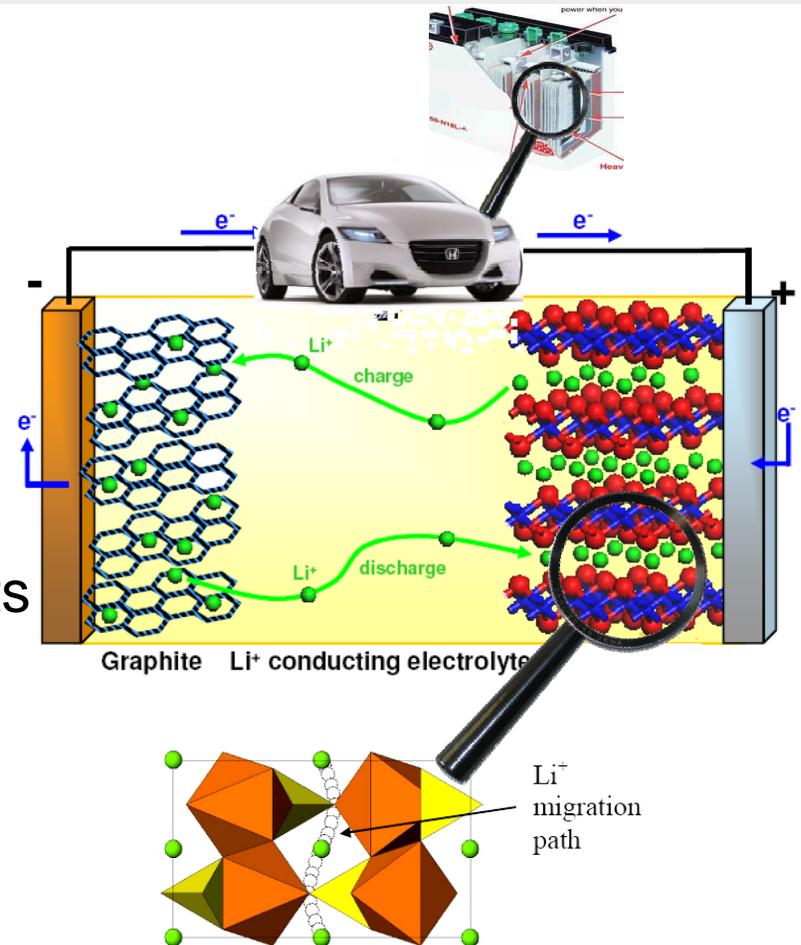


# **Lithium-Ion Batteries for Electric Cars: Opportunities and Challenges**

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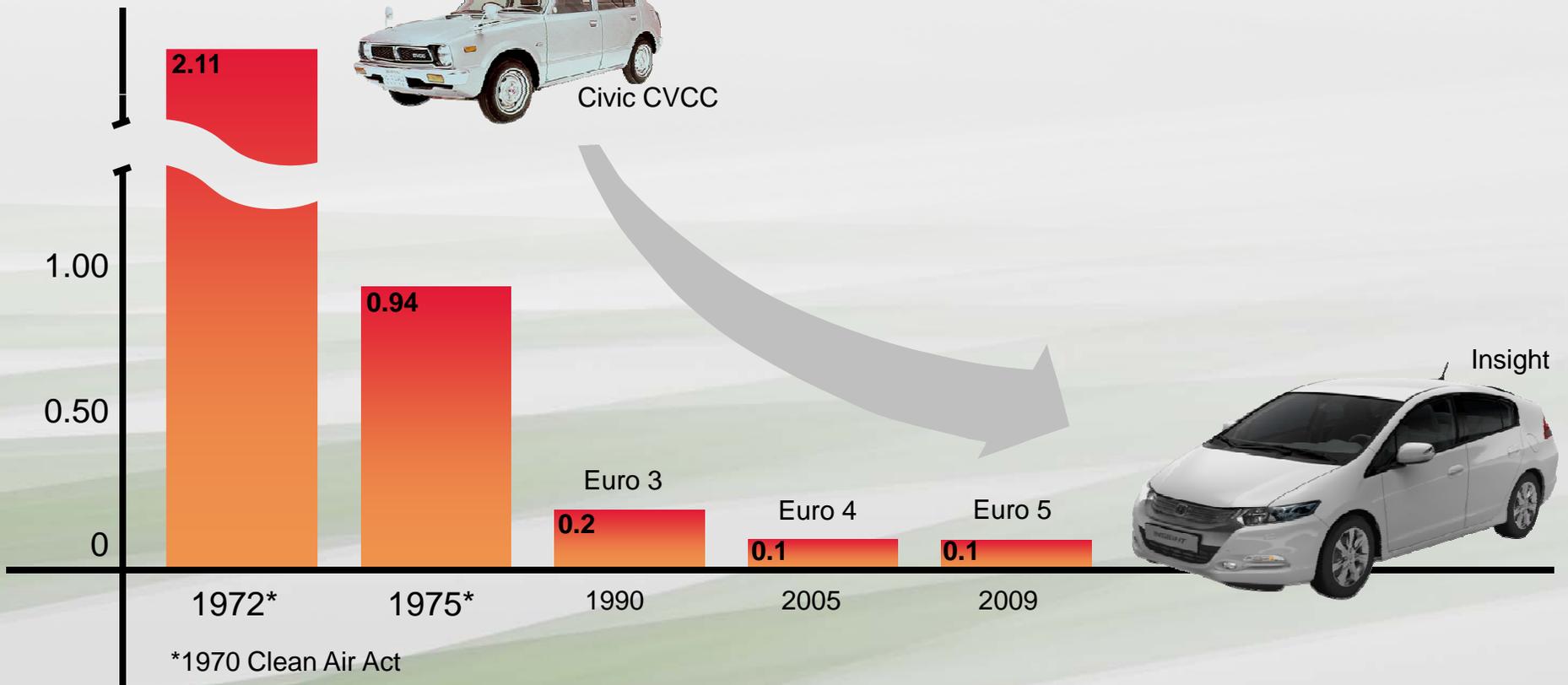
19.01.2010

