

# **LIB 18650 Cells New Replacement Cylindrical Cell Sizes (20650, 20700, 21700) Report**

**September 2016**

**Shmuel De-Leon  
Shmuel De-Leon Energy, Ltd.**

**[www.sdle.co.il](http://www.sdle.co.il)**

**[shmuel@sdle.co.il](mailto:shmuel@sdle.co.il)**

# Why Cylindrical Cells for LEV and x-EV`s?

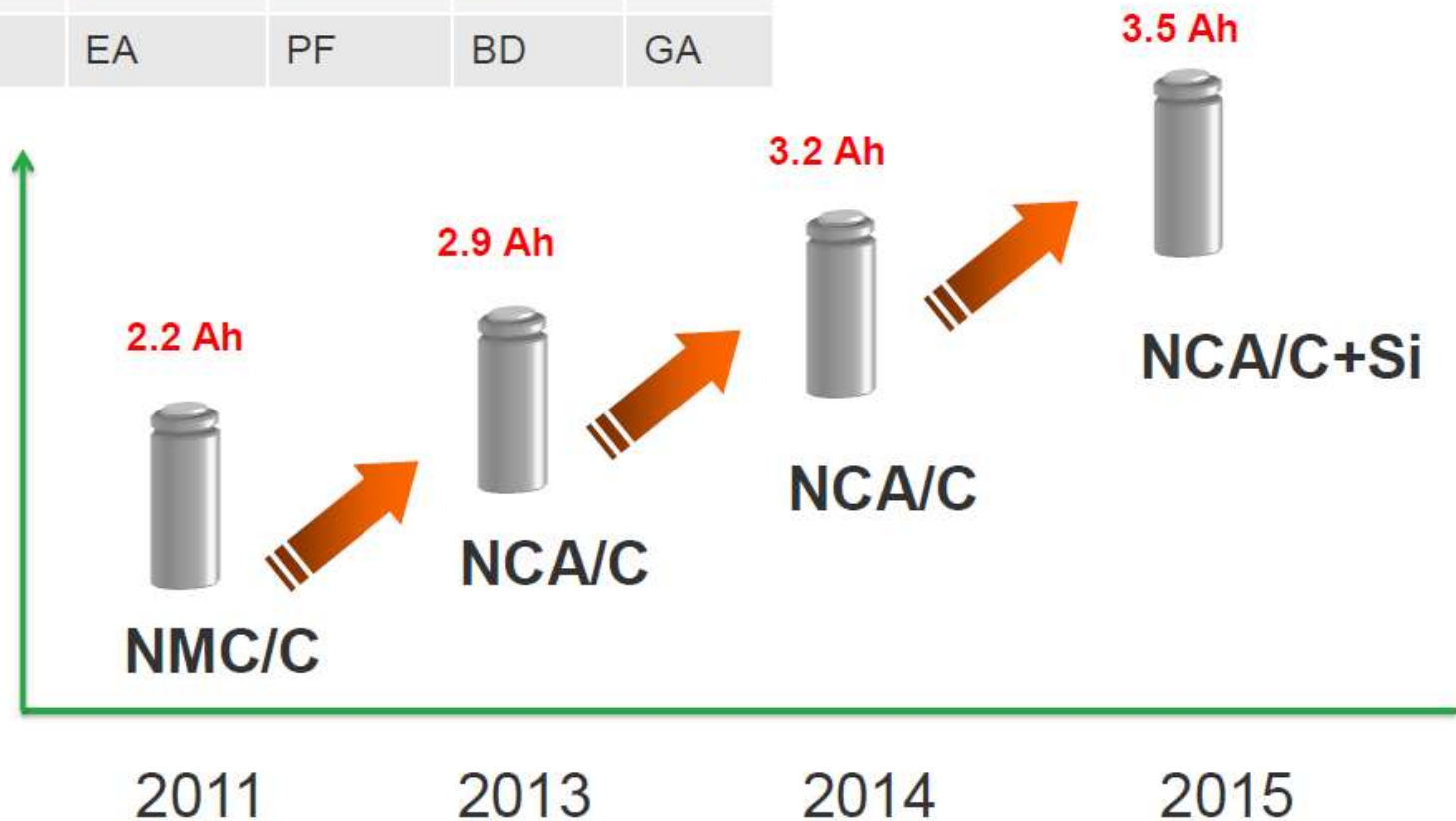
1. **Cost of cylindrical cells manufacture in mass production is lower than prismatic cells (Pouch/Hard case).**
2. **Higher energy density in compare to prismatic cells.**
3. **Flexible choice of suppliers (Many suppliers with mass production - 18650).**
4. **Integrated safety features (Vent, CID, PTC, Fuse, Shut down separator).**
5. **Robust construction (Can stand harsh environmental conditions).**
6. **High surface to volume ratio (Thermal management).**
7. **No gassing problems like in pouch cells.**
8. **Cycle life – Better than pouch or prismatic.**



# 18650 Cells for LEV

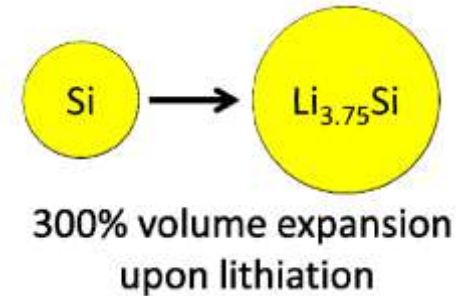
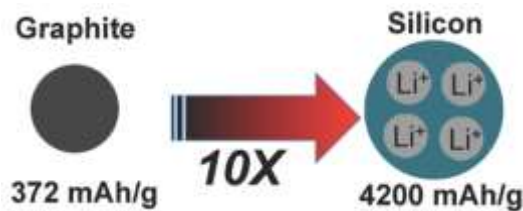
	2.2Ah	2.9Ah	3.2Ah	3.5Ah
Samsung SDI	22P	29E	32E	35E
LG Chem	MF1	MG1	MH1	MJ1
Panasonic	EA	PF	BD	GA

Limitation of 18650 cell?  
What's the next?



# New Cylindrical Cell with Silicon Nano Structure Anode

- Anodes are carbon based – Si stores 10X more energy than Li carbon (250-300 Wh/Kg).



- 18650 3.2-4Ah cells projected by American Lithium Energy, Panasonic, LG, Samsung (2015-2018).
- Lower nominal voltage: 3.5-3.6v.
- Low cut of voltage: 2-2.5v.
- 2C max current discharge.
- Limited cycle life - 250-300 cycles.



