Battery Growth Opportunities: Meeting the Requirements of Growing Markets and Applications

Samuel De-Leon
shmuel@sdle.co.il
www.sdle.co.il

Nazareth, Israel – The search for the "Perfect Bite"…

Basilica of the Annunciation

Fresh hot Humus

Street food Falafel

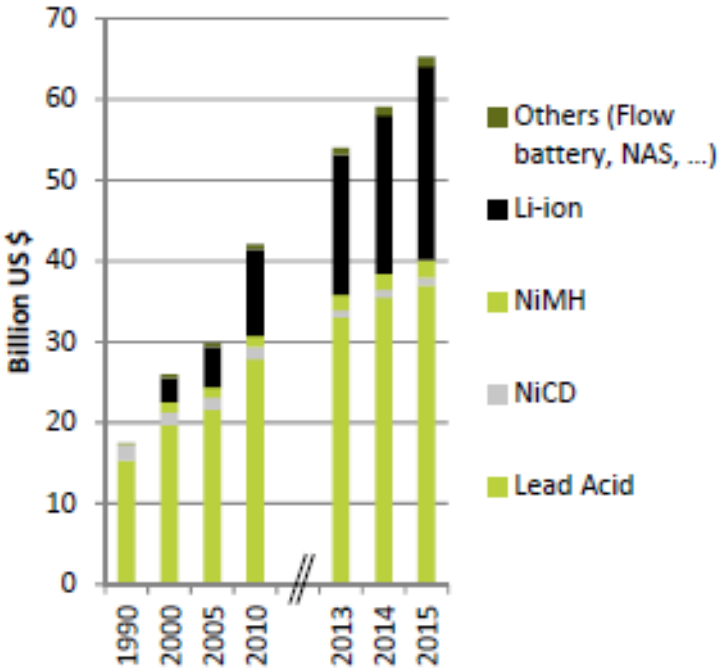
Attend the 6th Israeli Energy Storage Conference May 10-11th, Herzelia, Israel