- Introduction
- Li-Ion technology
- Future development and requirements
- Conclusion

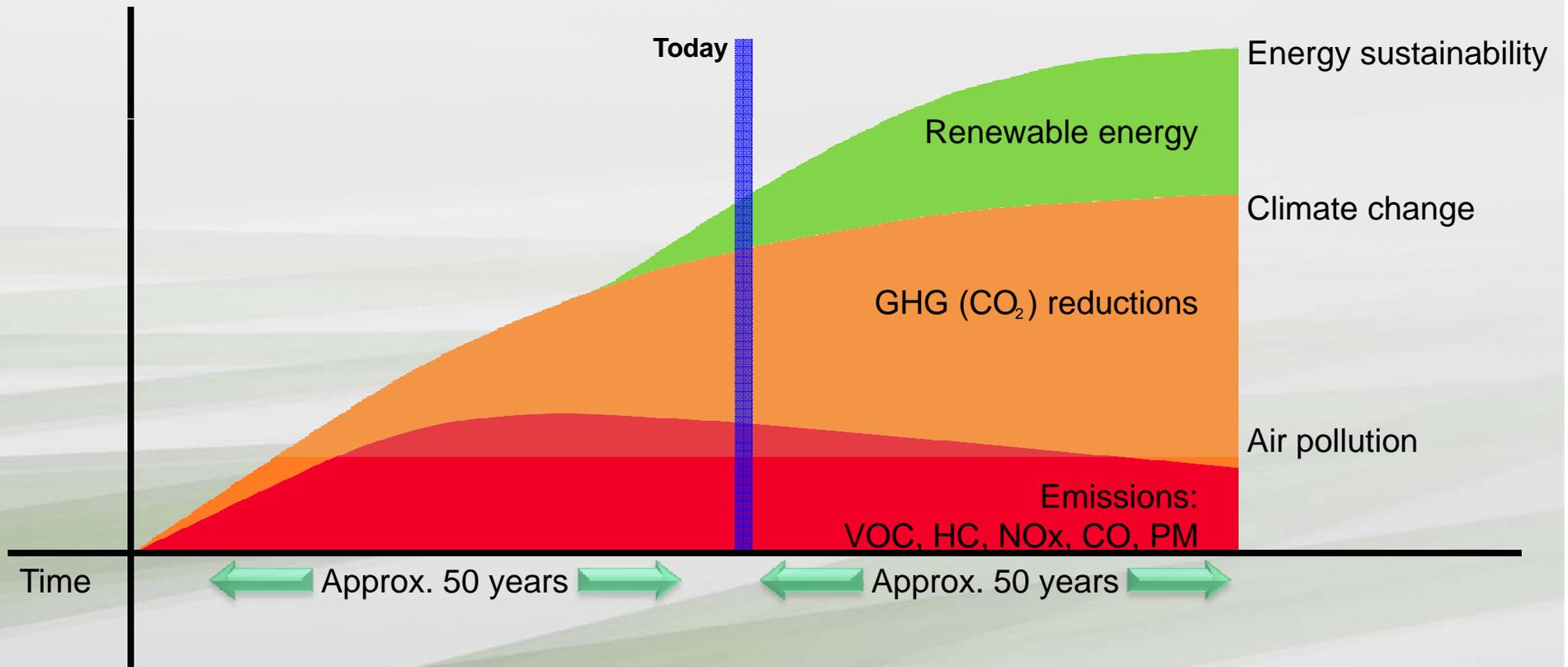


## Emission reduction

HC standard  
[g/km]