# 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



# LG Chem INR18650MJI



18650 3500mah LG Chem INR18650 MJI li-ion battery cell 3.6v 3500mah

- \* Quality Rechargeable Lithium-ion Cell 18650
- \* Brand: LG Chem
- \* Model: INR18650 MJI
- \* Nominal Voltage: 3.6V
- \* Nominal Capacity: 3500mAh
- \* Made in Korea

1. Nominal Capacity: 3500mAh
2. Minimum Capacity: 3400mAh
3. Nominal Voltage: 3.6V
4. Standard Charge
  - Constant current: 1700mA
  - Constant voltage: 4.2V
  - End condition(Cut off): 50mA
5. Max. Charge Voltage:  $4.2 \pm 0.05V$
6. Max. Charge Current: 3400mA
7. Standard Discharge
  - Constant current: 680mA(0.2C)
  - End voltage(Cut off): 2.5V
8. Max.Continuous Discharge Current: 10A
9. Weight: Max.49.0g
10. Dimension: Max.(D)18.5\*(H)65.2mm

# 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



PANASONIC  
NCR18650G-A

# Sony US18650VC7

	Value
Maximum Capacity	3.53Ah
Nominal Capacity	3.4Ah
Nominal Voltage	3.6V
Standart Charge Current	1.7A
Max Charging Voltage	4.2V
Standard discharge current	0.2C
Maxium discharge current	8A
Weight	48 g
Dimensions	18.5 X 65.2 mm
Cut off voltage	2V



SONY

# LG INR18659HG2

	Value
Maximum Capacity	3.1Ah
Nominal Capacity	3Ah
Nominal Voltage	3.6v
Standard Charging Current	4A
Max Charging Voltage	4.2V
Std Discharge Current	0.2C
Maximum Discharge Current	20A
Weight	48 g
Dimensions	18.3x65.2mm
Cut Off Voltage	2.5V

**18650 high power cell with the market highest capacity**



# Cells Discharge Comparison at 2A

## Characteristic(s)

Filter / Capacity [mAh]

### Cell(1)

<<< DB-BU >>> LG - INR18650MJ1(3500m)   
Load [A]    
Max.Cap.: 3326 [mAh] / Max.Temp.: 30,1 [°C]

### Cell(2)

<<< DB-BU >>> Panasonic - NCR18650GA   
Load [A]    
Max.Cap.: 3357 [mAh] / Max.Temp.: 31,9 [°C]

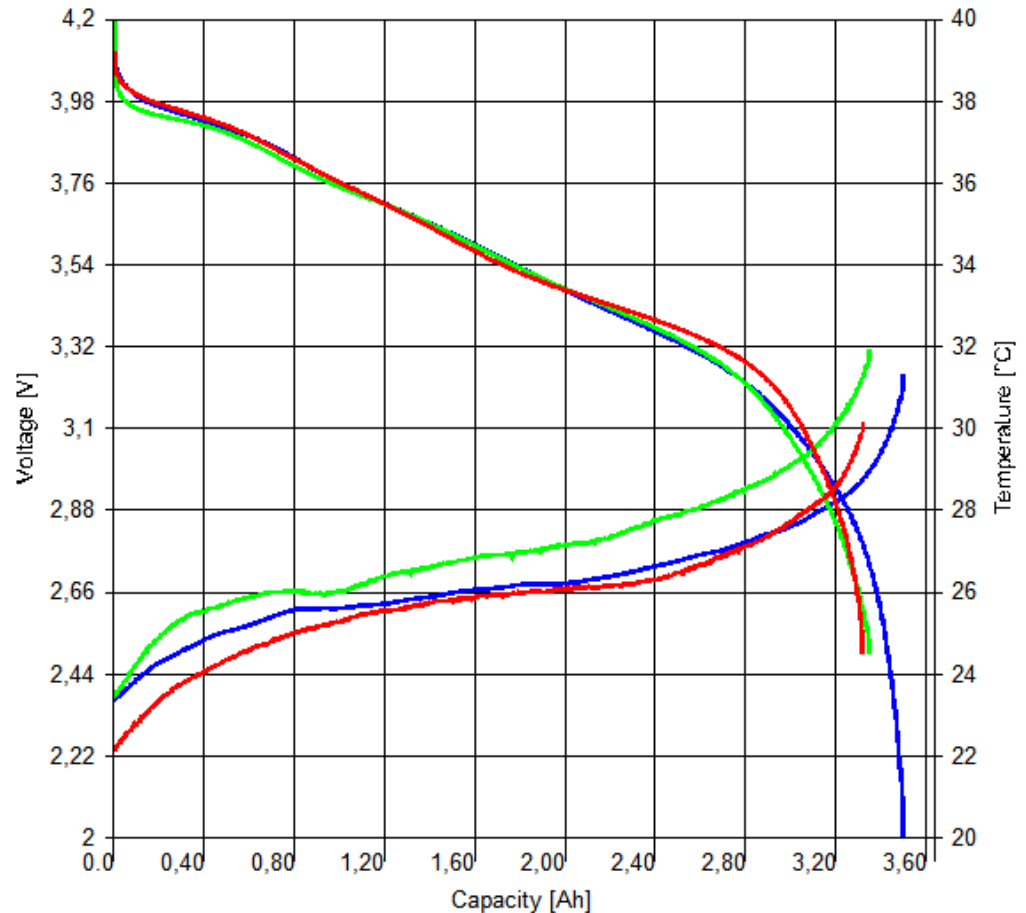
### Cell(3)

<<< DB-BU >>> Sony - US18650VC7(3530)   
Load [A]    
Max.Cap.: 3509 [mAh] / Max.Temp.: 31,2 [°C]

### Cell(4)

Load [A]    
\*

Zoom





# Cells Discharge Comparison at 5A

## Characteristic(s)

Filter / Capacity [mAh] Min. 3300 Max. 9999 Filter

Reset

### Cell(1)

<<< DB-BU >>> LG - INR18650MJ1(3500mAh) X  
Load [A] 5  
Max.Cap.: 3288 [mAh] / Max.Temp.: 46,4 [°C]

