Så bra kommer våra batterier att vara 2030!

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Energiledarkonferensen: Så räddar tekniken oss till 2030 !
Solna, 12 november 2009

Så mycket
större/kraftfullare/billigare/säkrare/”grönare”
kommer våra batterier att vara 2030!

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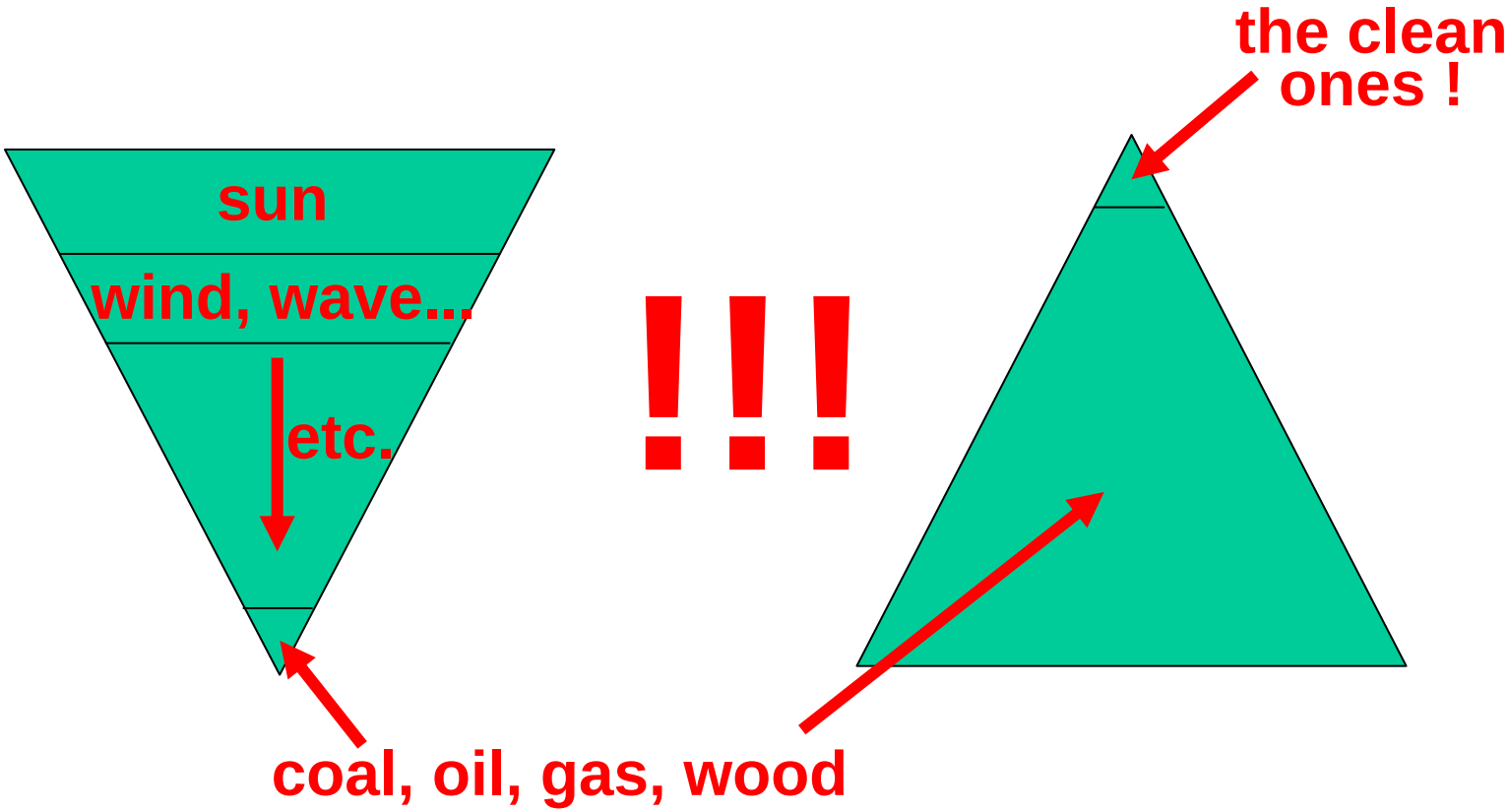
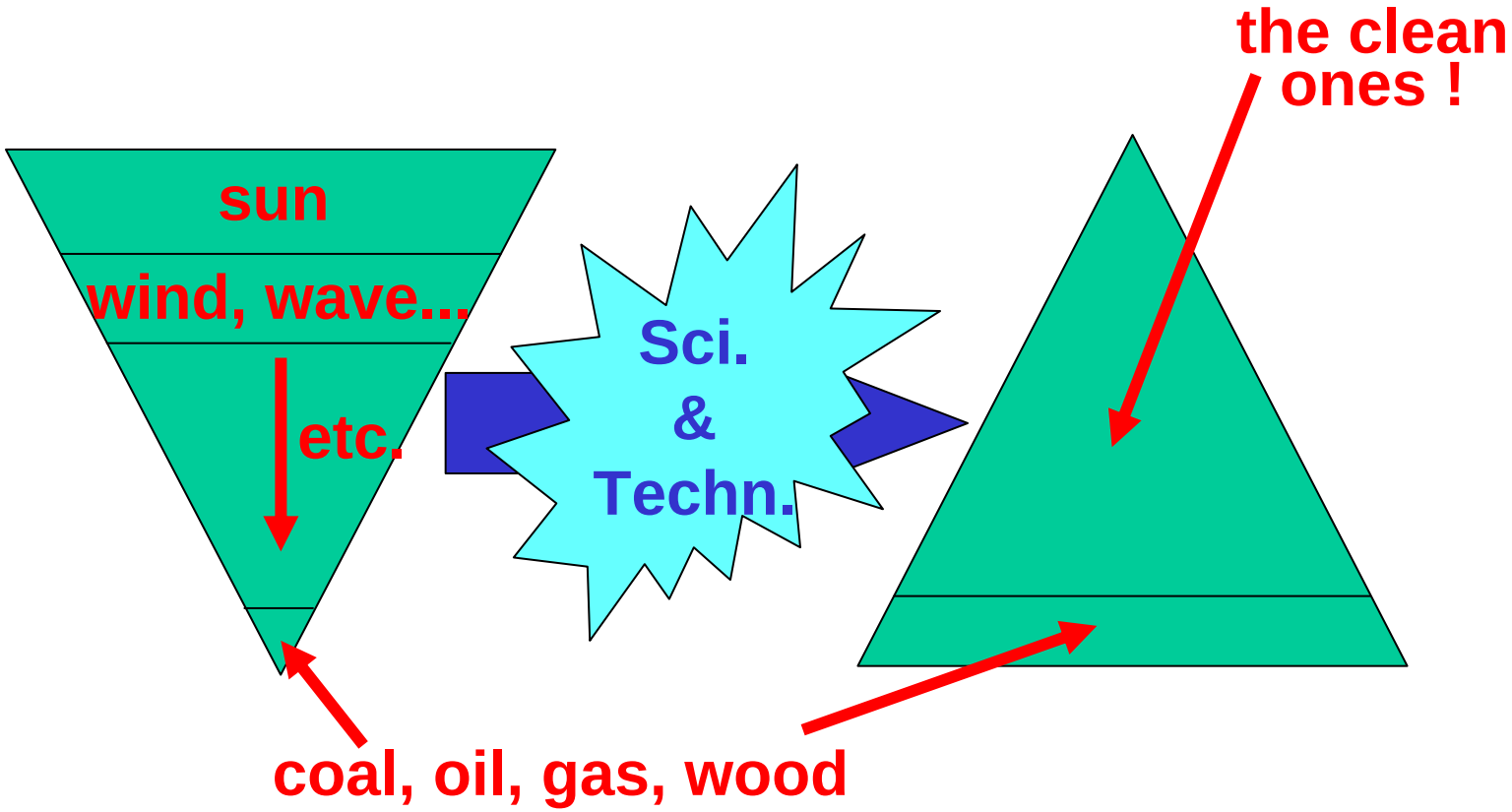
Energiledarkonferensen: Så räddar tekniken oss till 2030 !
Solna, 12 november 2009