Focus is shifting from emissions to GHG (mainly CO<sub>2</sub>) and Energy

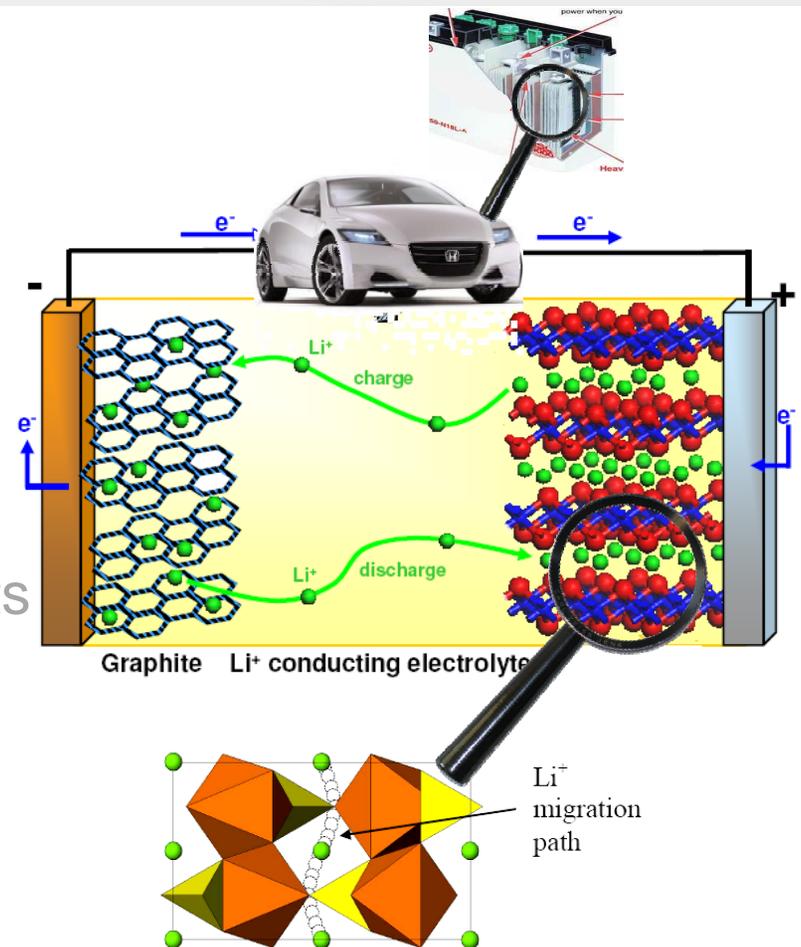


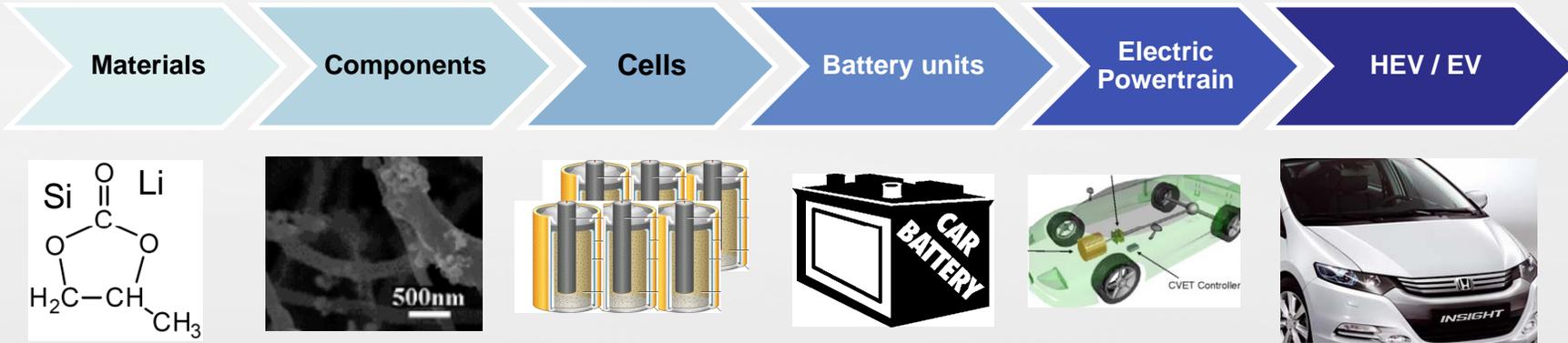
□ Introduction

□ Li-Ion technology

□ Future development and requirements

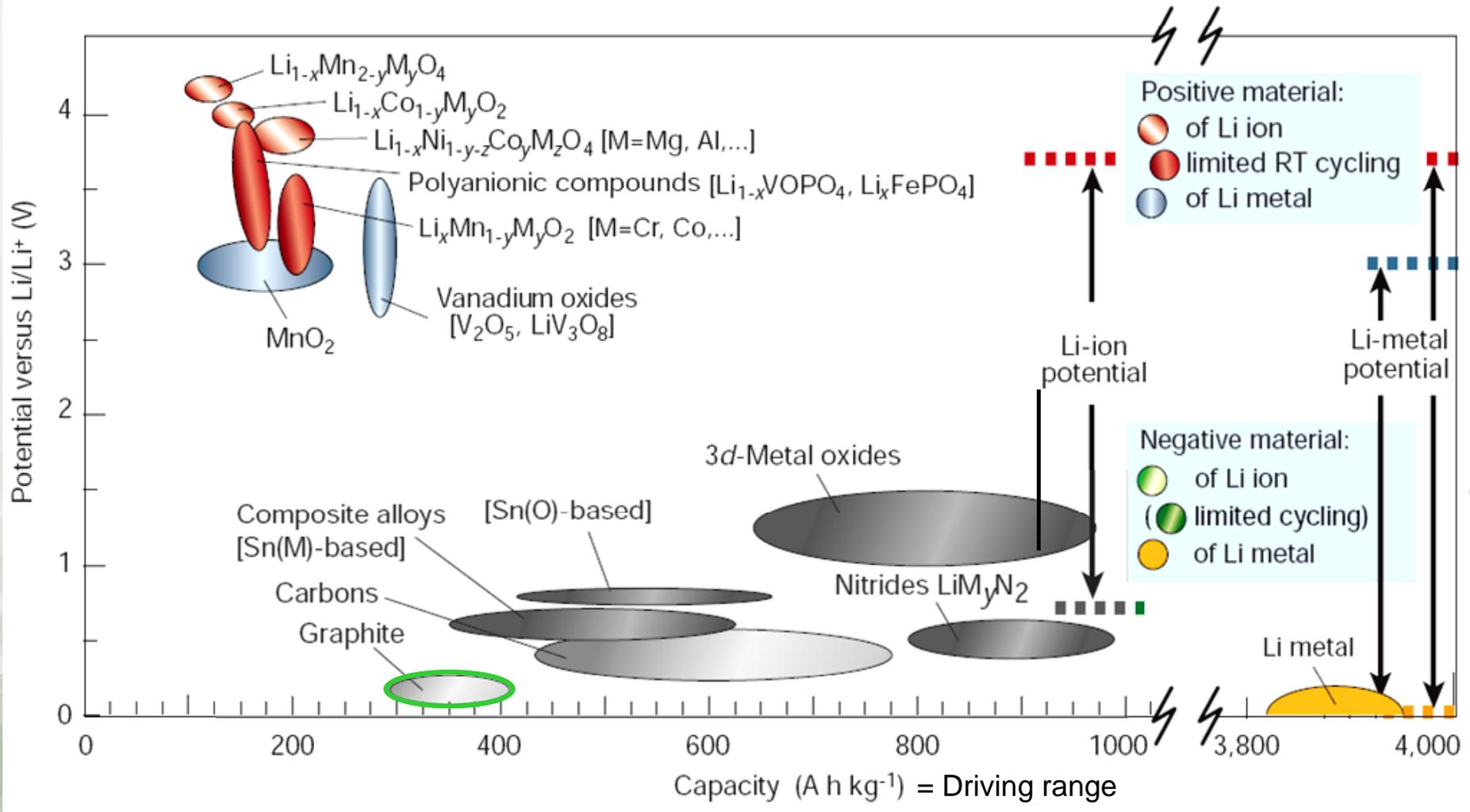
□ Conclusion





Application	EV Battery	HEV Battery (+ Engine)
Vehicle with the same weight and size	 <b>300 kg</b>	 <b>30 kg</b>
	Low Power per battery cell	<b>High Power</b> per battery cell
	<b>High Capacity</b> for driving range	Low Capacity / use of engine
	Discharge / Charge 1C – 3C	<b>Fast Discharge</b> / Charge More than 10C

Electrode Materials



Source: Nature 414, 359-367, M. Armand & J.-M. Tarascon.

