

# Electro-mobility is not a dream anymore. We reach the highways with promising technologies



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**In the framework of INREP  
Israel National Research center  
for Electrochemical Propulsion  
23 research groups, 6 Israeli prominent  
institutions**



**Many thanks to my faithful  
and diligent research group  
at Bar-Ilan university**

**In collaboration with:**



**Prof. Yang-Kook Sun  
Hanyang university  
South Korea**

# The need

**U.S. Oil-dependence is  
Driven by Transportation**

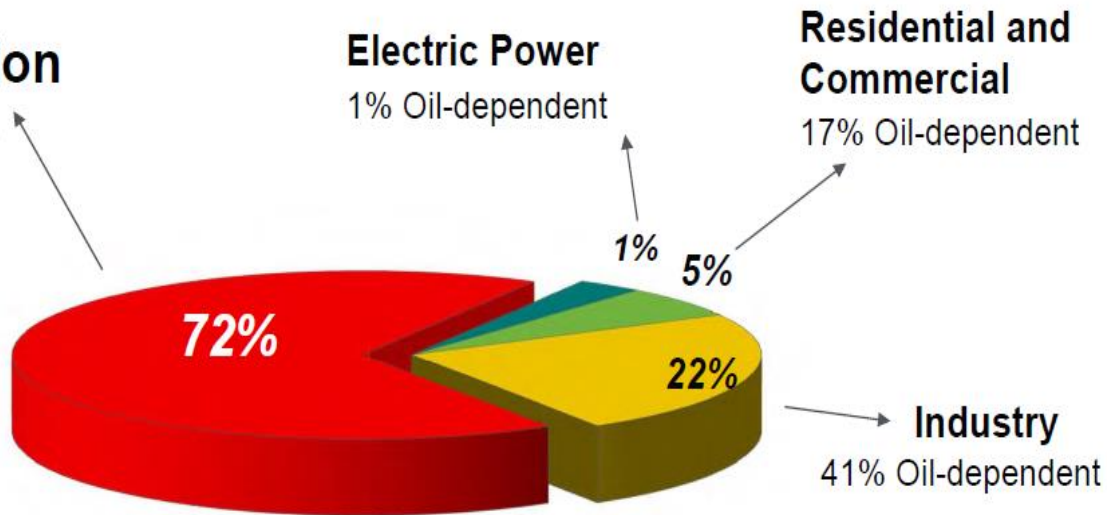


U.S. DEPARTMENT OF  
**ENERGY**

## Transportation

94% Oil-dependent

- On-road vehicles are responsible for ~80% of transportation oil usage



- Global warming
- Environmental pollution
- Geopolitics
- Oil prices & Instability





# Israel National Research center for Electrochemical propulsion

23 research groups from top 6 Israeli universities

Annual meeting, April 30<sup>th</sup> & May 1<sup>st</sup> 2018



**Prof. Doron Aurbach (S.C. ,head)**

**Prof. Arie Zaban**

**Prof. Dan Major**

**Prof. Ilya Grinberg**

**Prof. David Zitoun**

**Dr. Daniel Nessim**

**Dr. Adi Salomon**

**Dr. Lior Elbaz (S.C.)**

**Dr. Malachi Noked**



**Prof. Yair Ein-Eli (S.C)**

**Prof. Yoed Tsur**

**Prof. Zeev Gross**

**Prof. Dario Dekel**

**Prof. Slava Freger**

**Prof. Matthew Suss**



**Prof. Emanuel Peled (S.C.)**

**Prof. Dina Golodnitsky (S.C.)**

**Dr. Amir Natan**

**Dr. Sharly Fleischer**

**Dr. Brian Rosen**



**Prof. Menny Shalom**



**Dr. Michal Leskes**



**Prof. Alex Schechter**

## INREP international board

Jean Marie Tarascon (College de France, Paris, France), Peter Bruce (Oxford U. ,UK), Martin Winter (Muenster U., Germany), Linda Nazar (Waterloo U., Canada), Khalil Amine (ANL, USA), Piotre Zelenay (LANL ,USA) ,Sanjeev Mukerjee (NEU, Boston, USA), Andreas Fischer (BASF, Germany)



## INREP Research Topics

**INREP intends to fulfil a major goal of the Israeli Government in the field of energy:**

**Israeli science & technology should raise a significant contribution to release the world from dependence in petroleum.**