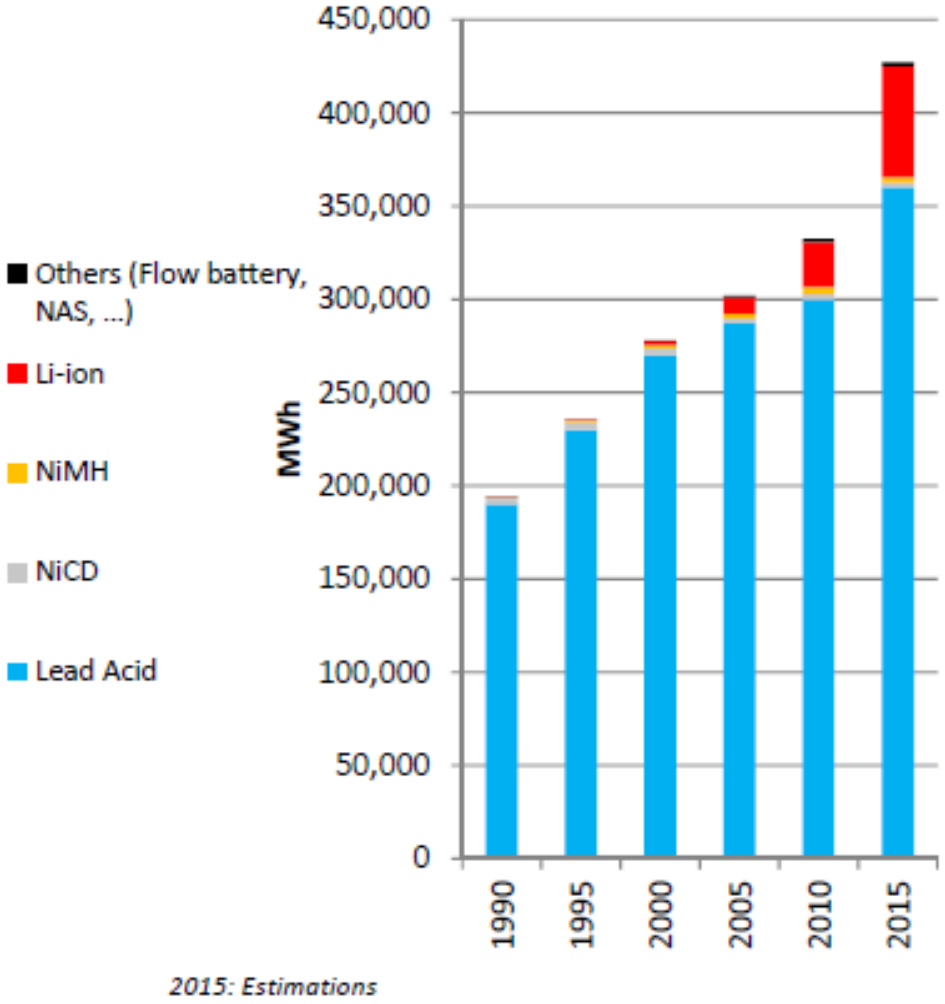
Sweet Baklawa

Street food Shawarma

Rechargeable Battery Market

- **Steady growing market 65B$ IN 2015**
- **Market is dominant by Lead Acid batteries**
- **Li-ion is the fastest growing technology**
- **NiMh market share is shrinking**





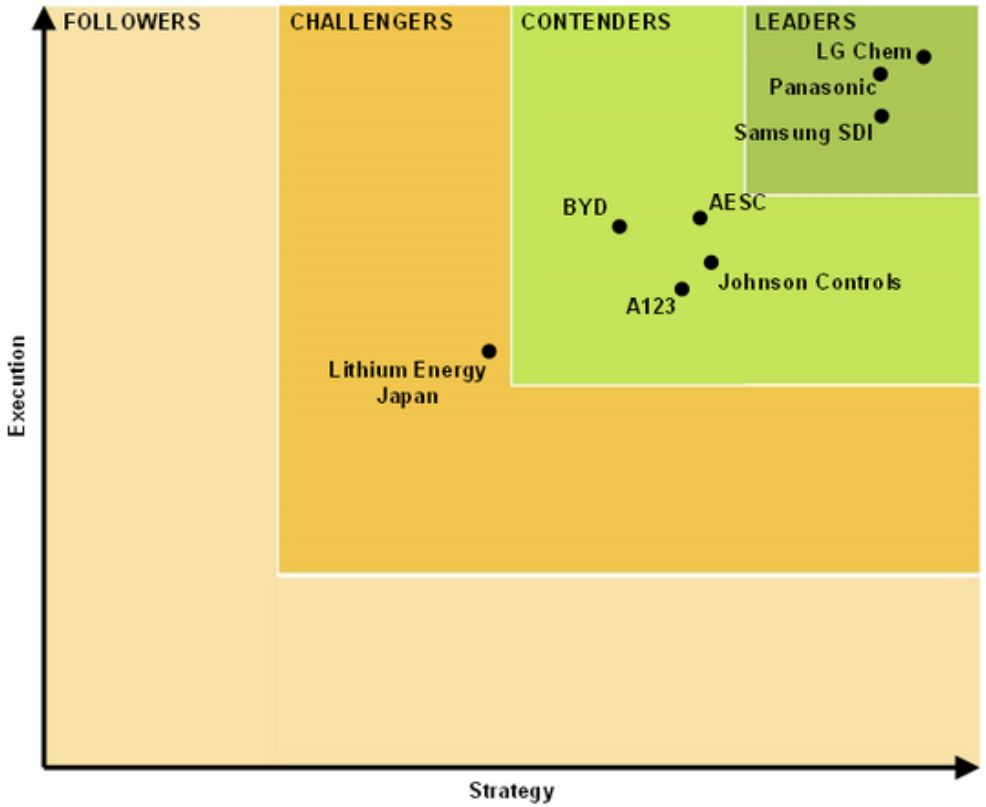
Source: Avicenne Energy, 2016

Li-Ion Market trends for 2016

- 2012-2014 The market was under over production
- Cell makers build production capacity for the EV and ESS markets but market demand was low then expected
- 2015-2016 We see a positive change – Market demand grow dramatically mainly because of the EV, E-BUS, E-Bike, ESS, Consumer Electronic and power tool markets
- Cell makers cant supply the current demand – We face slow pricing increase and longer delivery time
- It will not be a surprise if we will see higher pricing till 2018 at least

EV Market 2020

- **Navigant projects global market for Li-ion batteries for HEVs and PEVs will grow at a 2015-2020 compound annual growth rate (CAGR) of 31.9% in terms of energy capacity to 61.3 GWh**