What's wrong in our World today ?

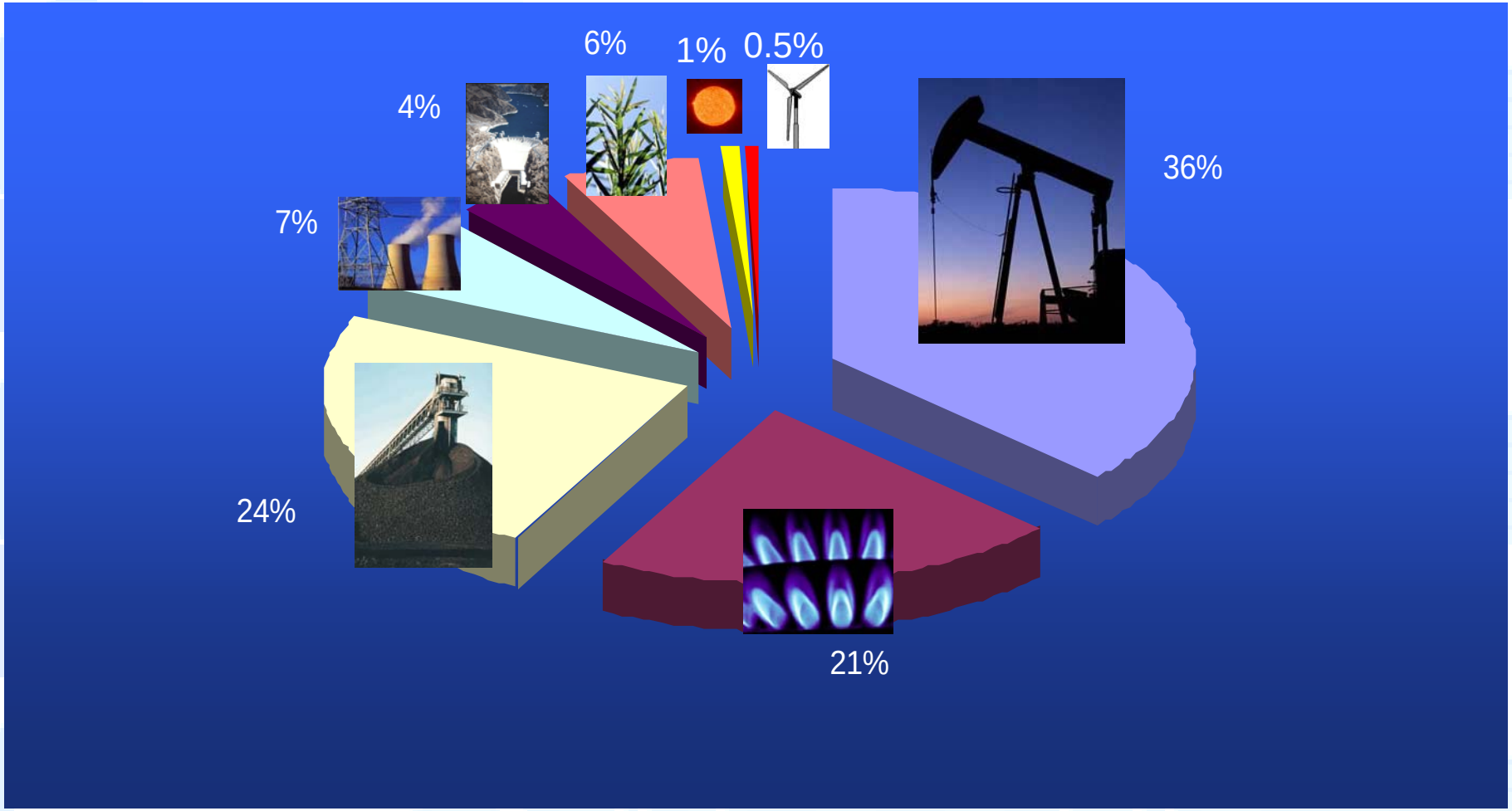


And how can we put it right ?

Re: ” Så räddar tekniken oss till 2030 ! ”



Energiformer i världen idag



De vanligaste är de smutsigaste !

How can batteries help ?

Clearly – we must invest in RENEWABLES !

