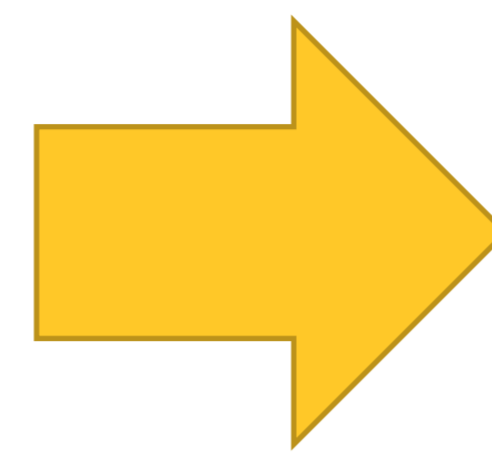


1. Introduction

“Electric cars will remain mostly niche products until they have a range of 800 kilometers, or roughly 500 miles, with an affordable battery.”

- Dr. Winfried W. Wilcke (Senior Manager IBM Research Center)



Research for alternative battery systems with more storage capacity and affordable prices is necessary. Only with a breakthrough in battery technologies, electric vehicles have a better chance on the mass market.

2. Three Future Batteries

Lithium-Air

- Lightweight electrodes
- High energy density
- Solid electrolyte interface
- Affordable materials
- Air preparation is necessary
- Dendrite growth → bad cycling, low lifetime
- Charging overpotential

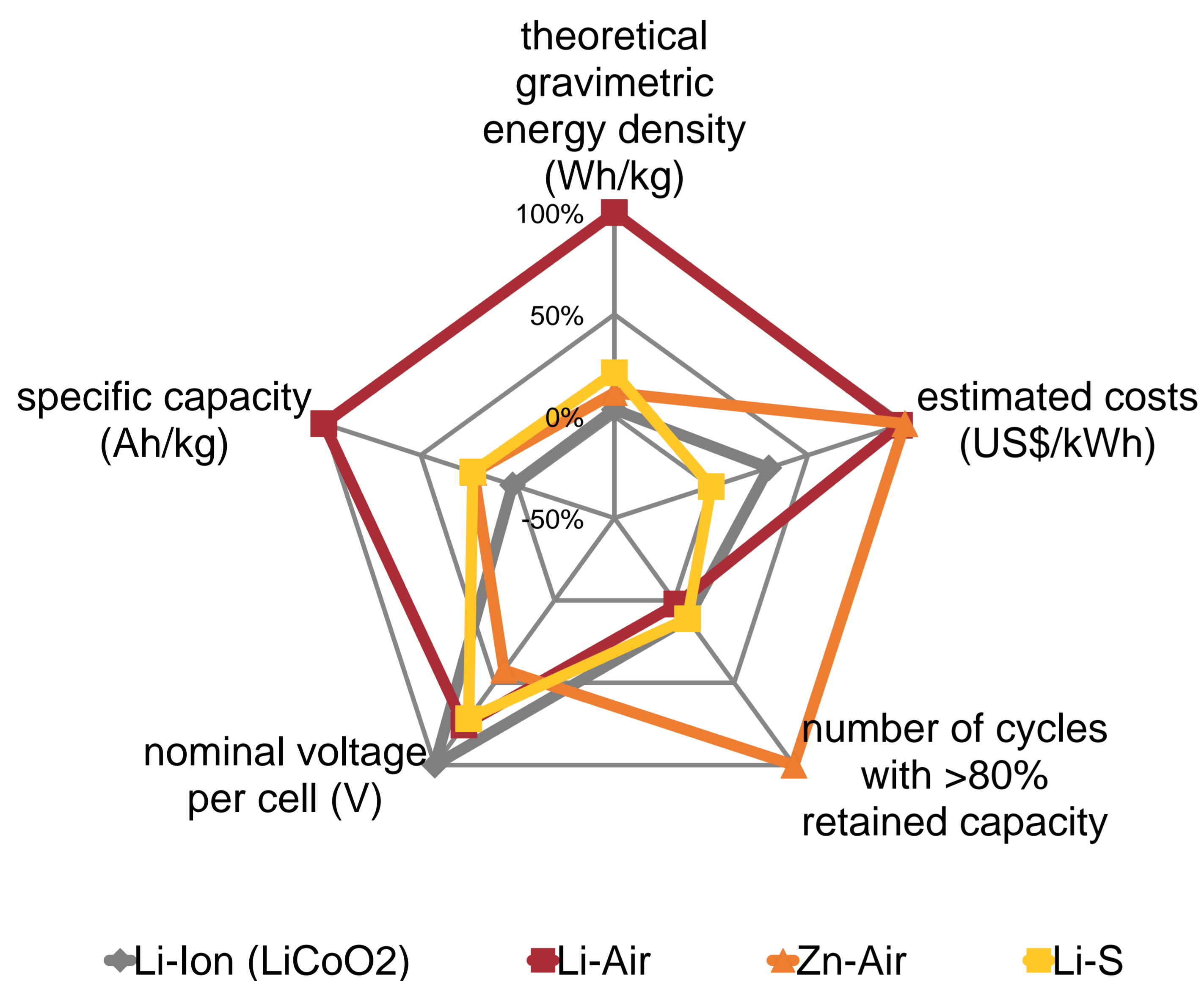
Zinc-Air

- Long life
- Non-inflammable
- Non-toxic
- Recyclable components
- Low costs
- High energy density
- Dendrite growth
- Shape change → loss of usable capacity
- Hydrogen evolution

Lithium-Sulfur

- High energy density
- Non-toxic
- Non-inflammable
- S seventeenth richest element in the earth
- S is an electrical insulator
- Volume expansion of S
- Many requirements for the electrolyte