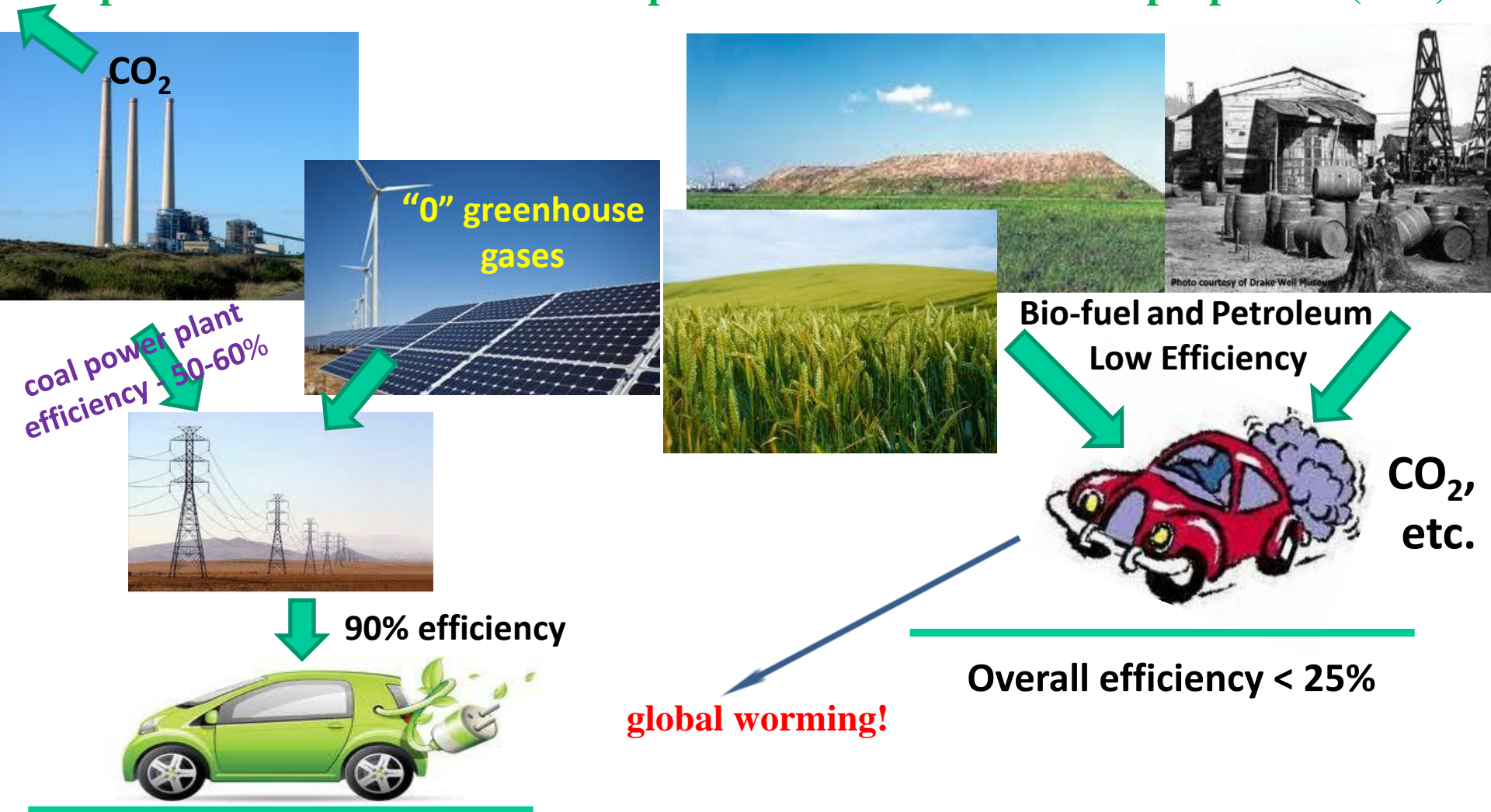
**Consequently, INREP develops power sources for electro-mobility.**

- **Developing most advanced research methodologies: computational, analytical electrochemical tools.**
- **Advanced cathode materials for high energy density Li ion batteries.**
- **New high capacity Li-Si-C anodes**
- **Li-oxygen, Li-sulfur, Na ion, metal (Na,Zn,Al) - air battery systems.**
- **Wide potentials liquid and solid electrolytes for advanced batteries.**
- **Advanced super-capacitors.**
- **Hydrogen/oxygen fuel cells designed for electric vehicles.**



# Why Electro-mobility?

The petroleum alternative for transportation is electrochemical propulsion (EVs).



**Overall efficiency > 40%**

We should switch propulsion energy sources from petroleum to electricity.

In parallel, power stations operated by combustion of coal, will be gradually replaced by sustainable energy sources: wind turbines & solar panels

# The (full) Electric Vehicle challenge

we want to drive normal cars, the cars makers are very conservative.



**So, we can install batteries that weigh no more than 300-500 Kg (150-250 L)**

An EV battery comprises many single cells connected in series and in parallel to form modules. The modules form high voltage/high capacity via the BMS (battery management system)

Single cells



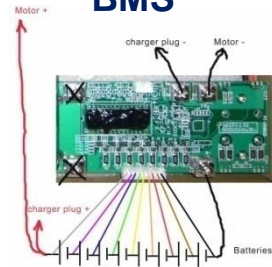
+

Module



+

BMS



=

Full battery  
220V, 30-50 kWh



Relevant Li ion battery technology:  
graphite-  $\text{Li}[\text{NiCoMn}]\text{O}_2$  Ni > 80%  
**because of safety, cycle life....**  
150Wh/Kg per a single cell!

**In the full battery level  
The energy density is  
Up to 120 Wh/Kg**

**We can expect 40K – 80K Wh  
Up to 500 km between  
charges.**

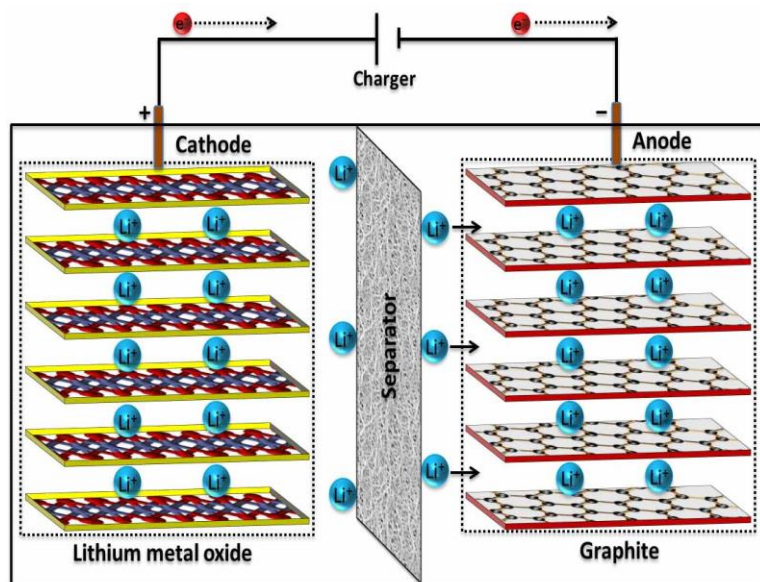
**We can use range extenders: small ICE, turbines, primary (recyclable Al-air batteries)**