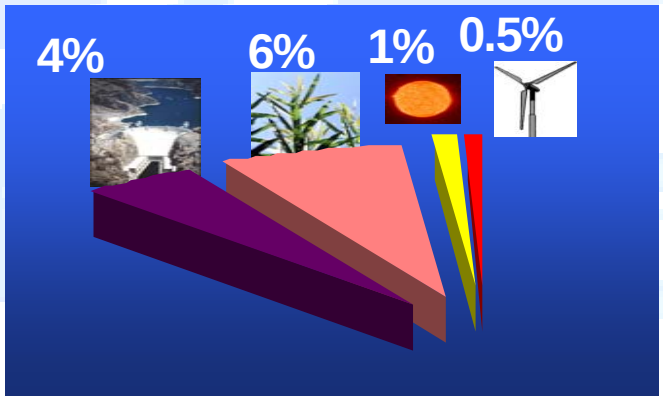
BUT ... the wind doesn't blow every day, nor does the sun shine on demand – or at night !

An indisputable future scenario:

Renewable E-sources

+ efficient E-conversion

+ E-storage



renewable E-sources

+ fuel-cells + batteries

Today's (Li-ion) battery research focusses on:

- cheaper, larger, safer, greener (Li-ion) batteries with higher energy- and power-densities

→ 1. EV/HEV:s

Transport

→ 2. Quality grid-power (the "smart grid")

Grid power

→ 3. "Uninterruptible Power Supply" (UPS) systems

From renewable E-sources →

Wind

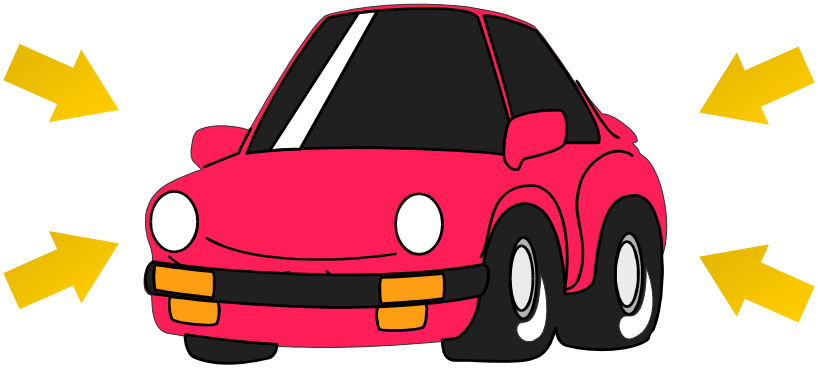
Sun

Wave

Bilen = miljöboven !!!!

Storstadsskalan

Globalskalan

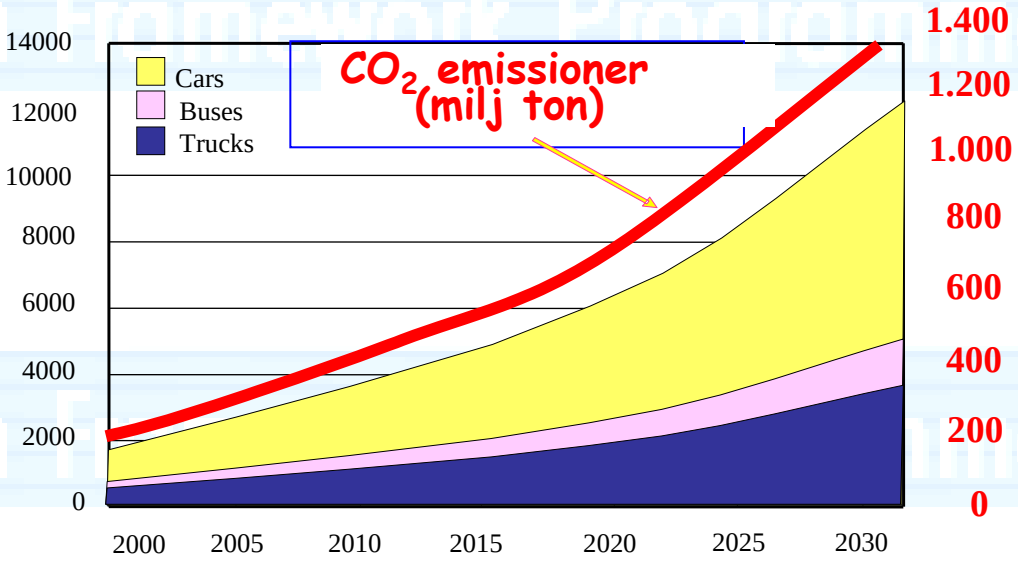


Luftföroreningar i världens städer

Projektion

Världens 10 smutsigaste städer (7 i Kina)