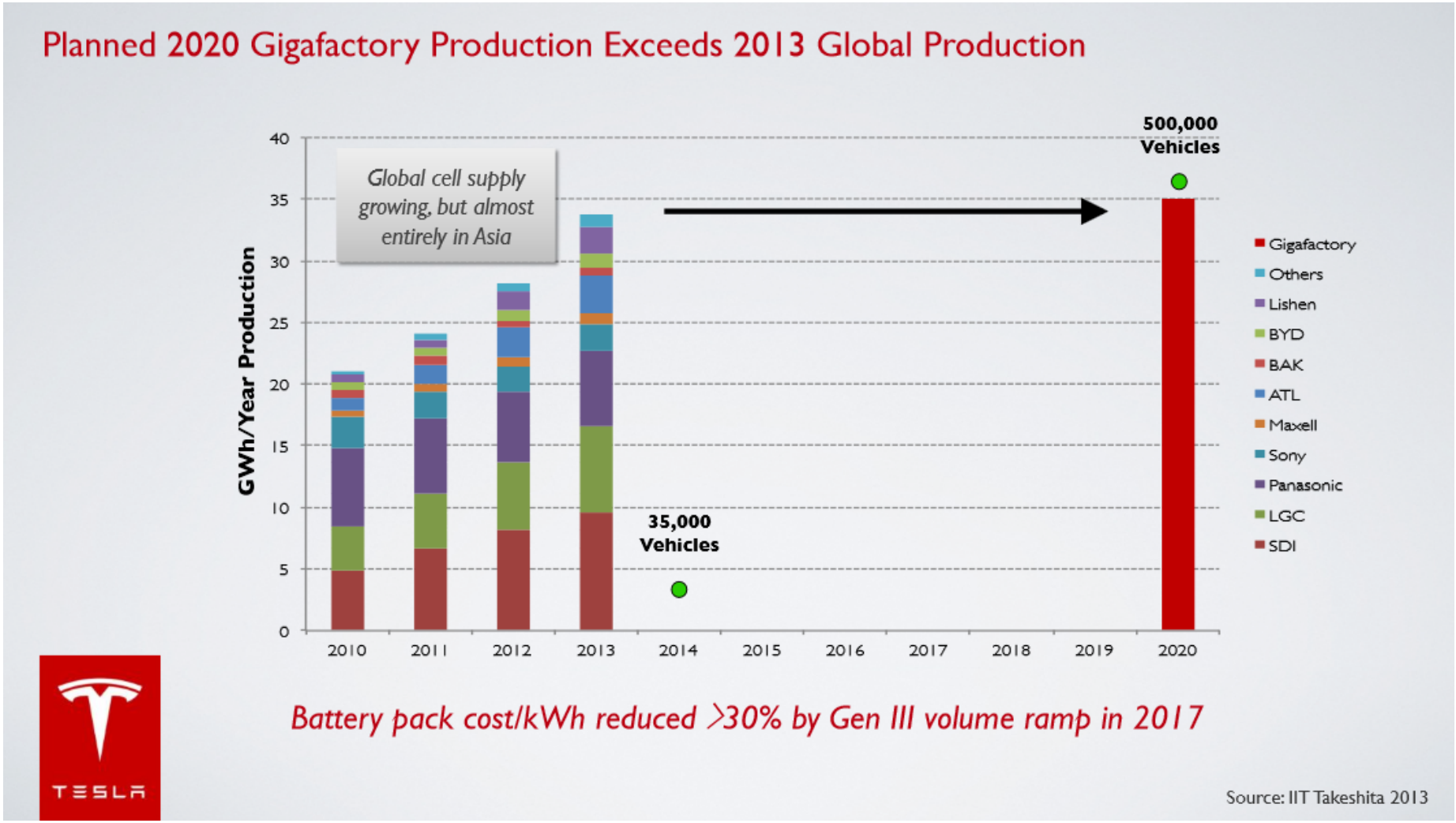
Source: Navigant research

Li-Ion Cell Production to Grow 2-3 Times till 2020

- Li-Ion market production size was estimated as 30GWh in 2015 (Source: Avicenne Energy).
- Demand from the EV and ESS markets push the cell maker to increase production
- Tesla Giga factory will produce 35GWh in 2020
- China li-ion battery industry is booming – From 15.7GWh production in 2015 it expected grow to 30-40GWh in 2020 (Source: CCM`s)
- LG Chem, MI, USA increase production to meet GM, EV Batteries needs
- Samsung invest 600M$ in their EV cell production facility in China till 2020
- A123 invested 200M$ in increasing production

The “Giga” factory is necessary for supplying the battery needed for 500k cars – current world production can`t support it.