**Li ion batteries are the right technology for electro-mobility.**  
**We can stay with modified graphite anodes.**  
**Cathodes are the key factor, determining the energy density.**

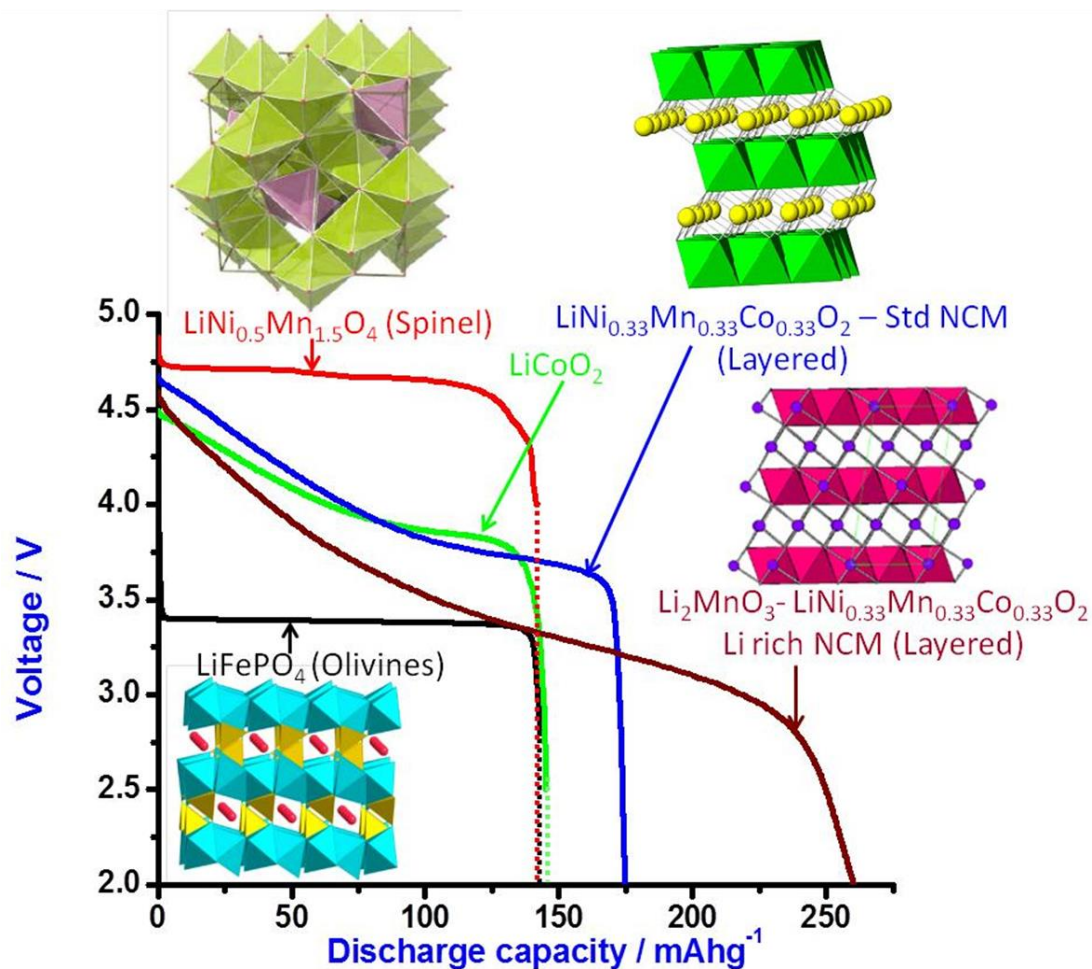


## Main types of positive electrodes (cathodes)

### A Scheme of Li ion batteries



**The positive electrodes (cathodes) are the limiting factor for