1. Taipei
2. Milano ! !
3. Beijing
4. Urumchi
5. Mexico
6. Lanzhou
7. Chongqing
8. Jinan
9. Shijiazhuang
10. Teheran

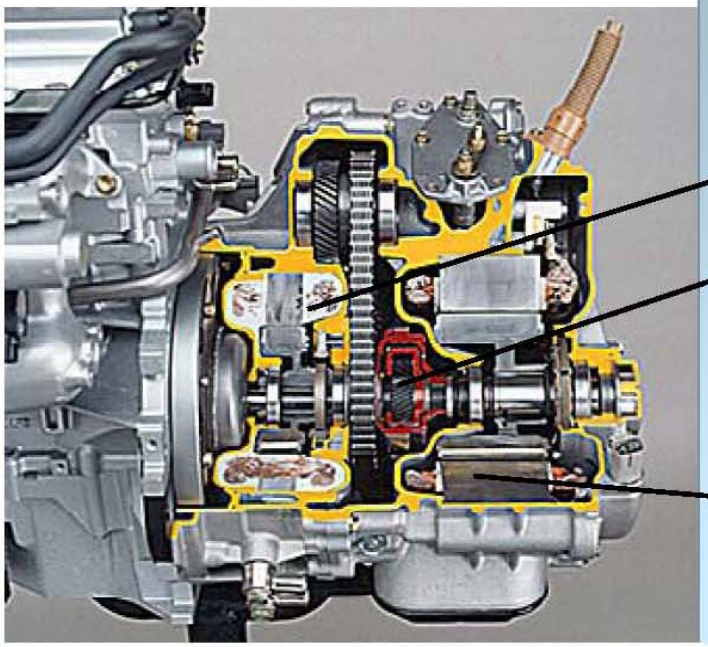


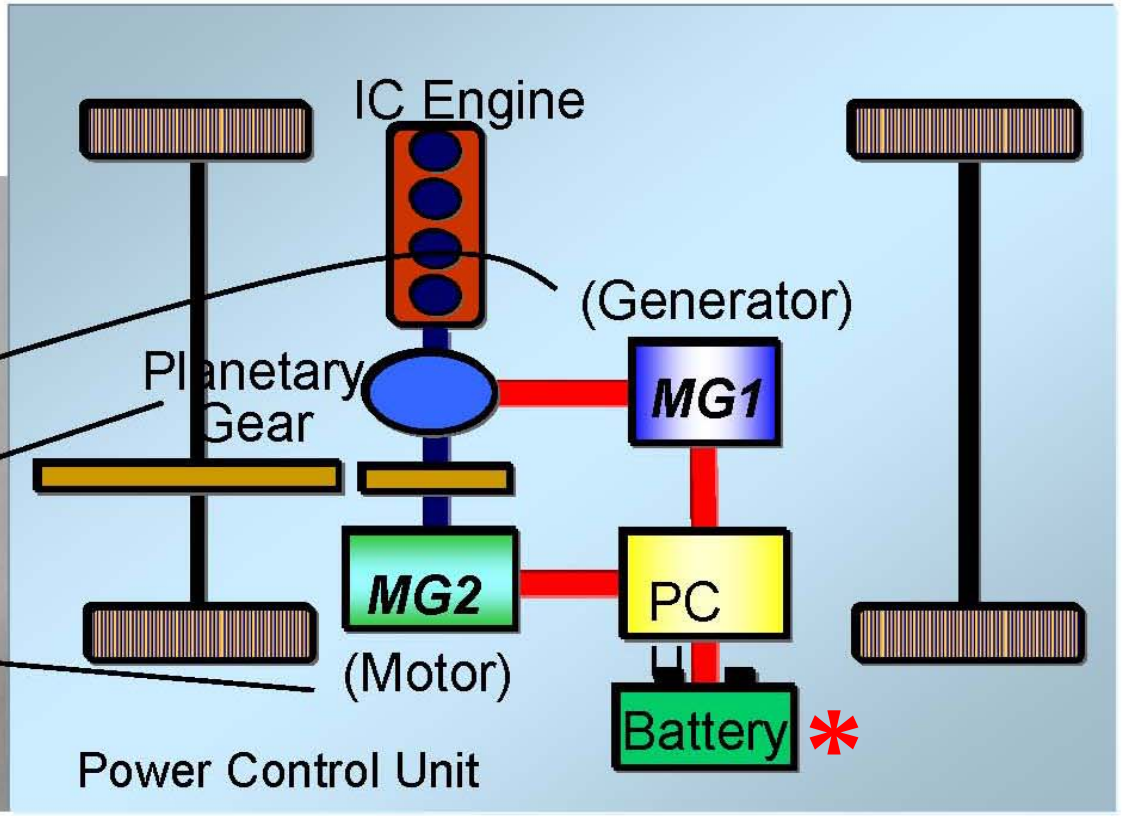
2006 : >300 milj bilar i Europa

En tillfällig lösning ...
... men en vändpunkt !

Toyota Prius (1997)

Toyota Hybrid System (THS)