The “Giga” factory to double word li-ion production capacity…



Li-Ion Cell Raw Material

- As cell production grow we see a strong demand increase for battery raw materials
- As an example - Lithium compound price doubled in the last 6 months
- Most of the battery raw material investing on increasing production
- Main issue is the battery raw material prices - Seems that with the grow in demand we can expect cost increase that will not support the planed li-ion battery cost reduction

SQM
THE WORLDWIDE BUSINESS FORMULA

FMC FMC Lithium

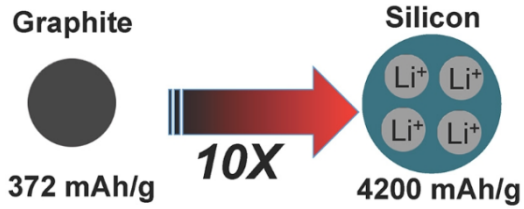
ALBEMARLE

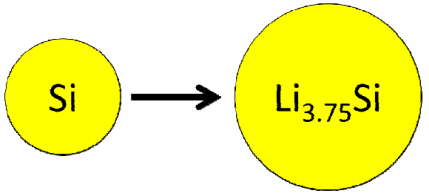
Potential Battery Technologies for Break- Through 2020-2050

- Lithium Ion with Silicon based anode
- High Voltage Li-Ion (4.4-4.7V)
- Li-Ion Solid Electrolyte (Li-ion, Li-metal)
- Lithium Sulfur
- Lithium Air

Li-Ion With Nano-Structure Silicon Anode

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





300% volume expansion upon lithiation

- **18650 3.5-4Ah cells projected by American Lithium Energy, Panasonic, LG, Samsung and Sony (2015-2018).**

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

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

Li-Ion High Voltage Cells

- Li-Ion cell voltages depend on the active materials in use (Cathode/Anodes) and non-active materials like (Separators and Electrolytes)
- A potential solutions for energy storage break through are the high voltage li-ion technologies (>4.35V)
- 4.35-4.45 high charging voltages li-ion cells (with 3.75-3.8V nominal voltage) already available commercially in the market by most of lthe eading players
- 4.5-5V high charging voltages li-ion cells are under development (Metal, Silicon and graphite materials).

High Power (China) 4.45v
cells, 3.72Ah,
772 Wh/l – Mass
production Q3/2016
www.highpowertech.com

INTERNATIONAL HIGHPOWER 豪鹏国际

Envia High Energy Pouch Cell

High Energy Drone Pouch Cells
(ENV35011-CRC)

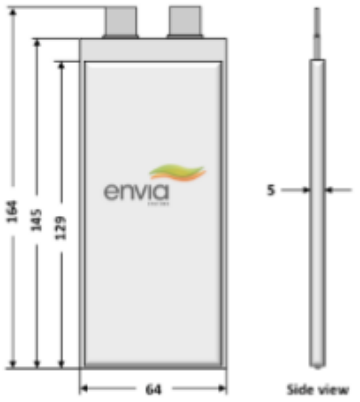
Key Features & Benefits:

- ✓ 350Wh/Kg usable specific energy at C/10 rate
- ✓ 840Wh/L usable energy density (without terrace) at C/10 rate
- ✓ Excellent high voltage (4.47V) stability
- ✓ Proprietary Si-based anode and Cobalt-rich composite (CRC) cathode
- ✓ Low cost

Applications:

- ✓ Unmanned aerial vehicles (UAVs)
- ✓ Flying automobiles
- ✓ Military applications
- ✓ Grid applications

Cell characteristics	Units	Value
Cell capacity at C/10 rate	Ah	10.6
Specific energy at C/10 rate	Wh/Kg	350
Energy density at C/10 rate	Wh/L	840
Cell weight (g)	g	111
Cell dimensions	mm	145 x 64 x 5
Nominal voltage (V)	V	3.65
Operating temperature (°C)	degrees °C	-10 to 55
Voltage range	V	2.5 to 4.47