energy**





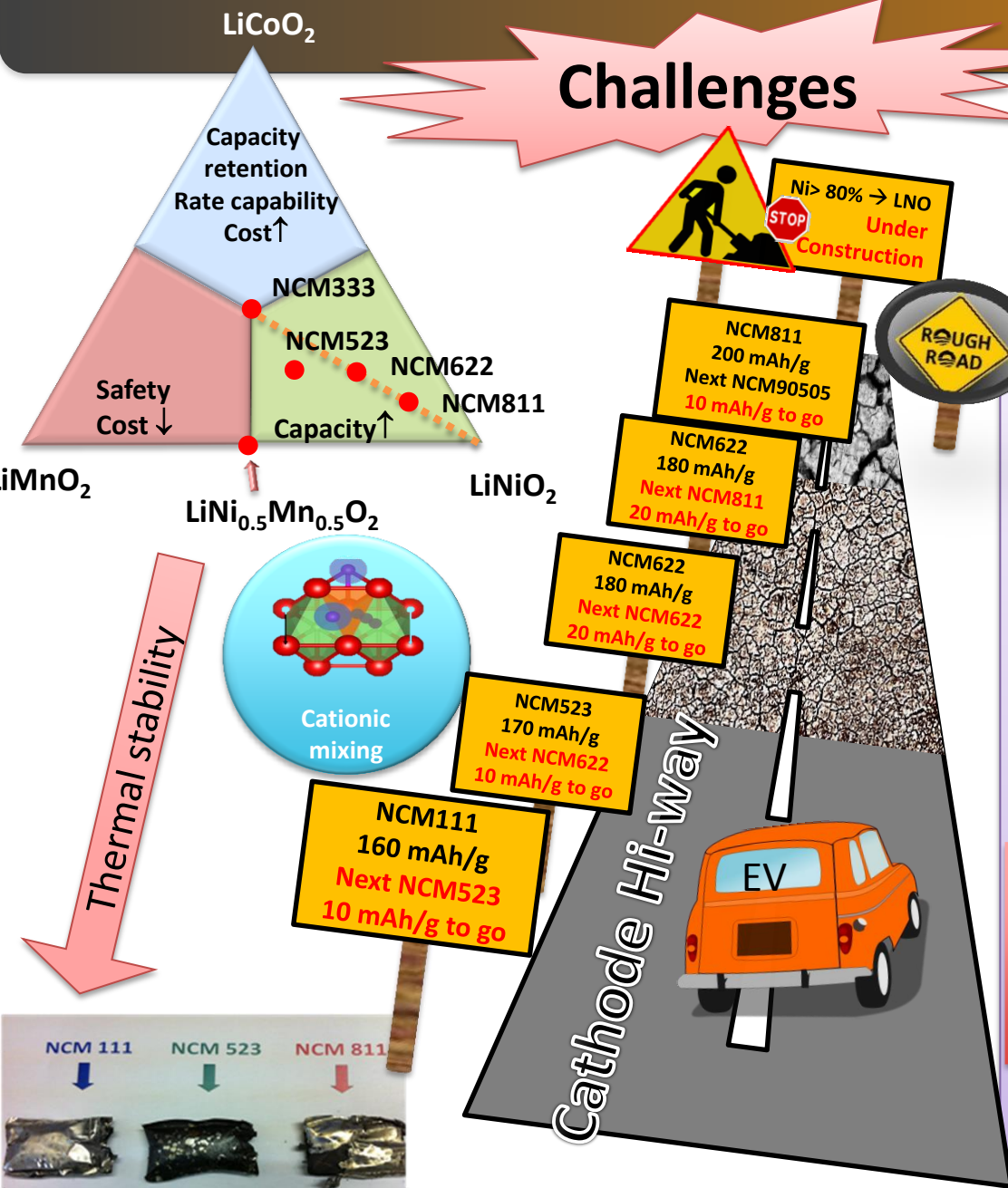
# Ni rich Li[NiCoMn]O<sub>2</sub> ; Ni → 100% is the winning cathode materials



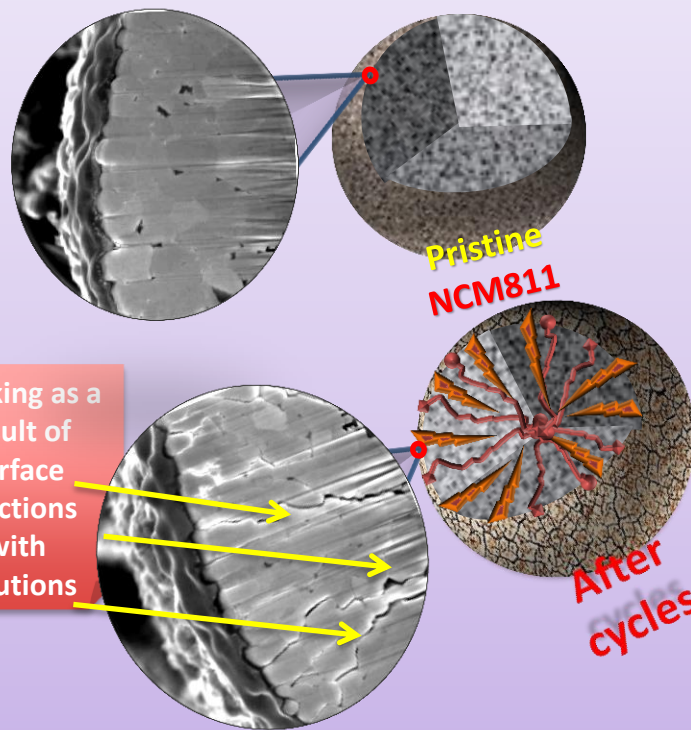
## Challenges

High Ni content >50% leads to unstable performance of NCM cathodes.

Interactions with EC-EMC/LiPF<sub>6</sub> solutions result in side reactions with highly reactive Ni-O surface.