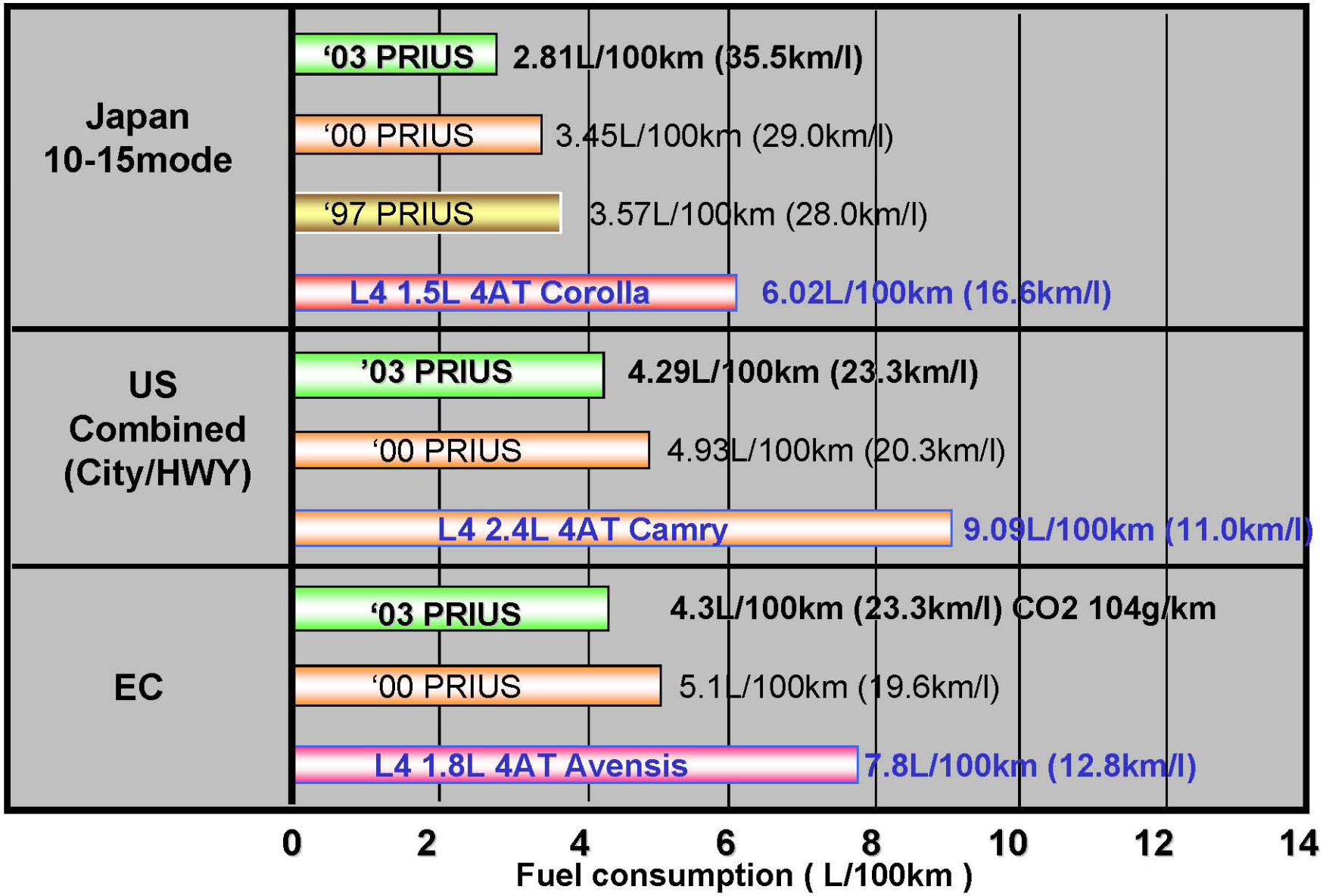




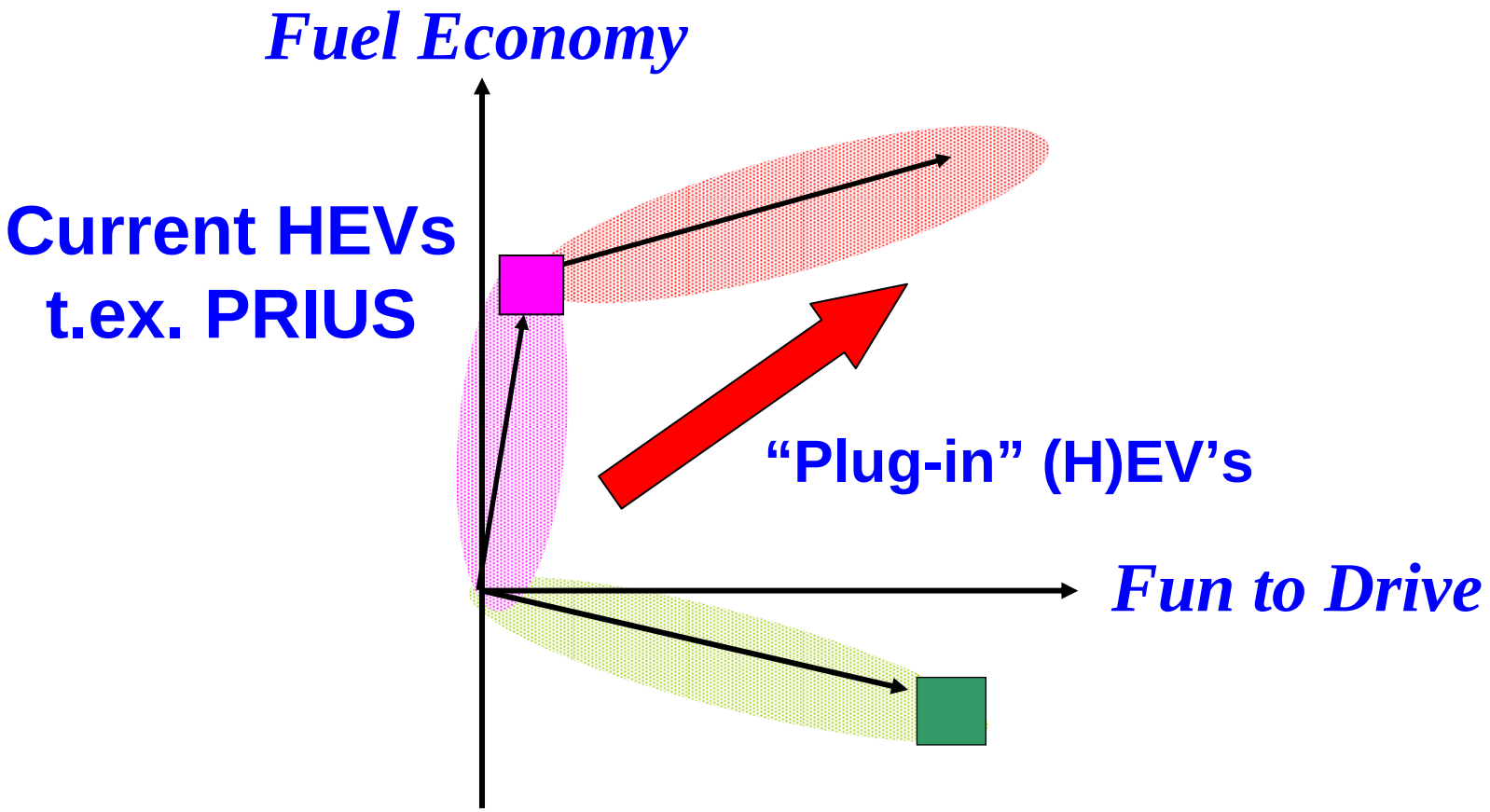
Strong or Full Hybrid with EV drive

New PRIUS Fuel Consumption

(Certification Results)



Better (H)EVs to come !