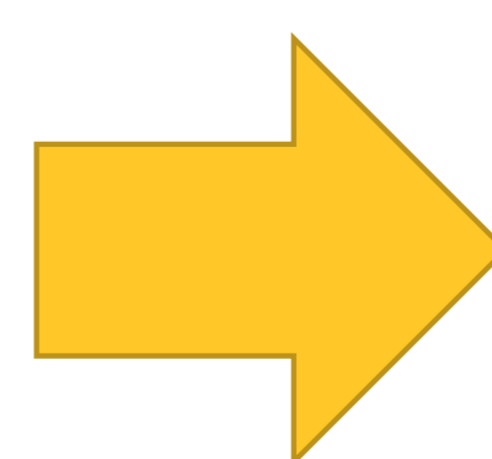
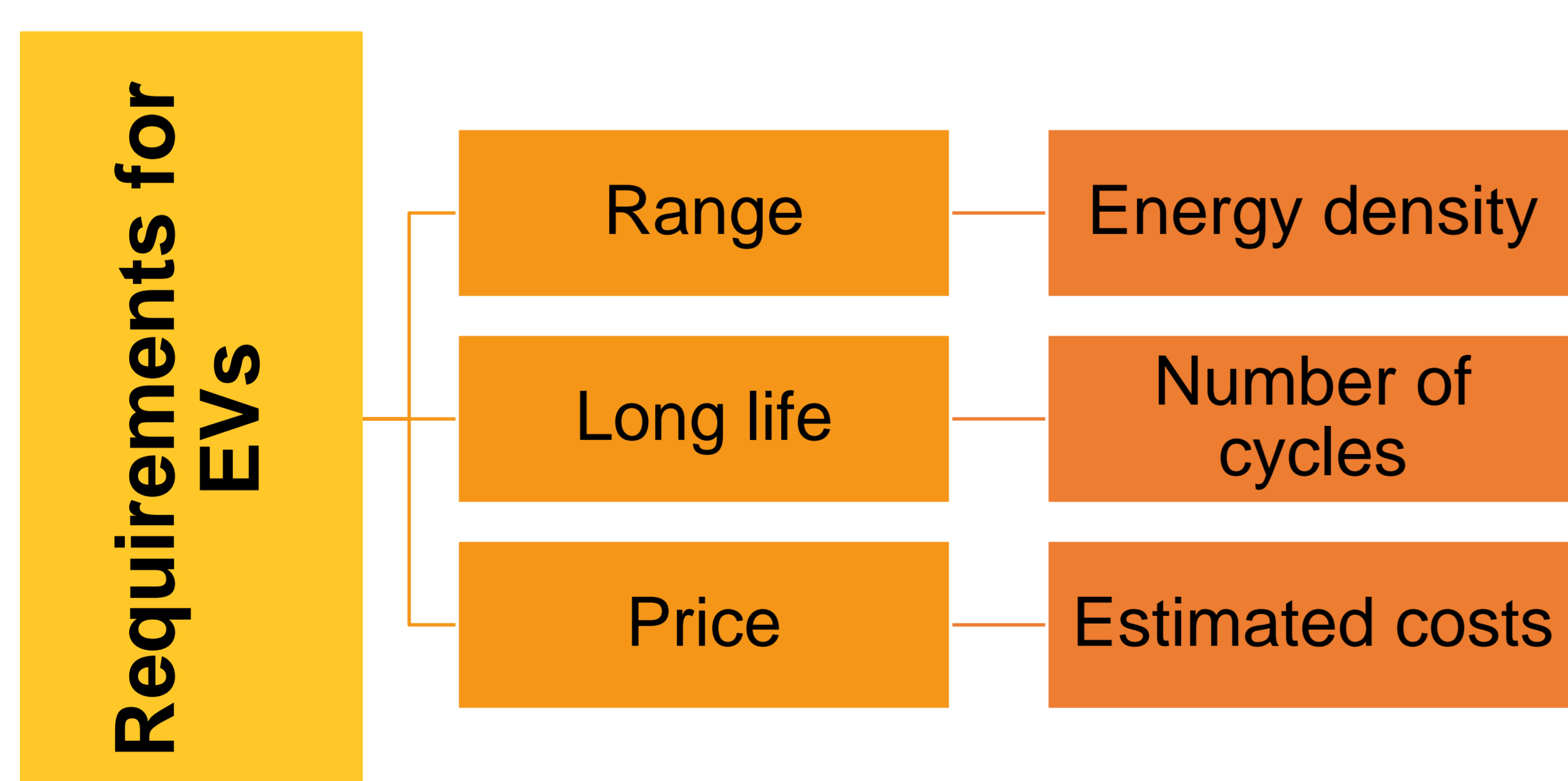
3. Comparison



Battery type	Lithium Ion	Lithium-Air	Zinc-Air	Lithium-Sulfur
Theoretical gravimetric energy density	387 Wh/kg	11700 Wh/kg	1350 Wh/kg	2500 Wh/kg
Theoretical volumetric energy density	570 Wh/l	6170 Wh/l	6091 Wh/l	2800 Wh/l
Estimated costs	195 \$/kWh	70-200 \$/kWh	65-135 \$/kWh	250 \$/kWh
Cycles with >80% retained capacity	1000	200	9000	1000
Theoretical specific capacity	99 Ah/kg	3860 Ah/kg	873 Ah/kg	893 Ah/kg ¹
Safety	-	0	+	+

¹ Value calculated with specific capacity = theoretical gravimetric energy density / nominal voltage

4. Conclusion



Lithium-air, zinc-air and lithium-sulfur batteries seem to have a high potential for the future and could replace lithium ion batteries prospectively. Nevertheless, the constant development of reliable batteries with more storage capacity and affordable prices is crucial for electric vehicles and energy storage in general.