### Cell(2)

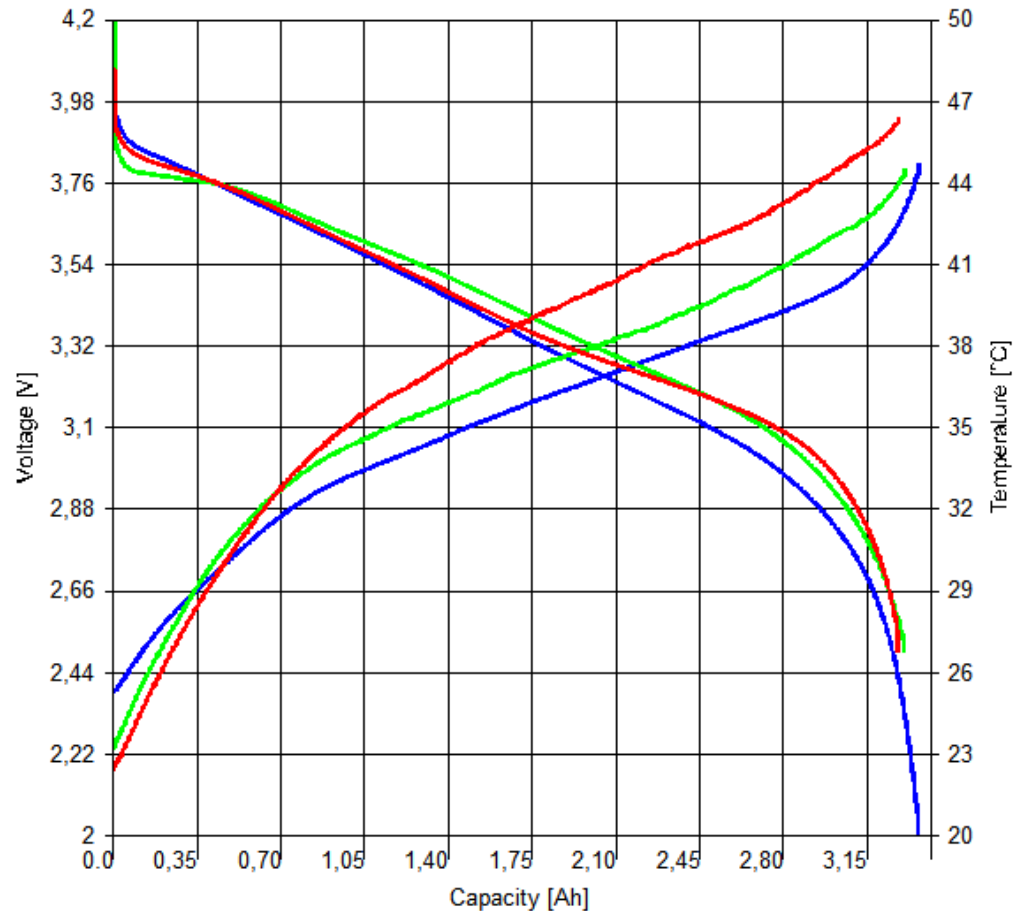
<<< DB-BU >>> Panasonic - NCR18650GA X  
Load [A] 5  
Max.Cap.: 3311 [mAh] / Max.Temp.: 44,4 [°C]

### Cell(3)

<<< DB-BU >>> Sony - US18650VC7(3530mAh) X  
Load [A] 5  
Max.Cap.: 3370 [mAh] / Max.Temp.: 44,6 [°C]

### Cell(4)

\*  
Load [A] \*  
Zoom



# Cells Discharge Comparison at 10A

## Characteristic(s)

Filter / Capacity [mAh]    Min. 3300    Max. 9999    Filter

Reset

### Cell(1)

<<< DB-BU >>> LG - INR18650MJ1(3500m)

Load [A] 10

Max.Cap.: 3325 [mAh] / Max.Temp.: 75,7 [°C]

### Cell(2)

<<< DB-BU >>> Panasonic - NCR18650GA

Load [A] 10

Max.Cap.: 3318 [mAh] / Max.Temp.: 67,6 [°C]

### Cell(3)

<<< DB-BU >>> Sony - US18650VC7(3530)

Load [A] 10

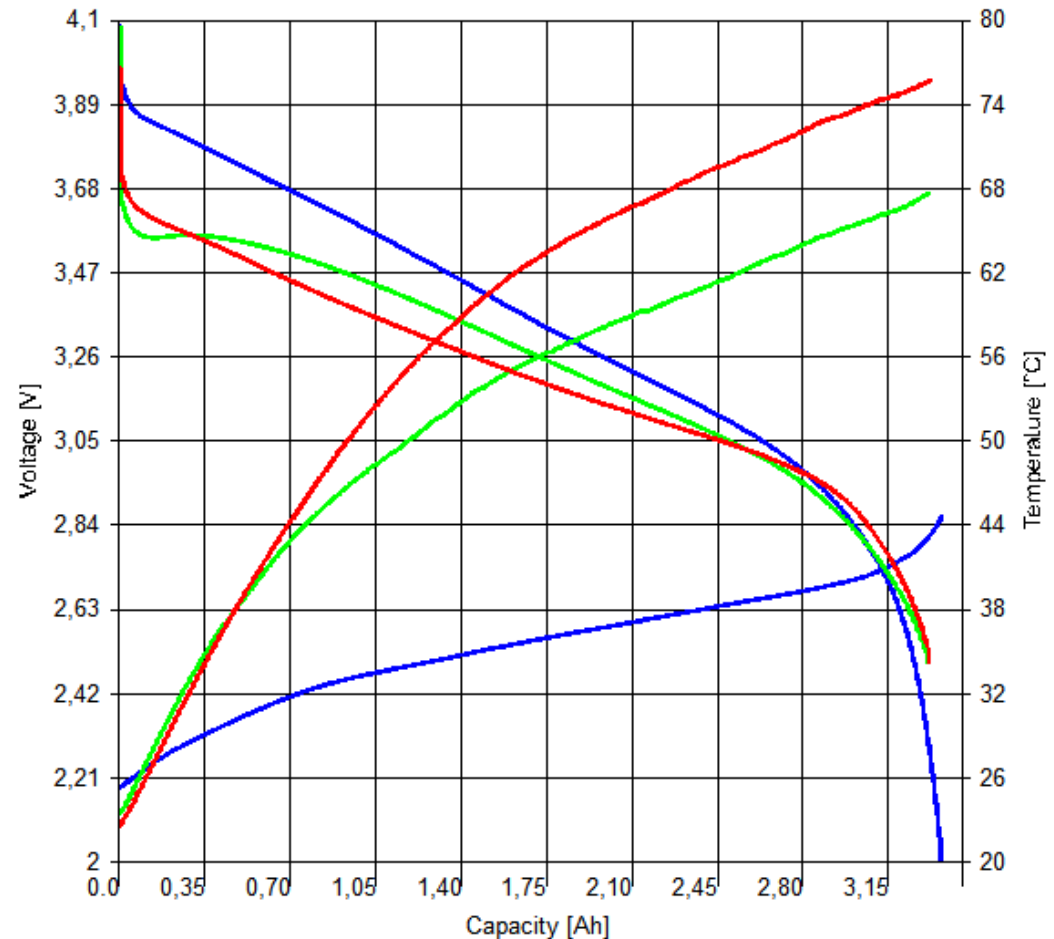
Max.Cap.: 3083 [mAh] / Max.Temp.: 65,3 [°C]