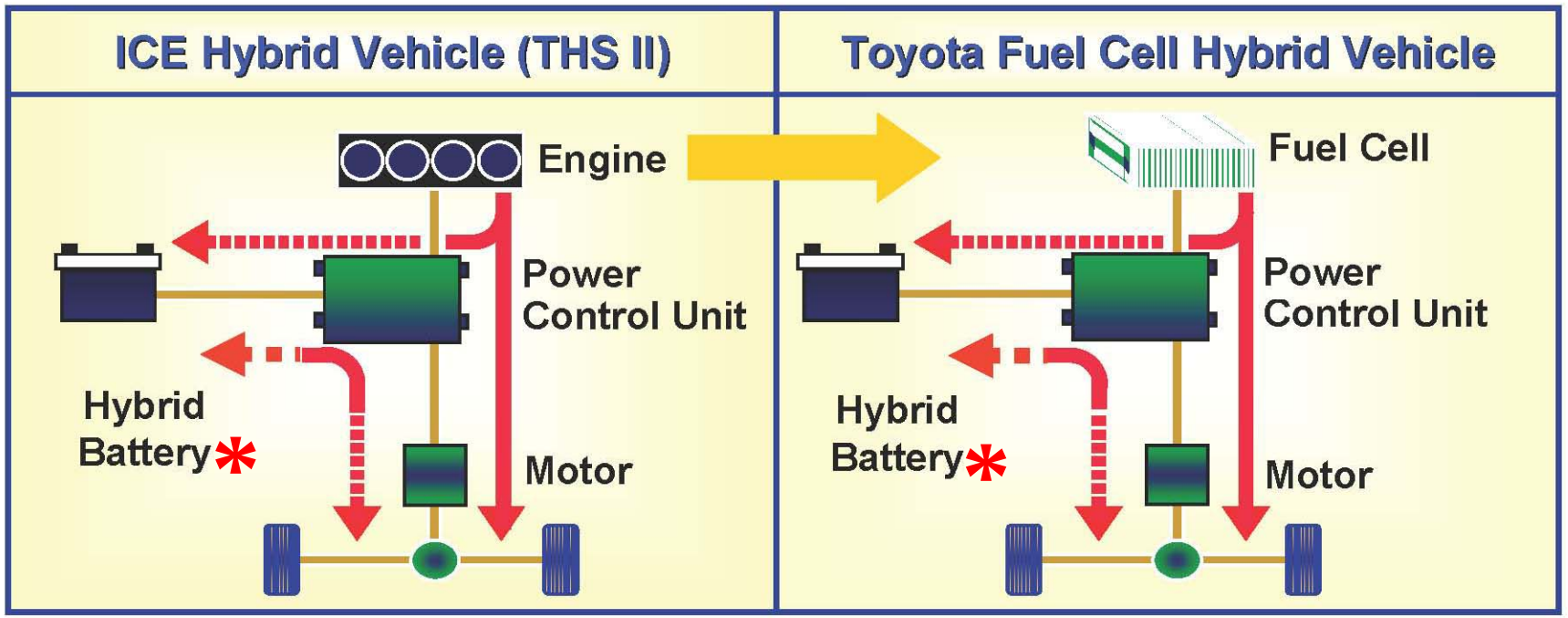


På längre sikt ?