Approximate dimensions in mm

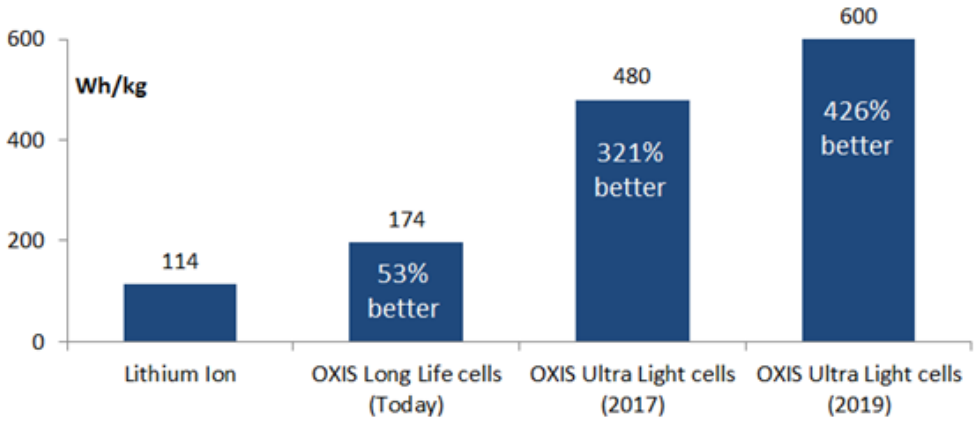
Solid Electrolyte Pouch Cells

Developers:
Toyota
Apple
Samsung
Imprint
Prologium
And 20 more…

- **Higher energy density than Li-Ion (When use Li-Metal anode)**
- **Safety – no flammable electrolyte, No leaks (Ceramic, Dry Polymer)**
- **less Lithium dendrite formation**
- **Can fit any casing shape (soft packaging)**
- **Cells can be made as thin as 0.1 mm or about one-tenth the thickness of the thinnest prismatic liquid Li-ion cells**
- **Low potentially manufacturing cost**
- **Excellent cycling stability**
- **Excellent shelf life**

Lithium Sulfur

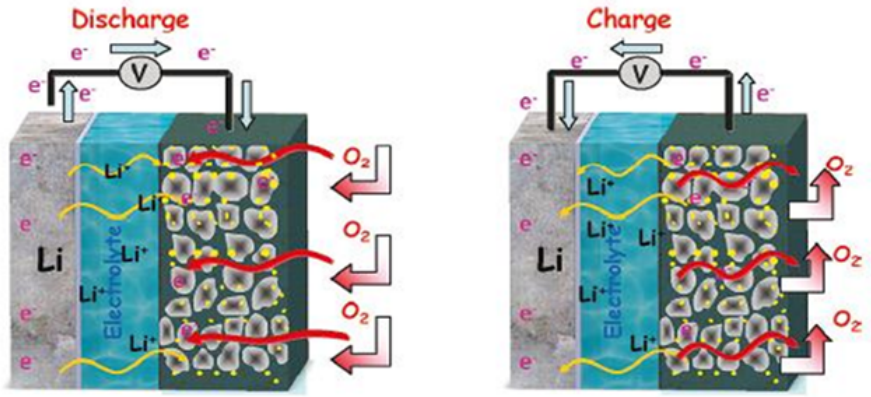
- High theoretical capacity, energy and power density – Expected for practical 300 to 600 Wh/kg
- Sulfur cost is cheap and environmentally safe
- Li-S can provide the break through we are waiting for – but farther development needed
- **Developers:** Sion power (U.S.A.), Eagle-Picher (USA), PulyPlus (U.S.A.), Oxis Energy (U.K.) - Oxis is leading with a 310 Wh/kg pre-production



	Li-S	Li-Ion
Wh/Kg	2500	580
Wh/L	2660	1810

Li-Air Rechargeable - Background

- **Metal Air batteries provide higher energy densities**
  - **Aluminum Air**
  - **Zinc Air**
  - **Silicon Air**
  - **Lithium Air**
- **But these metal air batteries up till now have been primary batteries (non rechargeable or only mechanically rechargeable)**
- **Academics and Industry alike are working on making the lithium air battery rechargeable.**



Shmuel De-Leon
Shmuel De-Leon Energy Ltd
www.sdle.co.il
shmuel@sdle.co.il

Information for presentation obtained by:

1. **Public web sources.**
2. **Shmuel De-Leon Battery/Energy Sources DataBase ® (Includes 29000 cell PDF data sheets) http://www.sdle.co.il/Default.asp?sType=0&PageId=45580**