### Cell(4)

Load [A]

\*

Zoom



# The Need for Larger LIB Cylindrical Sizes

1. **18650 size was developed for notebooks and camcorders – that market has been changed.**
2. **High demand for more energy lead to larger battery packs – 18650 is not ideal size for them.**
3. **Larger packs with 18650 cells need a complicated BMS.**
4. **New larger cylindrical cells sizes will allow to increase energy density, reduce cells number in battery packs and to increase the pack efficiency.**
5. **Cell makers selected 20650, 20700 and 21700 sizes as the most efficient for small E-Bike packs as well as for EV packs.**
6. **Converting current 18650 production lines to the new sizes is possible – Save the need to buy complete new production line.**



# What Cylindrical LIB Next Generation

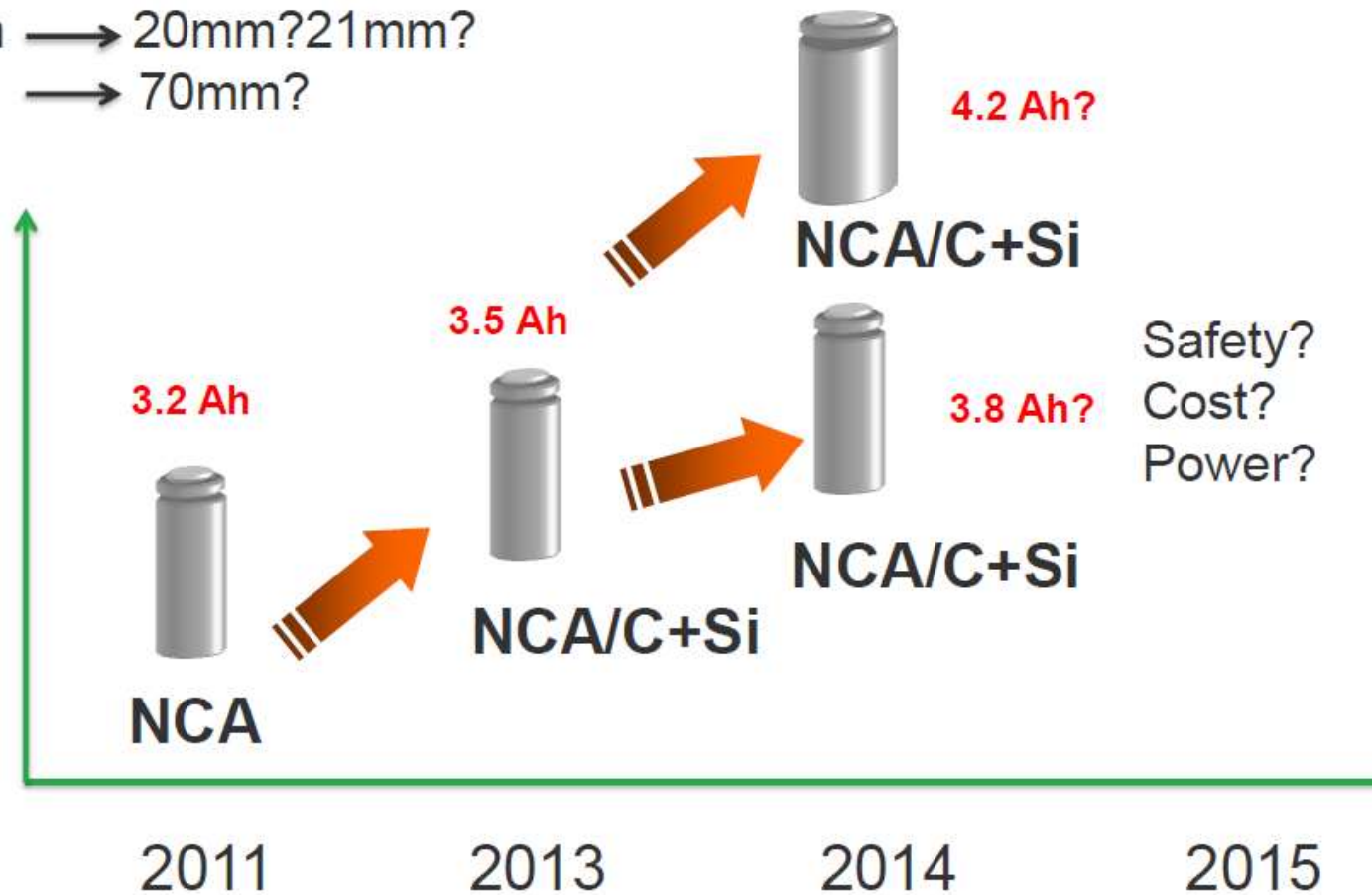
Limitation of 18650 cell?

What's the next?

Form factor change:

D: 18mm → 20mm? 21mm?

L: 65mm → 70mm?



# 2016 The New Sizes

Manufacturer	Model	Capacity [Ah]
<b>LG</b>	<b>M42</b>	<b>4.2</b>
	<b>HG6</b> 20650	<b>3</b>
	<b>HH2</b>	<b>3.5</b>
<b>Samsung</b>	<b>INR21700-30T</b>	<b>?</b>
	<b>INR21700-48G</b>	<b>?</b>
	<b>INR21700-35T</b>	<b>?</b>
	<b>INR21700-38P</b>	<b>3.75</b>
	<b>INR21700-48E</b>	<b>?</b>
<b>Panasonic</b>	<b>NCR20700B</b>	<b>4.25</b>
	<b>NCR20650A</b>	<b>3.1</b>
	<b>NCR20700A</b>	<b>3.3</b>

End of Life

End of Life

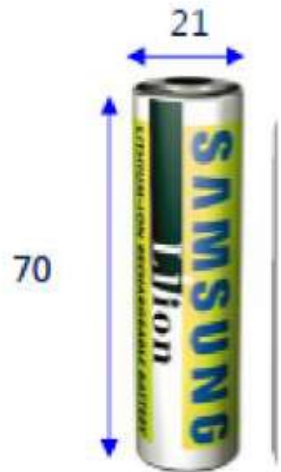
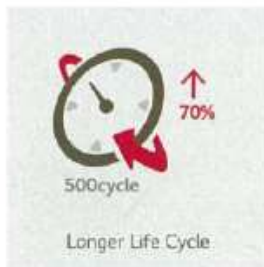
<b>Panasonic</b>	<b>NCR20700C</b>	<b>3.5Ah</b>
<b>Sony</b>	<b>US21700VXX</b>	<b>5Ah</b>
<b>E-one Moli</b>	<b>INR20700A</b>	<b>3Ah</b>
<b>LG</b>	<b>H30 (21700)</b>	<b>3Ah</b>