Application of Hybrid Technology

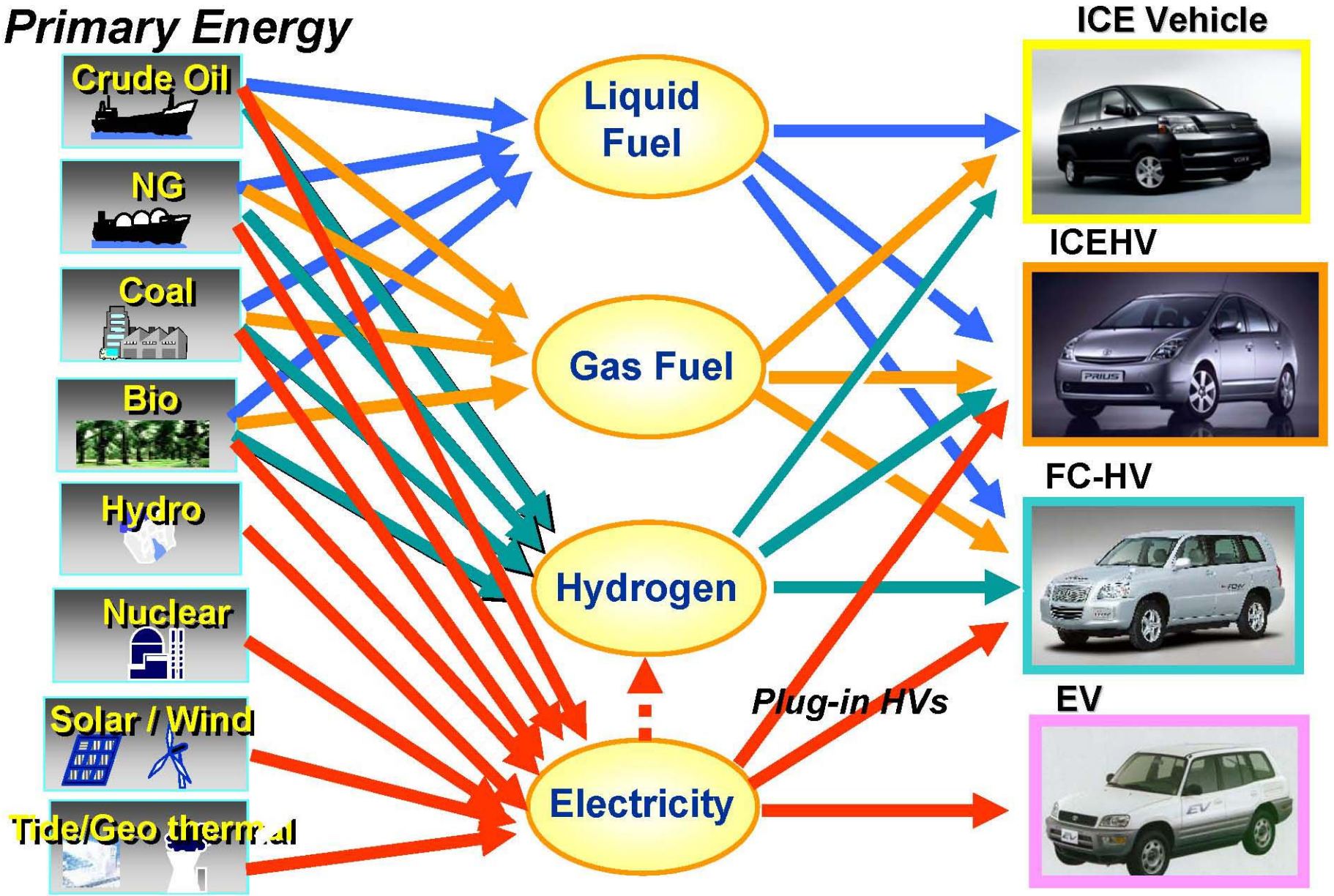
Lexus RX400h

TOYOTA FCHV

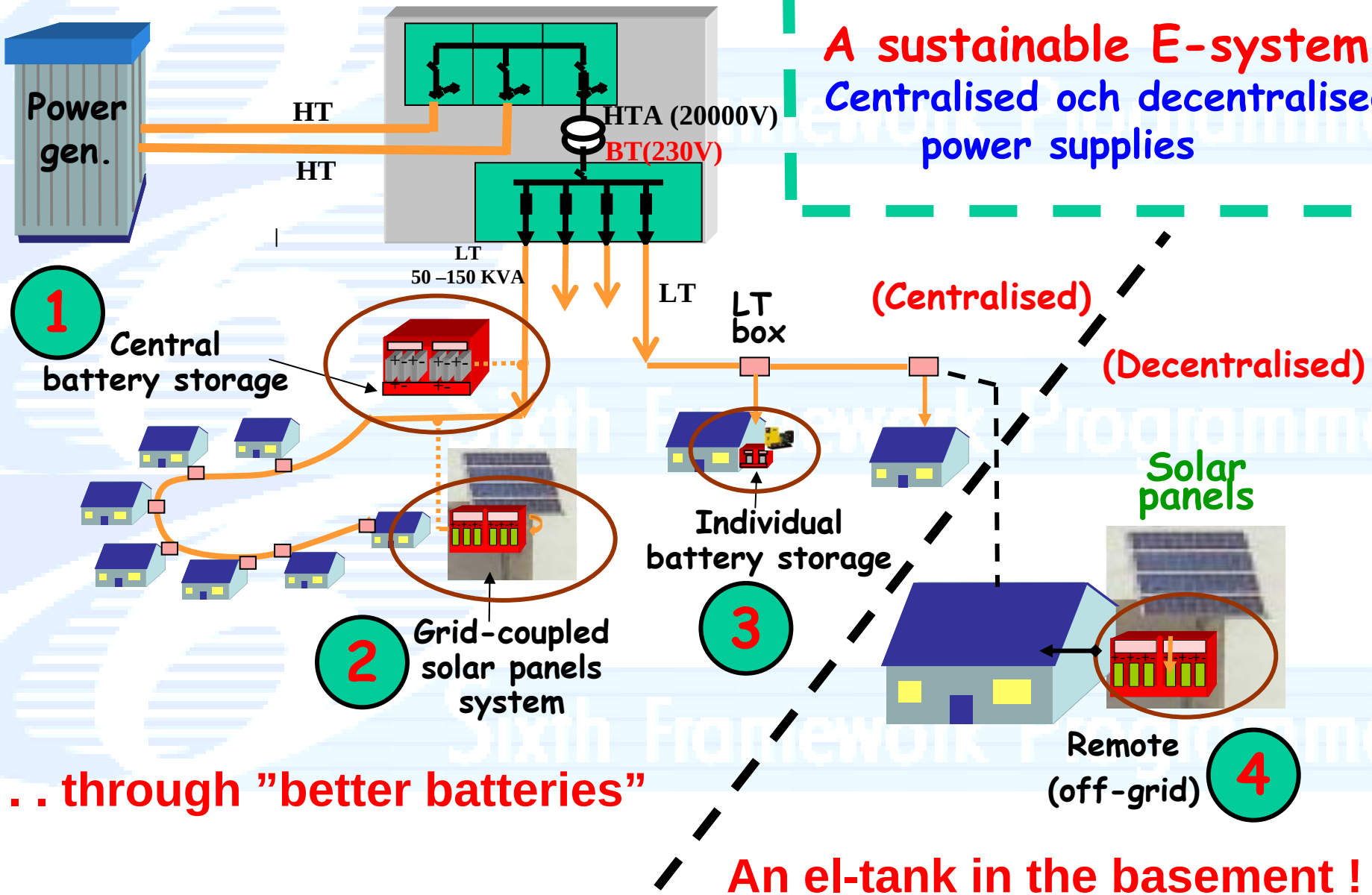


ca. 2030 !?

Energy Diversification for future automobiles



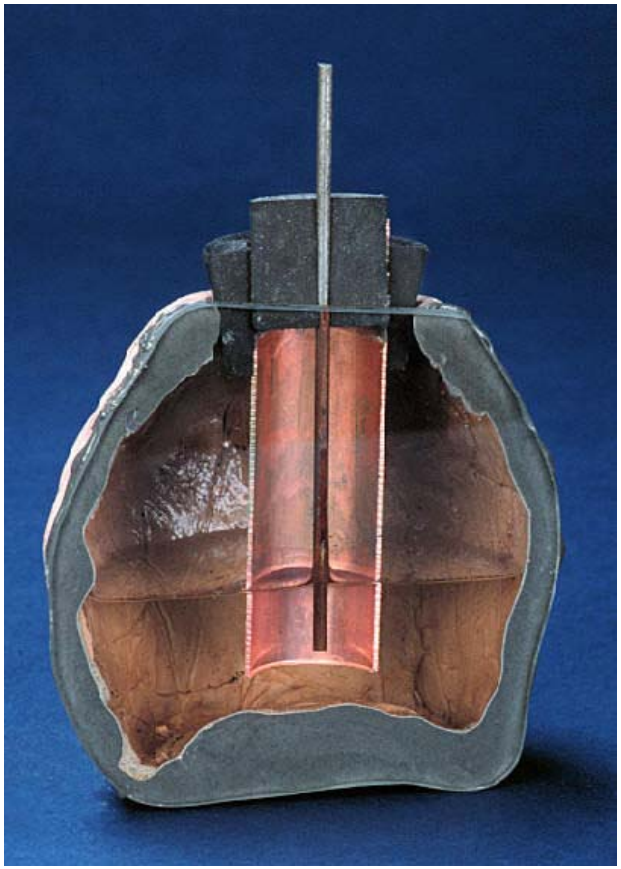
On a broader scale: "sustainable electrical power supplies"



So we need ”better” batteries !

I what way will they be better?

The first battery ?



A clay jar containing an iron rod surrounded by a copper cylinder; when filled with vinegar + an electrolytic solution, the “battery” produced 1.1 volts DC.

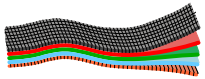
Present day Iraq: 250 BC to 640 AD

Where are we today – after two centuries ?