There exist many different possible arrangements for high capacity batteries but performance, reliability, safety and cost must fulfil the customer demand.

❑ Characteristics of lithium-ion batteries using various chemistries

Chemistry Anode/cathode	Cell voltage Max/nom.	Ah / g Anode/cathode	Energy density Wh/kg	Cycle life (deep)	Electrode material \$/kg Anode/cathode	Electrode material cost \$/kWh	Thermal stability
Graphite/ NiCoMnO <sub>2</sub>	4.2 / 3.6	0.36 / 0.18	100-170	2000-3000	12/25	48	Fairly/ stable
Graphite/ Mn spinel	4.0 / 3.6	0.36 / 0.11	100-120	1000	12/8	30	Fairly/ stable
Graphite/ NiCoAlO <sub>2</sub>	4.2 / 3.6	0.36 / 0.18	100-150	2000-3000	12/25	48	least/ stable
Graphite/ LiFePO <sub>4</sub>	3.65 / 3.25	0.36 / 0.16	90-115	<b>&gt;3000</b>	12/20	<b>49</b>	stable
Li-titanate/ Mn spinel	2.8 / 2.4	0.18 / 0.11	60-75	<b>&gt;5000</b>	25/8	<b>88</b>	most stable

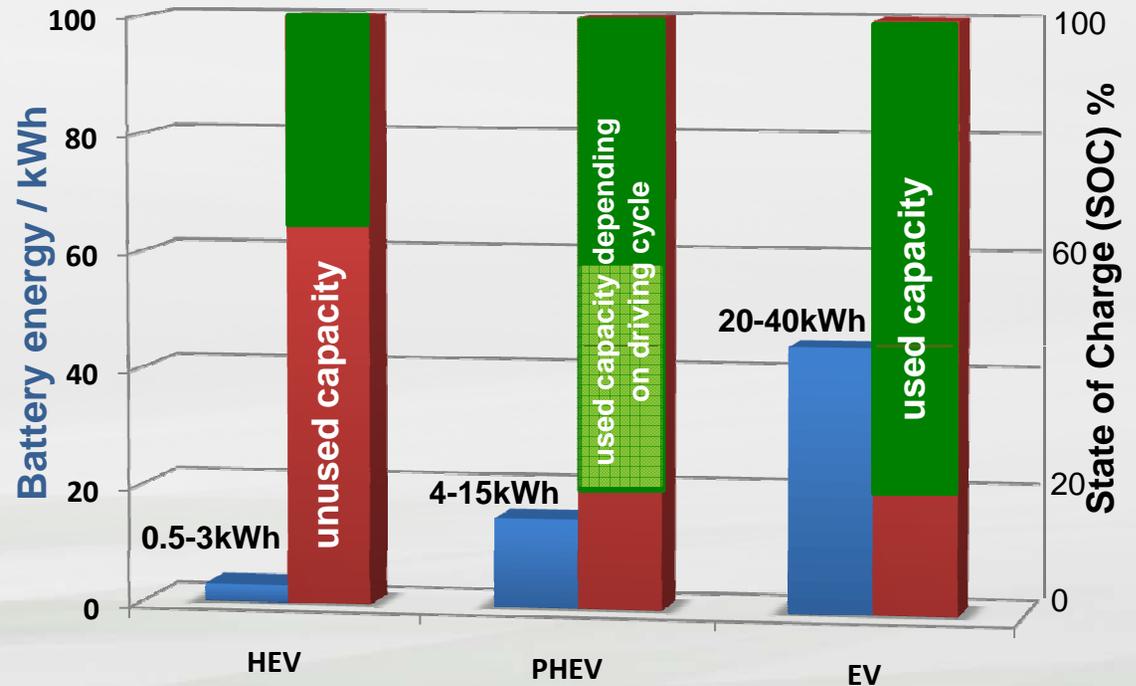
Source: EVS24 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium, A.Burke, M.Miller

- What fraction of energy density is useable in a specific vehicle application?
- How to increase relative advantage of different chemistries?
- How much is return on investment?