Some of the manufacturers start production of all that list and saw that 20650 size is not competitive and stop production – 21700 seems the main future cell size



Model	M42
Diameter x Height (mm)	20x65
Nominal Capacity (Ah)	4.2
Energy (Wh)	15.3
Nominal Voltage (V)	3.64
Weight (g)	58
Max Discharge Current (A)	15

**M42**



[ 21700 ]

**Specification**

Type		INR21700-38P
Chemistry		NCA-NCM /Gr.
Dimension (mm)	Diameter	21
	Height	70
Max. Weight		75g
Initial IR (mΩ AC 1kHz)-Estimated		20
Initial IR (mΩ DC (10A-1A)-Estimated		40
Nominal Voltage (V)		3.6
Charge Current	Standard current (A)	6
Discharge	End voltage (V)	2.5
Discharge Capacity	Standard (mAh) (0.2C)	3750

**NCR20700**  
**B**  
**10~12A type**



Nominal Voltage	3.6 (V)
Capacity	4000 (mAh)
Charge voltage	4.2 (V)
Diameter(with tube)/Max.	20.3 (mm)
Height(with tube)/Max.	70.3 (mm)
Approx. Weight	63.5 (g)

# Panasonic NCR20700A

	Value
Maximum Capacity	3.3Ah
Nominal Capacity	3.1Ah
Nominal Voltage	3.6v
Standard Charging Current	2.205A
Maximum Charging Current	4.0A
Max Charging Voltage	4.2V
Std Discharge Current	0.6A
Maximum Discharge Current	30A
Weight	62.3 g
Dimensions	20.3x65mm
Cut Off Voltage	2.5V
Max Operating Discharge Temperature	70
Min Operating Discharge Temperature	-20

# LG INR20650 HG6

	Value
Maximum Capacity	3Ah
Nominal Capacity	2.9Ah
Nominal Voltage	3.6v
Standard Charging Current	1.5A
Maximum Charging Current	4.0A
Max Charging Voltage	4.2V
Std Discharge Current	0.6A
Maximum Discharge Current	20A
Weight	58 g
Dimensions	20.3x65mm
Cut Off Voltage	2.5V

**Application: Power Tools,  
Vacuum Cleaners, Garden  
Tools**

# HG6 20650 Form Factor High Power Cell

HG6 is new power-driven cylindrical solution with high capacity of 3.0Ah and high power

## Major Features

### Minimal Dimensional Change

- Diameter increase : 18→20mm
- No height change : 65mm

### 2-Tab for Cathode

- Two electric paths decrease resistance and enable higher power



### Safety-reinforced Top-cap

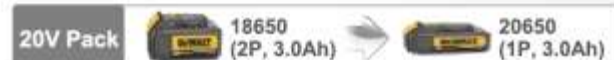
- Increased thickness for top-cap enhances safety (e.g. external short circuit)



## Key Values

### Compact Power Solution

- **3.0Ah Compact 5S1P Pack**
  - 20V pack with high capacity(3.0Ah) & power(16mΩ) for impact drivers, hammer drills



### Cordless Heavy-duty Solution

- **Corded to cordless for heavy duty tools**
  - Enables expansion of corded heavy duty circular saws and grinders to cordless