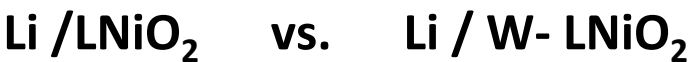


## Cross-sectional SEM view of cracks formed due to cycling of NCM811

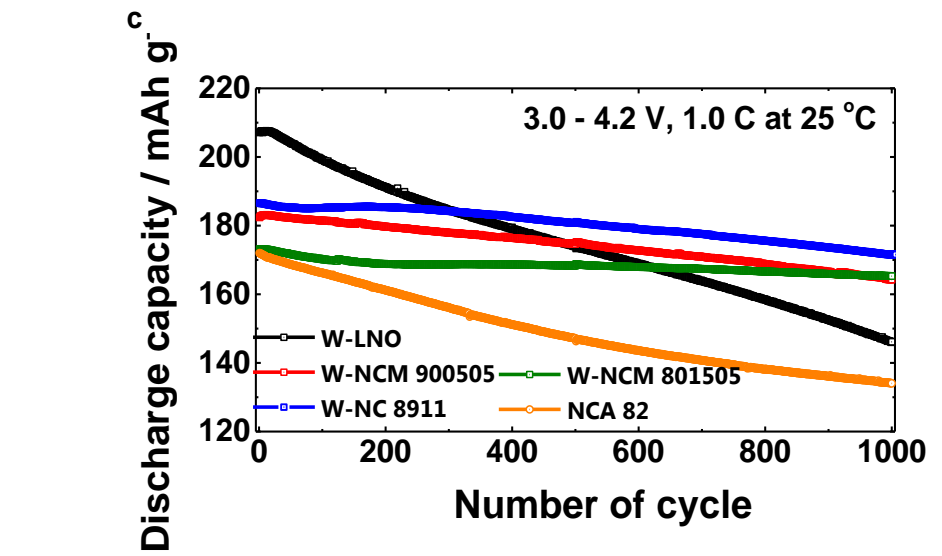
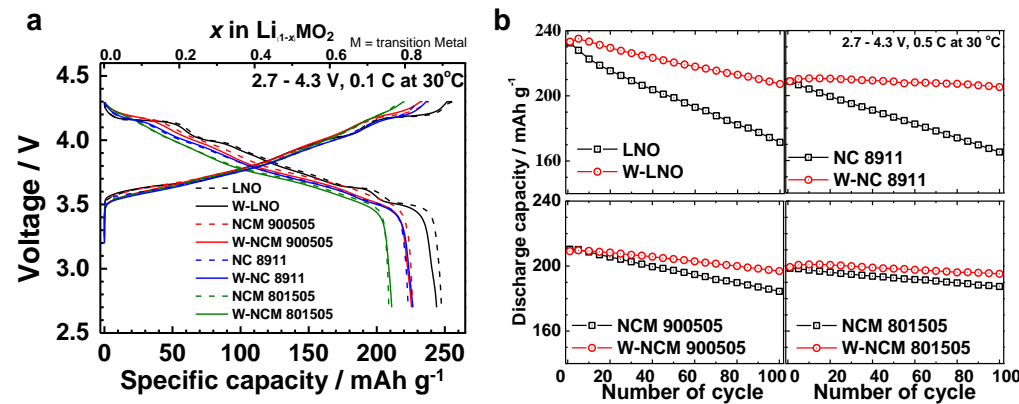




Doping by some foreign elements stabilizes Ni rich NCM

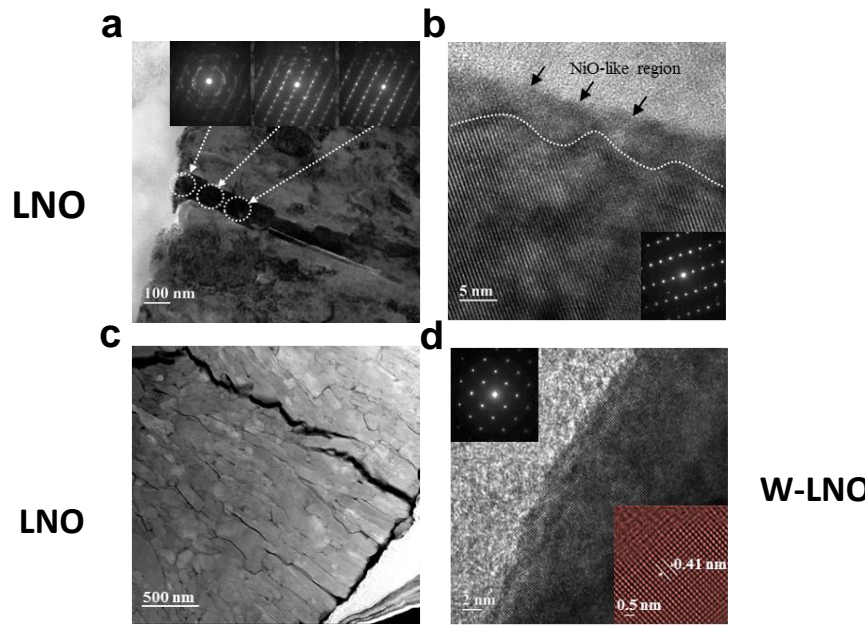
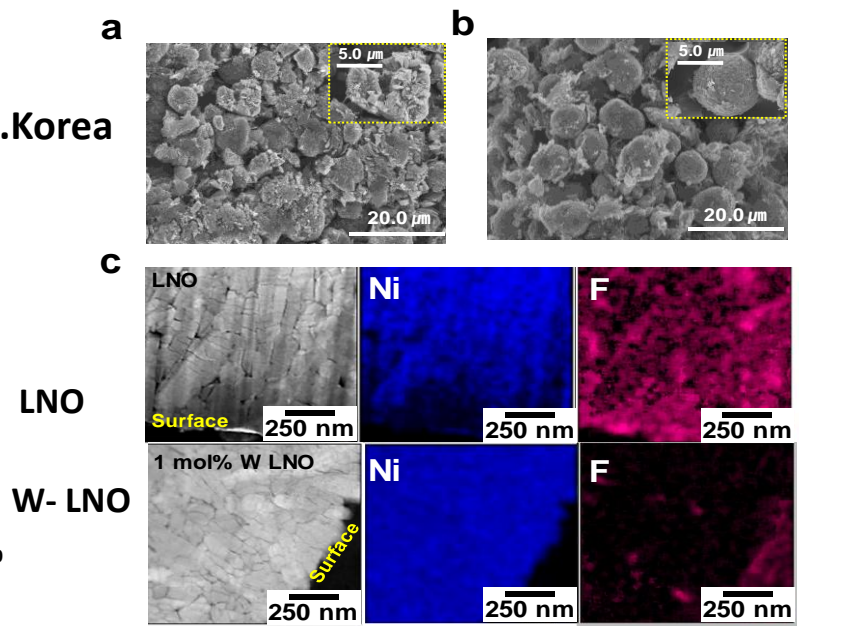