**Cycle life goals for batteries**

**HEV** : 300,000 shallow cycles  
**PHEV (CD mode)**: 5,000 deep cycles  
**PHEV (CS mode)**: 300,000 shallow cycles  
**EV**: 1,000 deep cycles

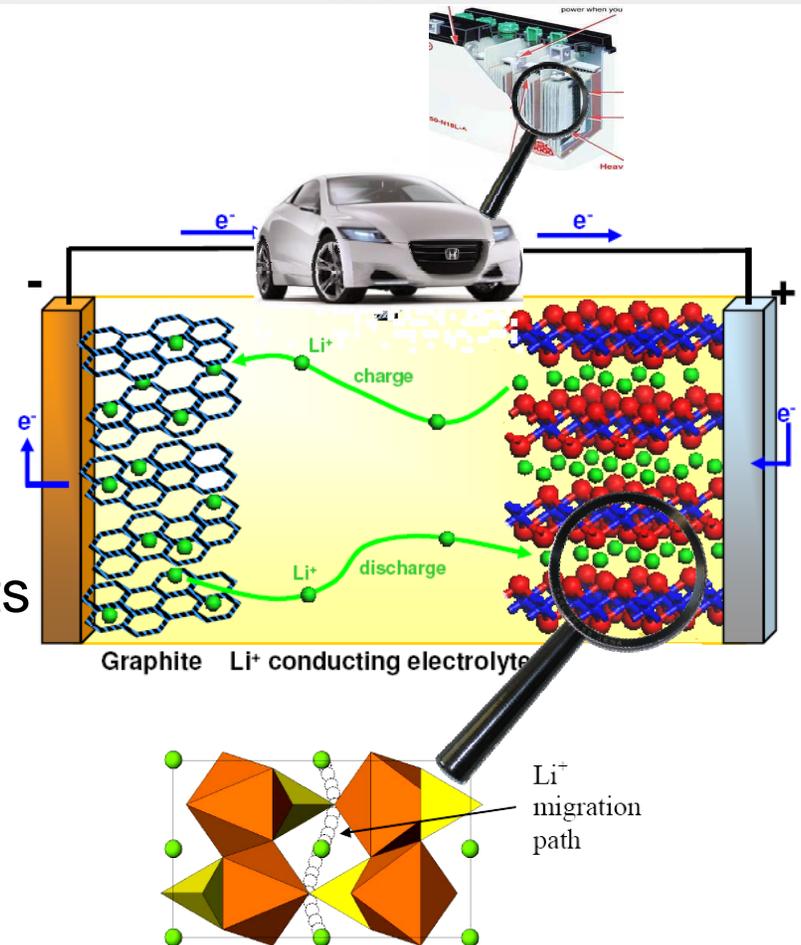
- ✓ High energy density
- ✓ High power density
- ✓ Calendar lifetime
- ✓ Good safety
- ✓ Low cost
- ✓ Material availability
- ✓ Recycling