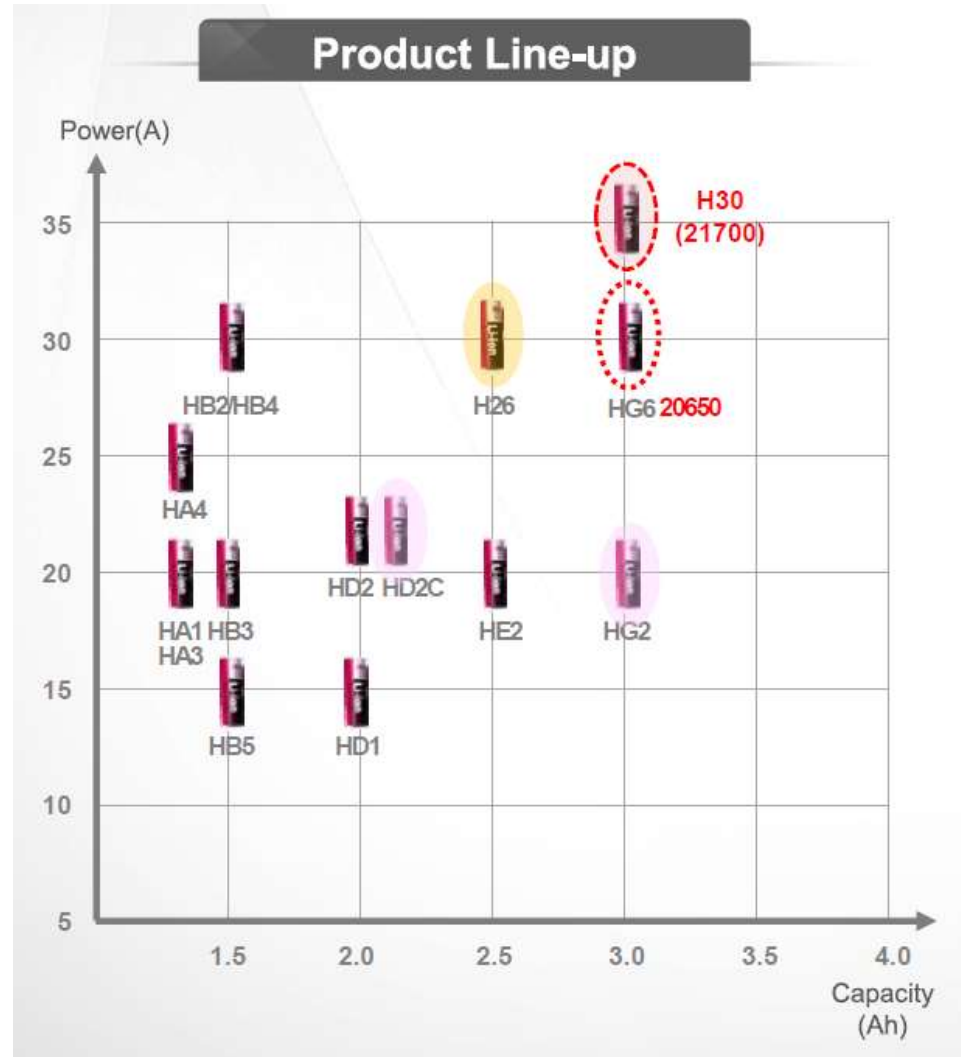
### Garden tool Solution

- **Compact 10S pack**
  - Compact 6.0Ah(2P) for 10S garden tool pack





# LG H30 21700



**Application: Power Tools, Vacuum Cleaners, Garden Tools**

**Planned for Q2 2017**

# Specs. for NCR20700A

Specifications			Dimensions		
Rated capacity <sup>(1)</sup>		3100mAh			
Capacity <sup>(2)</sup>	Minimum	3150mAh			
	Typical	3300mAh			
Nominal voltage		3.6V			
Charging	Method	CC-CV			
	Voltage	4.20V			
	Current	Std. 2200mA			
	Time	Std. 180min.			
Weight (max.)		60.0g			
Temperature	Charge	10 to +45° C			
	Discharge	-20 to +60° C			
	Storage	-20 to +50° C			
Energy density <sup>(3)</sup>	Volumetric	512 Wh/l	With tube	H	Max. 70.3mm
	Gravimetric	192 Wh/kg		D	Max. 20.35mm
				d	Max. 10.5mm

(1) At 20° C (2) At 25° C

(3) Energy density is calculated using bare cell dimensions (without tube).

When designing a pack, refer to the cell's mechanical drawing for precise dimensions.

# Specs. for NCR20700B

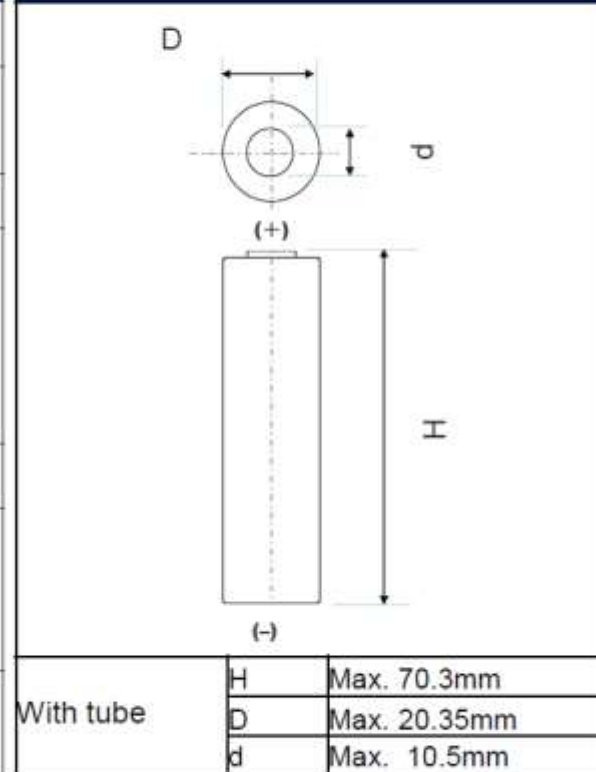
## Specifications

Rated capacity <sup>(1)</sup>		4000mAh
Capacity <sup>(2)</sup>	Minimum	4050mAh
	Typical	4250mAh
Nominal voltage		3.6V
Charging	Method	CC-CV
	Voltage	4.20V
	Current	Std. 2000mA
	Time	Std. 180min.
Weight (max.)		63.0g
Temperature	Charge	10 to +45° C
	Discharge	-20 to +60° C
	Storage	-20 to +50° C
Energy density <sup>(3)</sup>	Volumetric	659 Wh/l
	Gravimetric	224 Wh/kg

<sup>(1)</sup> At 20° C <sup>(2)</sup> At 25° C

<sup>(3)</sup> Energy density is calculated using bare cell dimensions (without tube).

## Dimensions



When designing a pack, refer to the cell's mechanical drawing for precise dimensions.

# Panasonic NCR20700C

	Value
Max Capacity	3.5Ah
Nominal Capacity	3.45Ah
Nominal voltage	3.6V
Maximum Discharge Current	30A
Weight	62 g
Dimensions	D=20.4mm, L= 70.3mm
Cut Off Voltage	3V
AC Impedance	10m Ohm
DC Impedance	14m Ohm

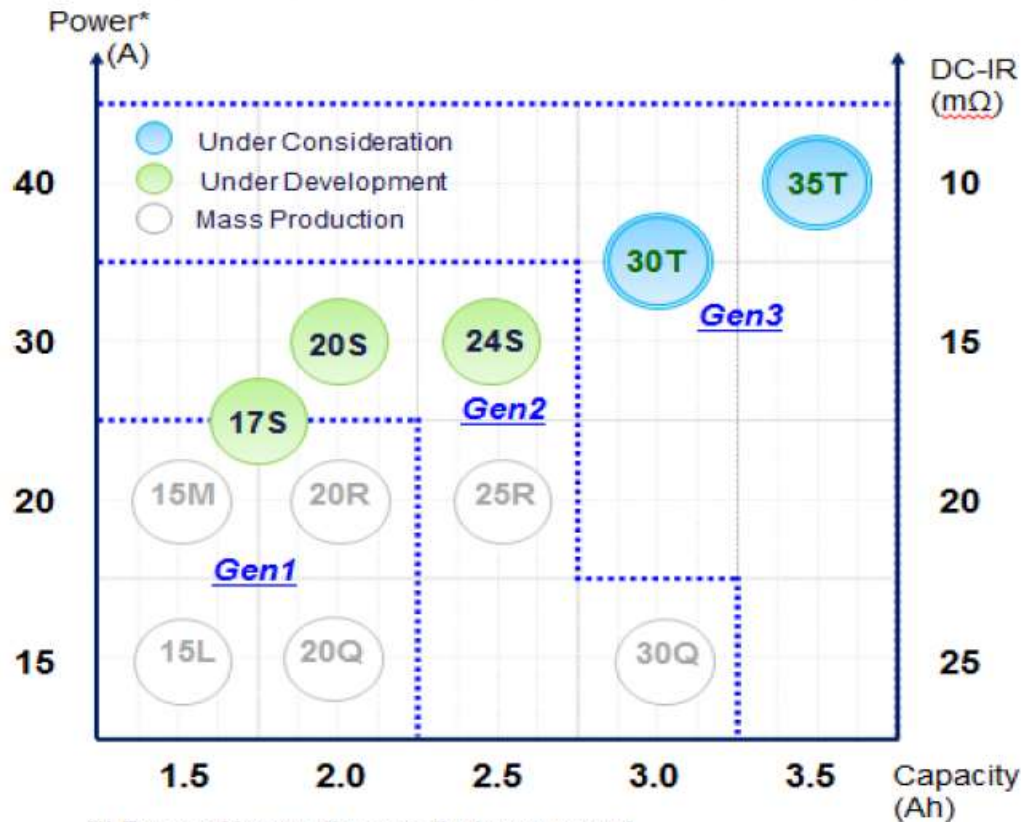
New High Power Cell from Panasonic under development – Mass production expected in 2017