In collaboration with Prof. Y.K. Sun Hanyang Univ. Seoul, S.Korea



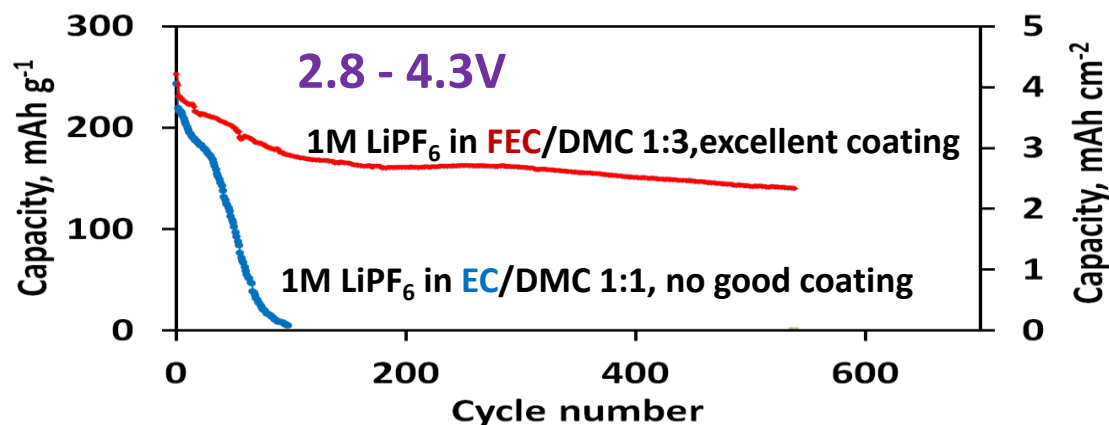
graphite/LNO and graphite/Ni-rich NCM cells

cycled LNO electrodes      cycled W-LNO electrodes

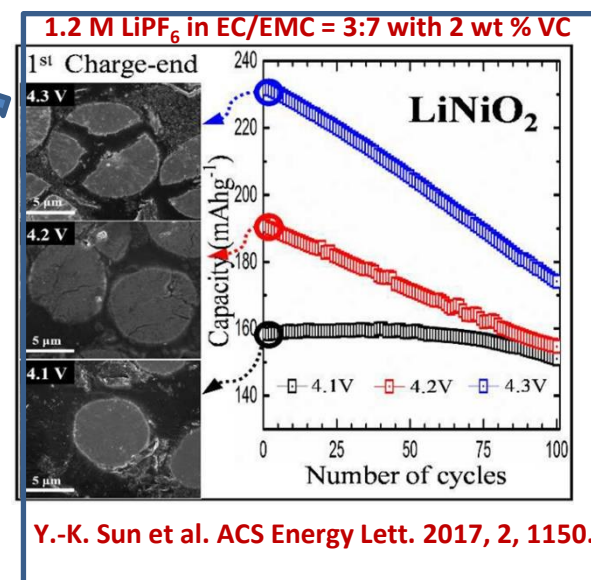
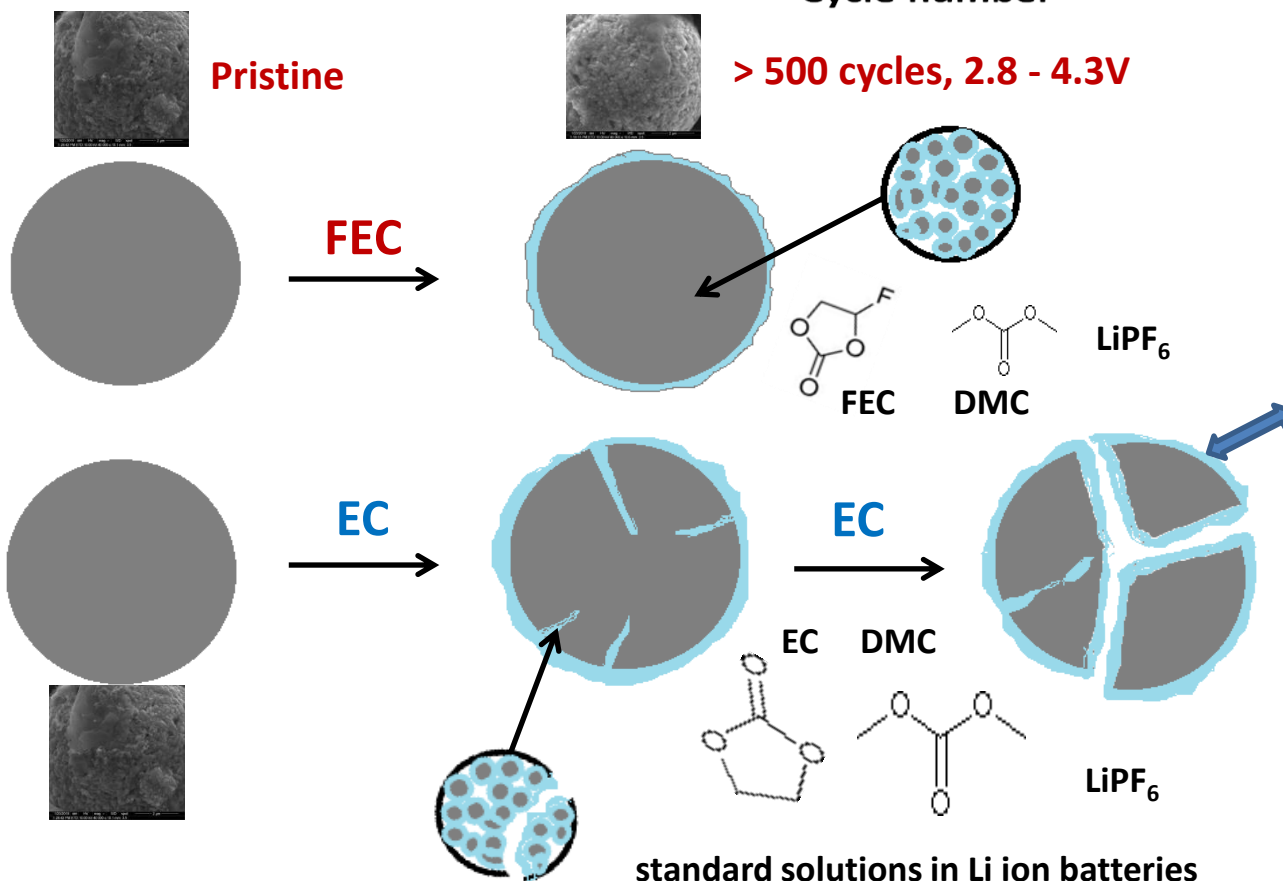