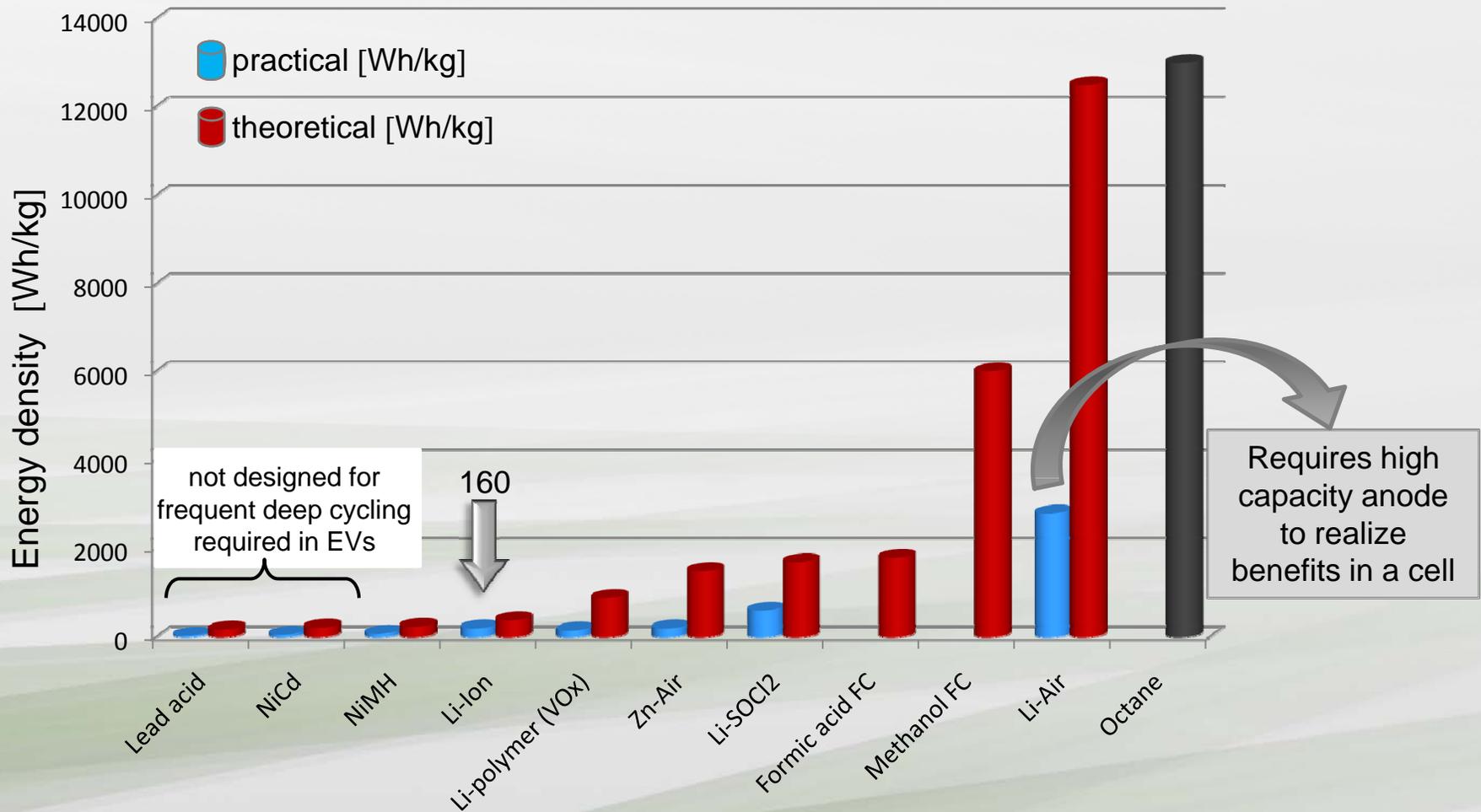
Different requirements guide the choice of the battery chemistry!

Currently, there is no unique material that meets all needs equally well!

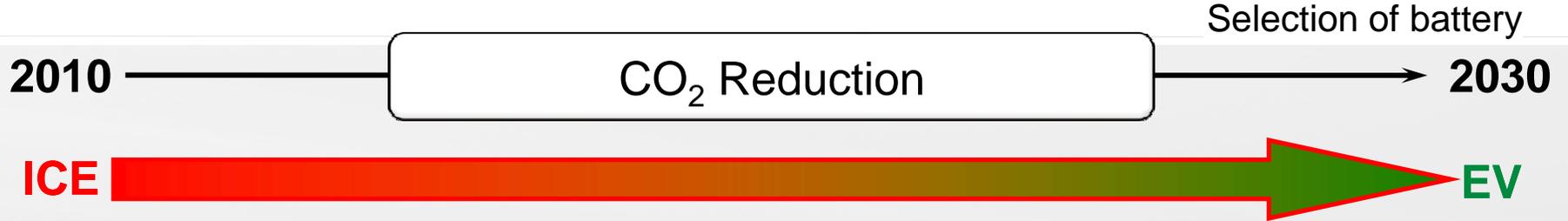
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## Energy density comparison of common technologies



Huge difference between theoretical and practical energy density  
There is a strong need for further research!