# Samsung SDI Road Map

## PRODUCT ROADMAP – HIGH POWER CELL

**S series are on track**

**New form factor under consideration for T series**



※ Power: Max continuous discharge current

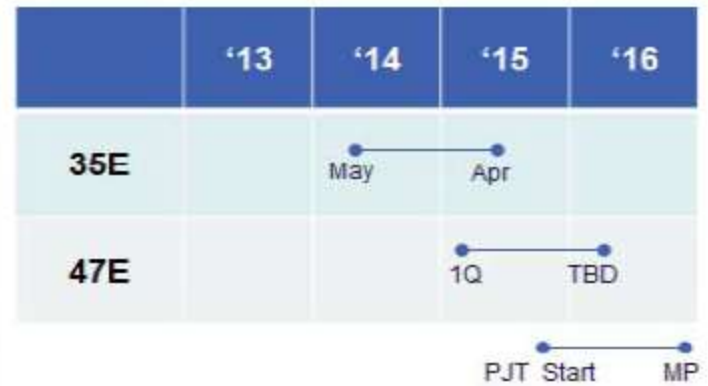
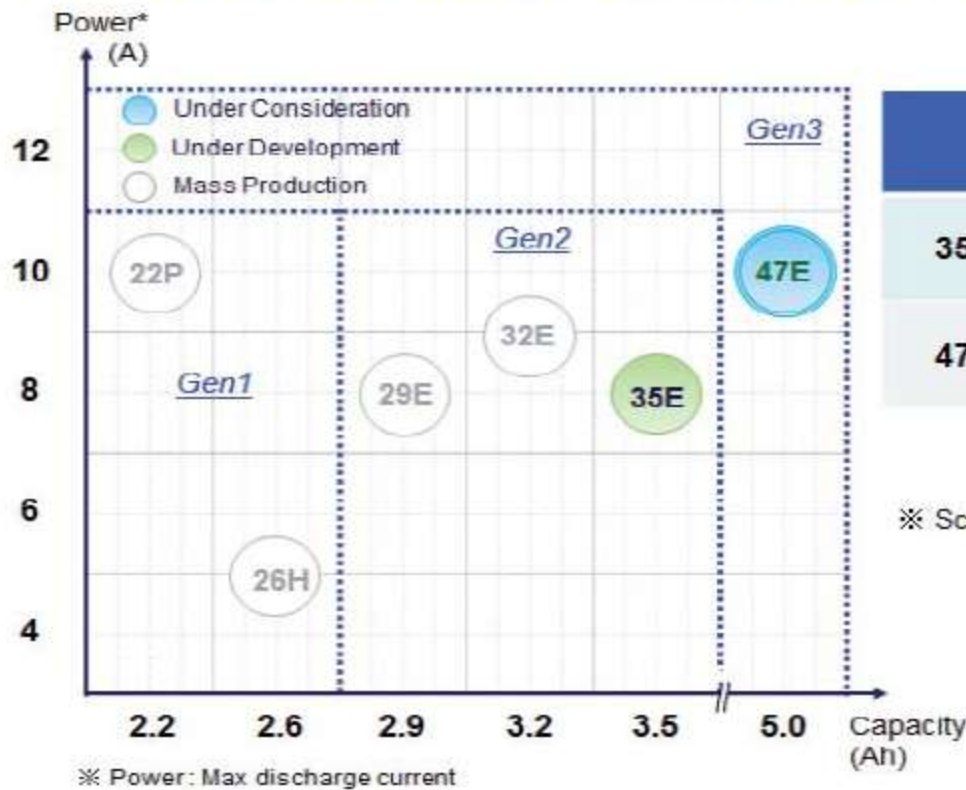


※ Schedules can be adjusted

# PRODUCT ROADMAP – HIGH CAPACITY CELL

**35E is ready and in MP**

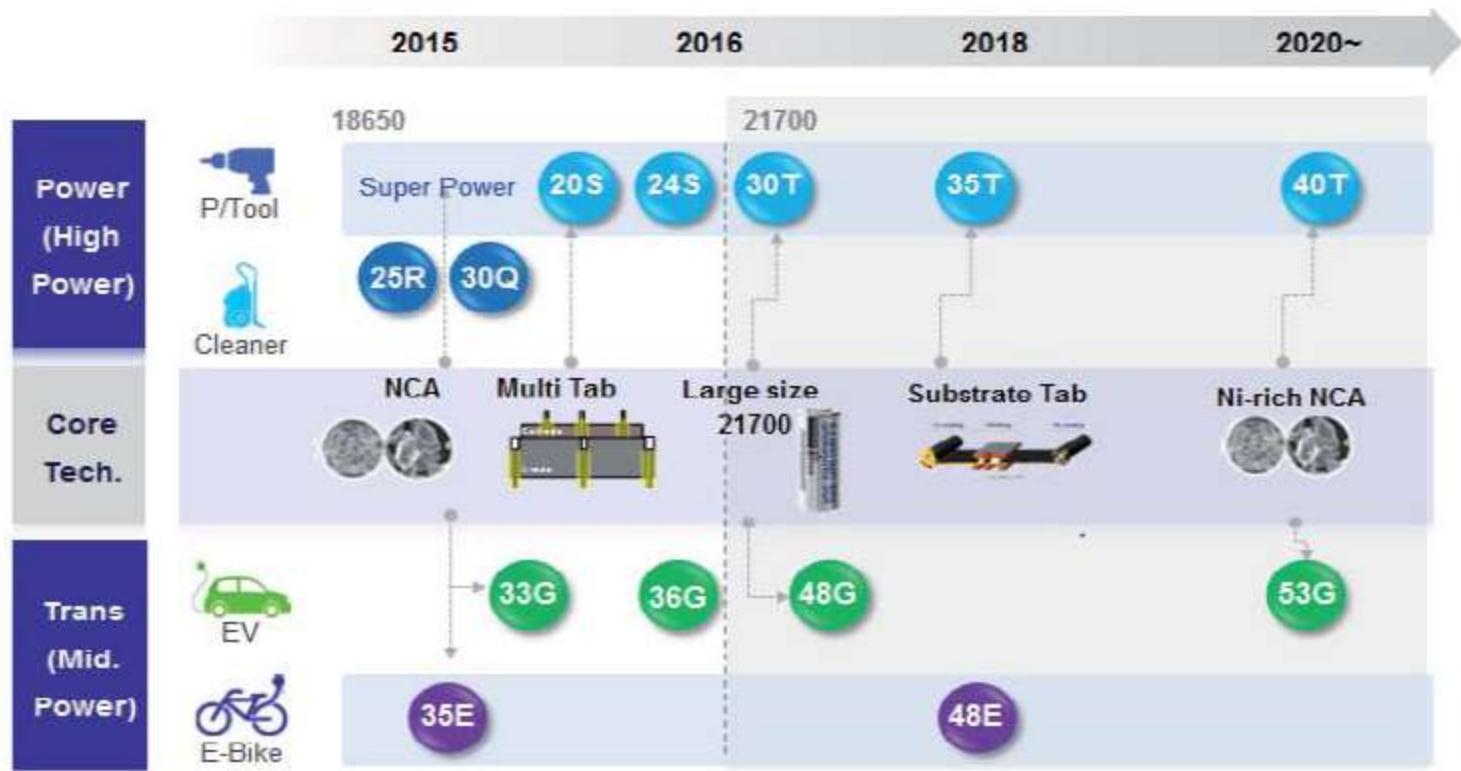
**47E under consideration with new form factor**