# We can win by applying protective coatings

Li batteries  
LiNO<sub>2</sub> cathodes  
Practical loading,  
3mAh/cm<sup>2</sup>  
➤ 300 Wh/Kg  
Practical



We explore the most promising positive electrodes



**Next challenge: to use renewable energies instead of fossil fuels: oil, coal, in order to reduce global warming.**

**The world energy consumption is around  
17-18 TW**

### **Biomass**

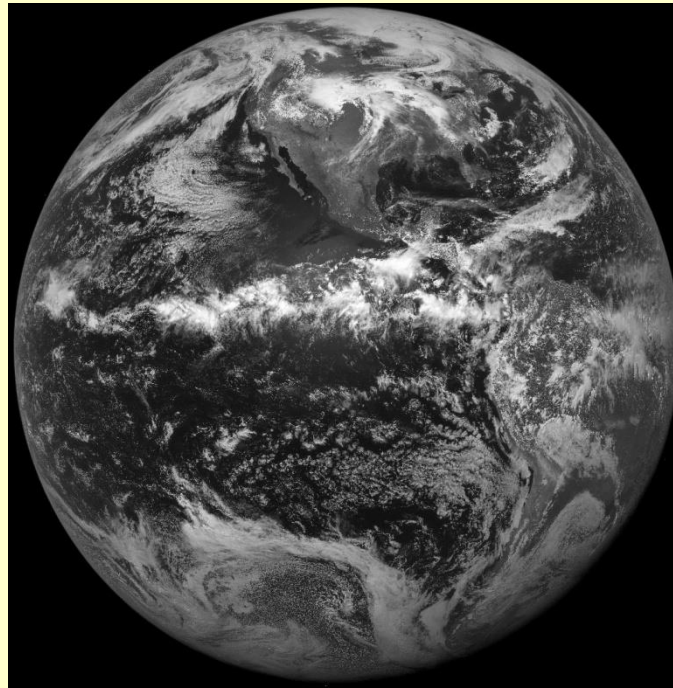
50% of all cultivatable land: 7 TW (**H<sub>2</sub>O**)

### **Wind**

Gross: 50 TW  
Economic: 3 TW  
Installed: 0.08 TW

### **Solar**

potential  $1.2 \times 10^5$  TW  
**practical 600 TW**



### **Hydroelectric**

Gross: 4.6 TW  
Economic: 0.9 TW  
Installed: 0.6 TW

### **Geothermal**

Gross: 12 (+30 ocean)  
Economic: 2 TW  
Installed: 0.01 TW



# On the global energy challenges:

We do not have a real energy crisis. We have enough coal for electricity production for the next millennium. We suffer from energy related crises: environmental problems due to the use of fossil energy sources, the green house effect, global warming due to evolution of gases such as  $\text{CO}_2$ . Hence, there is a strong incentive to move faster to sustainable energy sources.

The world's current power supply needs several TW

**Main sustainable energy sources: Wind & Sun**

**Wind: Up to 4-5 TW theoretical  
20% from it practical.**



**Storage !!**

We lack  
Suitable  
Energy  
storage  
Technologies.

We need  
rechargeable  
batteries  
for load  
leveling  
applications.

Can Li ion  
battery  
technology  
contribute to the  
storage of  
sustainable  
energy?