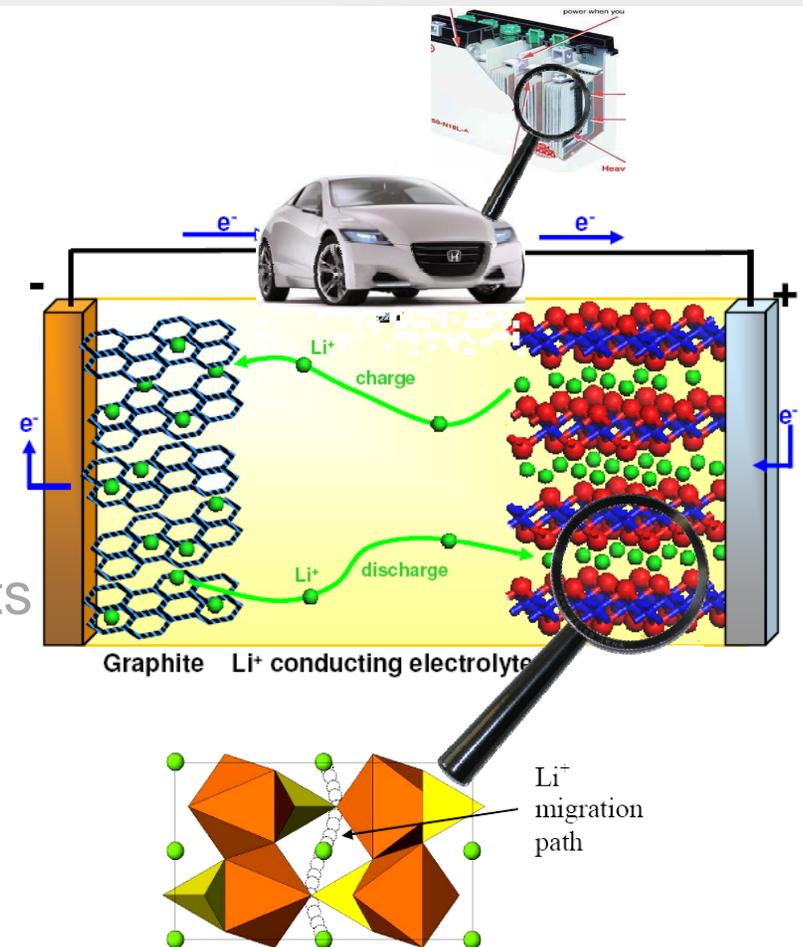


Hybrids	Plug-in-Hybrids / ICE Range Extender				Pure EV
Do small HEVs need Li?	C/LiM <sub>2</sub> O <sub>4</sub>	C/Li <sub>2</sub> MSiO <sub>4</sub>	New anode / New cathode	Li(Si) – S Li(Si) – air	Fuel cell (still a hybrid)
	C/LiFePO <sub>4</sub>	Titanate chemistry		Zn – air	Range extender EV

Upscaling of lithium batteries requires further R&D:

- reasonable driving distance (energy density)
- safe energy storage system with acceptable size and weight
- better recharging time
- lower production costs

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## Conclusion

- ❑ Li-ion is currently the dominating technology for EV/PHEV
- ❑ Li-based chemistry provides higher energy densities compared to existing commercially available batteries.
- ❑ There is strong need to
  - increase specific capacity by optimizing cell chemistry
  - improve battery lifetime by enhanced stability of electrode materials
  - reduce the costs
- ❑ Customer driving style influences battery performance (life time, driving range)

**HONDA**



Speedometer background changes color

ECO guide  
(Multi-information Display)

eco GUIDE

Y Y Y | |

■ | ■

B2345.6 miles

30°C

# Eco Guide

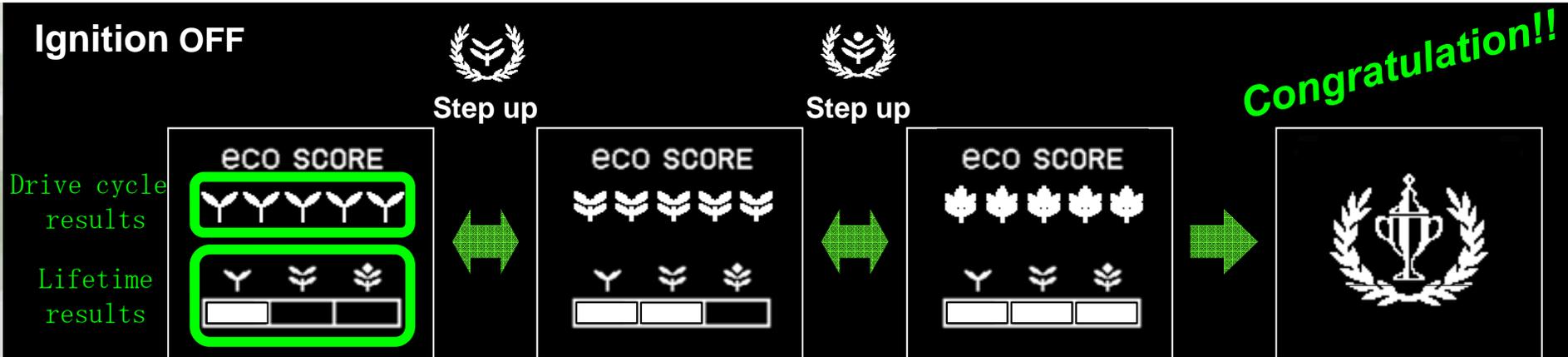
## Scoring Function

provides feedback about current driving practices, as well as feedback on cumulative, long-term fuel-efficient driving.

### Driving



### Ignition OFF



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