※ Schedules can be adjusted

# NEXT GENERATION CELL – “21700”

Fully ready to support future innovation with newest technology



Source: BMZ presentation in a German conference

# Cell Performance Comparison

	LG INR18650MJ1	Samsung IR18650-35E	Sony US18650VC7	Panasonic NCR18650GA	
Wh/kg	259.6	248.4	264	250	
Wh/l	736.46	709	725	707	
W/kg	741	576	1500	581	
WH/l	2104	1644	4110	1641	
	Medium Power	Medium Power	High Power	Medium Power	
	LG INR20650HG6	LG INR20650M42	Panasonic NCR20650A	Panasonic NCR20700A	Panasonic NCR20700B
Wh/kg	186	260	197	190	242
Wh/l	513	698	532	519	669
W/kg	1862	752	1911	1733	228
WH/l	5136	2018	5153	4752	630
	High Power	Medium Power	High Power	High Power	low Power
	LG INR18650HG2	Panasonic UR18650NSX	Samsung INR18650-25R	Sony US18650VTC6	
Wh/kg	229	204	200	242	
Wh/l	630	533	526	643	
W/kg	1531	1572	1600	1548	
WH/l	4200	4103	4209	4110	
	High Power	High Power	High Power	High Power	

## Conclusions:

1. Sony Has the highest energy density on 18650 cells with silicon nano structure anode
2. Sony also the only one to have 18650 high power cell with silicon nano structure anode
3. The new cells with 20-21mm diameter are in early stage – the energy density is less then 18650 although we could expect it to be higher – It will increase after some extra development progress



# Samsung New E-Bike Battery Packs

**Samsung SDI** also unveiled a battery pack product equipped with 21700 batteries, noted for their upgraded energy capacity compared to previous cylindrical types. The 18650 battery, or rather the small cylindrical battery of 18mm diameter and 65mm length, has been in dominant use until recently. However, the creation of new battery applications has boosted the demand for high capacity batteries. In response, Samsung SDI has come up with a battery that has upgraded a maximum of 35% of energy volume, now known as the 21700 battery, and has successfully applied it onto e-bikes for the first in the world.

The 21700 model can have various applications other than e-bike, such as in electric tools, laptops, and more. It is expected to become the new standard in small cylindrical battery usage.



# E-ONE Moli 20700 Cell

E-One Moli from Canada is manufacturing Li-Ion 20700 size cell in mass production for 1 customer – We are waiting for some more information regarding that cell and will present it soon.



Molicel INR-20700A	
Nominal Capacity	3Ah
Nominal Voltage	3.6V
Standard Charge Rate	3A
Max Charge rate (UL rating)	3A*
Charge Voltage	4.2V
Max Continuous Discharge	35A
Weight	57g
Dimensions	20.5mm X 70mm

# Tesla – 20700 Cell Sizes?

1. **Tesla is the biggest customer of Panasonic 18650 cells.**
2. **Moving into 20700 cell size will gain some benefits to Tesla.**
3. **Tesla took already the decision for a new size – Announcement is expected soon.**
4. **“Current high-energy 18650 cells deliver 50% higher energy per unit weight than current large cells. In the future, the main opportunity for energy density enhancement and cost reduction in 18650 cell construction is in the implementation of materials with higher capacity and/or lower cost; there would also be some benefit in moving to slightly larger cells (20700 or so)”**



# Chinese LIB New Sizes Market

- **When Panasonic, Samsung SDI and LG are all developing new LIB cylindrical larger sizes we could expect the same trend in China from companies like, Lishen, BYD, Sinopoly, ATL, Coslight...**
- **After checking with all our Chinese resources it seems like the Chinese market is waiting for the new sizes to penetrate successfully the market and then they will decide to start production of the new sizes.**



# Summary

1. **Since the 3 leading cell makers are moving into new cylindrical cells sizes it seem that we can expect for a change in the market.**
2. **Main applications are E-Bike, LEV, EV`s and Power Tools.**
3. **Mass production expected from mid-end 2016.**
4. **Chinese cell makers still consider the new sizes.**



**Shmuel De-Leon  
Energy Ltd**

**Shmuel De-Leon Energy, Ltd.  
Mazal Arie 10, Hod-Hasharon, Israel 45309  
Tel/Fax: 972-77-5010792, Mobile: 972-52-8601517  
[www.sdle.co.il](http://www.sdle.co.il), [www.batteriesdatabase.com](http://www.batteriesdatabase.com)  
[shmuel@sdle.co.il](mailto:shmuel@sdle.co.il)**

**Information in this report was obtained by:**

- 1. Public web sources.**
- 2. Shmuel De-Leon Battery/Energy Sources DataBase<sup>®</sup> (Includes 30,000 cell PDF data sheets).**
- 3. Shmuel De-Leon Batteries & Fuel Cells Seminar<sup>®</sup> presentations.**