stock - (China)	✓	✓	http://en.lishen.com.cn/	MH27663
EVE Energy - (China)	✓	✓	https://en.evebattery.com/	MH28717
Dalian CBAK Power Battery - (China)	✓		http://www.cbak.com.cn/	MH61126
Guangzhou Great Power - (China)	✓	✓	http://www.greatpower.net/	MH27311
Jiangsu Highstar Battery Manufacturing - (China)	✓	✓	http://www.highstar.com/	MH46739
Dong Guan K-Tech New Energy - (China)	✓	✓	https://www.greenway-battery.com/	MH49877
Jiangsu Tenpower Lithium - (China)	✓	✓	https://www.tenpowercell.com/	MH46259
DLG (Shanghai) Electronic Technology - (China)	✓		https://www.dlg-battery.com/	MH29824

65 Li-Ion Cylindrical Hard Case Cells Manufacturers covered by our battery market report, Li-Ion Cylindrical Cells Market Review 2022, <https://www.sdle.co.il/products/market-research-reports/>

Cylindrical Cells Giga Factories planned in Europe/USA

Company Name	Web-Site
AMTE (Turso, Scotland)	https://amtepower.com/
Blackstone Resources (Switzerland)	http://www.blackstoneresources.ch/
British Volt (UK)	https://britishvolt.com/
Evercharge Energy (UK)	https://everchargeenergy.com/
FAAM/Lithops (Italy)	https://www.faam.com/eng/
Freyr (Norway)	www.freyrbattery.com
HE3DA (Czech Republic)	https://www.he3da.com/
InoBat Auto (Hungary)	https://inobatauto.eu/
Italvolt (Italy)	https://www.italvolt.com/
Morrow Battery (Norway)	https://www.morrowbatteries.com/
Northvolt (Sweden, Germany)	https://northvolt.com/
Phi 4 Technology S.L. (Spain)	https://www.phi4tech.com/
Saft, PSA & Opel (France, Germany)	https://www.acc-emotion.com/
Tesla (Germany)	https://www.tesla.com/
Varta (Ellwangen, Germany)	http://varta.com/
Verkor (France)	http://verkor.com/

Company Name	Web-Site
Tesla	https://www.tesla.com/
iMperium3	http://chargecccv.com/
Moli Energy	http://www.molicel.com/

These companies may produce cylindrical cells but their effect on the market will be not before 2024.

Cylindrical Cells Manufacturing Capacity Forecast

- 1. Cylindrical li-ion cell manufacturing capacity is around 850 Million per month during 2021 and will reach 3.2 Billion during 2025 and 6.7 Billion during 2030 (Carin Energy).**
- 2. Tesla is the largest customer.**
- 3. Cylindrical cells market are dominant by Panasonic, Samsung SDI, LG ES, Murata from Korea, Japan and tier one Lishen, BAK, EVE from China.**
- 4. 46800 new Tesla cell format – When Tesla will move to 46800 cell format that may free some 21700 cells demand and may effect the market – However Tesla 46800 cells production are in delay, and it is not clear when Samsung, LG, BAK, EVE, DMEGC will start production.**

2021- mid 2022 Cylindrical Cells Market Shortage Root Causes

1. **Tesla!!!!** - with 5000-7000 cylindrical cells on each EV battery pack and increasing EV sales.
2. **Panasonic** is fully committed to Tesla – small deliveries to other customers.
3. **Other EV & ESS Customers** batteries made from Cylindrical cells increasing sales (Volvo trucks,).
4. **LG** supply cylindrical cells to Tesla in China and prioritize that it over other customers (Models 3 and Y).
5. **Covid** and warm weather effect – Periodically Production capacity reduction at LG, Samsung, Murata, Moli Energy.



5. **Limited investment on expending cylindrical production lines (2020-2021).**
6. **The large cell manufacturers prioritize expending production resources on EV cells because of better profitability (Hard case and pouch prismatic) over cylindrical cells production capacity.**
7. **Long time for production capacity expansion – 2-3 years for existing cell makers, 3-4 years for newcomers.**
8. **Shortage on battery raw materials since all li-ion cells production capacity expansion use the same materials.**



**For how long that shortage will exist?
What the cell customers should do for securing the cells supply?**

What to Expect?

1. **Shortage in some cylindrical cell models for at least 2-3 years until new production capacity will be release.**
2. **Stronger shortage on 18650 cells since most cell manufacturers moving to 21700 as their new production.**
3. **Production expansion mainly lead by Chinese manufacturers that can fast increasing production capacity (Strength market position of Chinese manufacturers).**
4. **Some expansion expected also by Korean and Japanese leading companies.**
7. **Customer move to purchase cylindrical cells from Chinese suppliers and Moli Energy from Taiwan when Samsung, LG, Panasonic, Murata can't deliver.**
8. **Customers move to Chinese pouch cells where there is better availability.**

More detailed information in our battery market report:

Li-Ion Cylindrical Cells Market Review 2022

<https://www.sdle.co.il/products/market-research-reports/>

Q3/2022 Market Status

1. **LG & Samsung delivering now cell models that were in high shortage at the end of 2021.**
2. **Many cell customers hold new cell orders because of stocks they purchased at the end of 2021 and cell cost increase.**
3. **Lower demand from power tools makers due to low sales.**
4. **Main suppliers planned to increase cost again in Q3-Q4 this year – However market status block them from cost increase.**
5. **We can expect strong shortage return in 2023.**
6. **Shortage in IC`s, and other battery pack components decrease battery pack assemblers' production capacity – they order less cells – However we see first signs for better chip delivery from the end of 2022.**



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Information in this report was obtained by:

- 1. Public web sources.**
- 2. Shmuel De-Leon Battery/Energy Sources DataBase[®] (Includes 15,000 cell PDF data sheets).**