**Main solar power sources: Solar - photo thermal**



**Solar – photovoltaic**

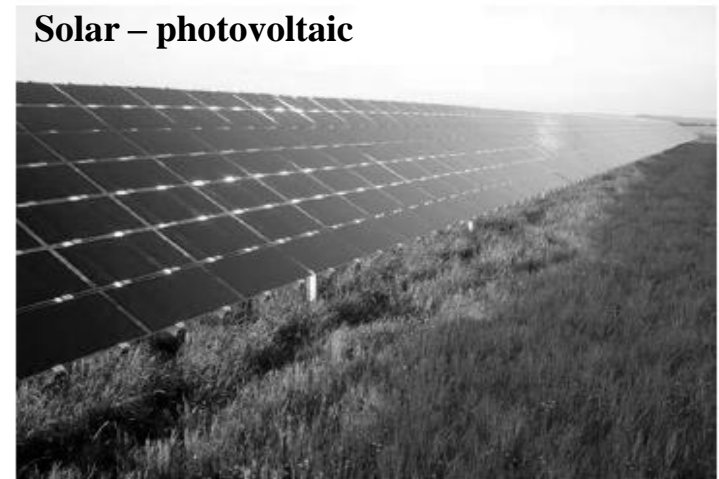


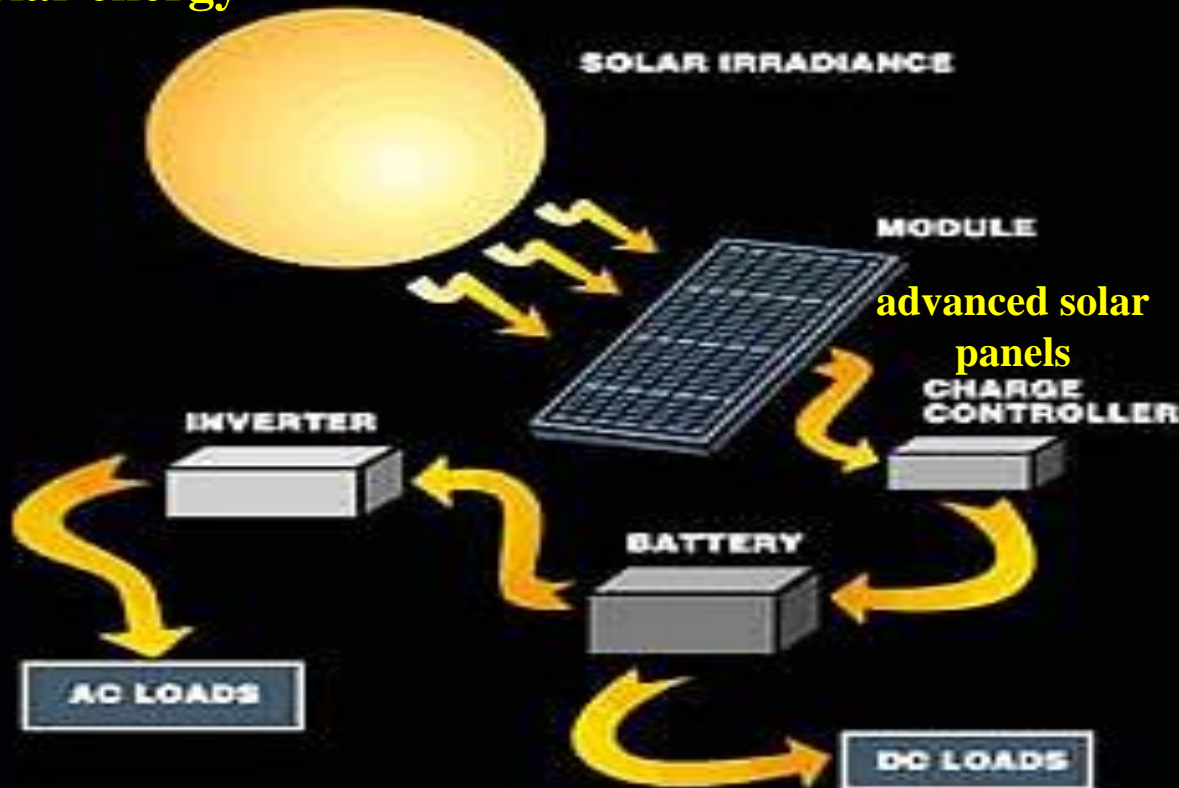
Figure 13.12. Part of a large multi-megawatt array.

**Solar energy: unlimited! Hundreds of TW theoretical**

## Our dream:

**Develop effective autonomous electricity supply for hundred millions of people that have no connection to the grid. We intend to promote Israeli industry that will produce completed energy solutions.**

### Solar energy



We develop at BIU rechargeable battery systems for large energy storage based on abundant and cheap elements:

- Sodium
- Manganese
- Carbon
- Oxygen
- Nitrogen
- Aqueous electrolytes



**Many millions of potential customers wait anxiously to our energy solutions:  
solar panels with appropriate long term energy storage technologies**





# Conclusions:

1. **Electro-mobility : not a dream! It is real by advanced Li ion batteries. We have now a solid ground: graphite anodes + Ni rich  $\text{LiNi}_x\text{Co}_y\text{Mn}_y\text{O}_2$  ( $x \rightarrow 1$ ) cathodes. We can promise long distance driving.**
2.  $\text{H}_2/\text{O}_2$  fuel cells are becoming highly important power sources for electro-mobility. Major challenges: high durability and cost effective catalysts & membranes.
3. **Next great challenge: Large energy storage for grid applications. We can offer very good battery technologies. A key issue – using devices based on most abundant elements.**
4. Israeli science and technology can contribute a lot to fields of energy and power sources for both electro-mobility and load-leveling, grid applications.
5. **We hope that our developments will promote elaboration of creative Israeli energy industry that will provide global solutions for off-grid populations.**

Thank you very much for your kind attention.