Alessandro Volta, 1799
(Cu/Zn)

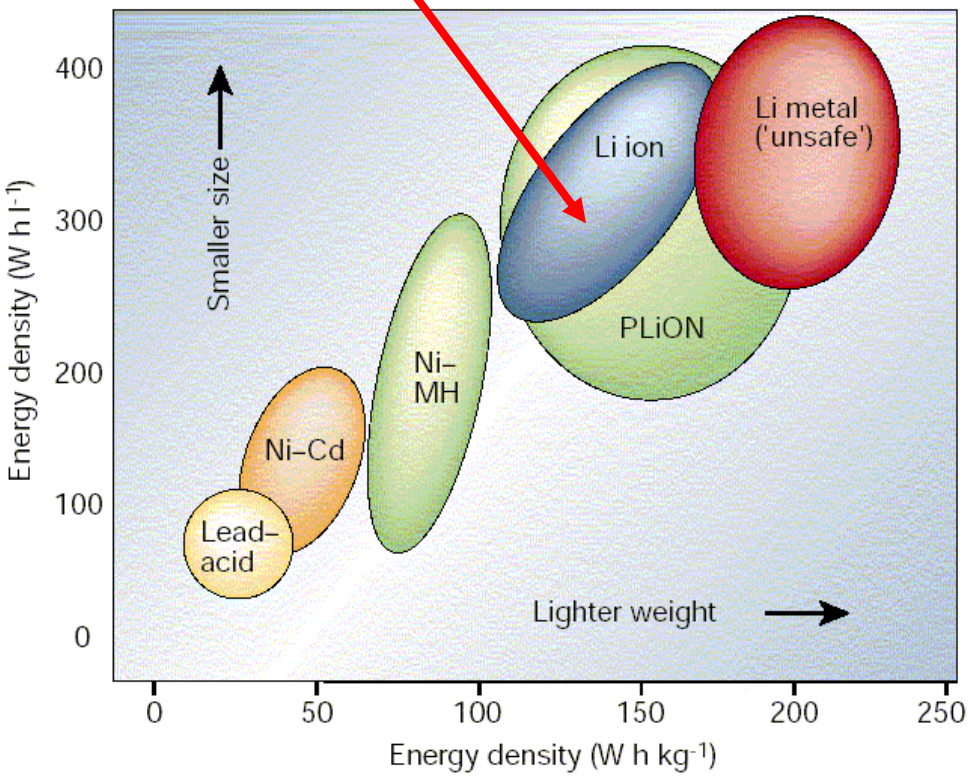
1839	Fuel cell
1859	Pb-battery
1899	Ni-Cd (Swedish)
1973	Li-metal
1975	Ni-MH
1979	Li-polymer

Li-ion: Sony 1990



Li-ion-polymer: 2000

80% of electronics market today

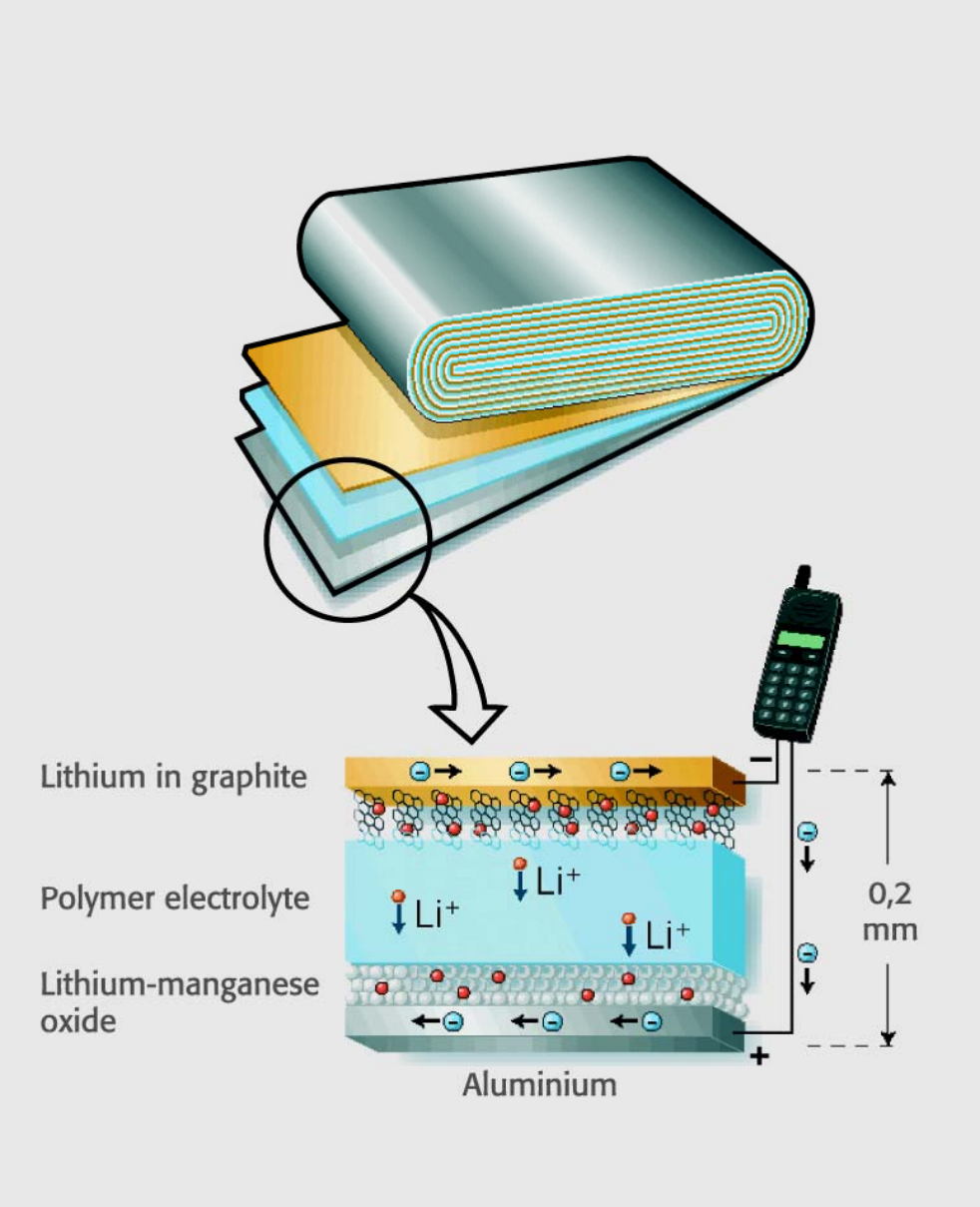


Very slow development
- definitely NOT Moore's law !

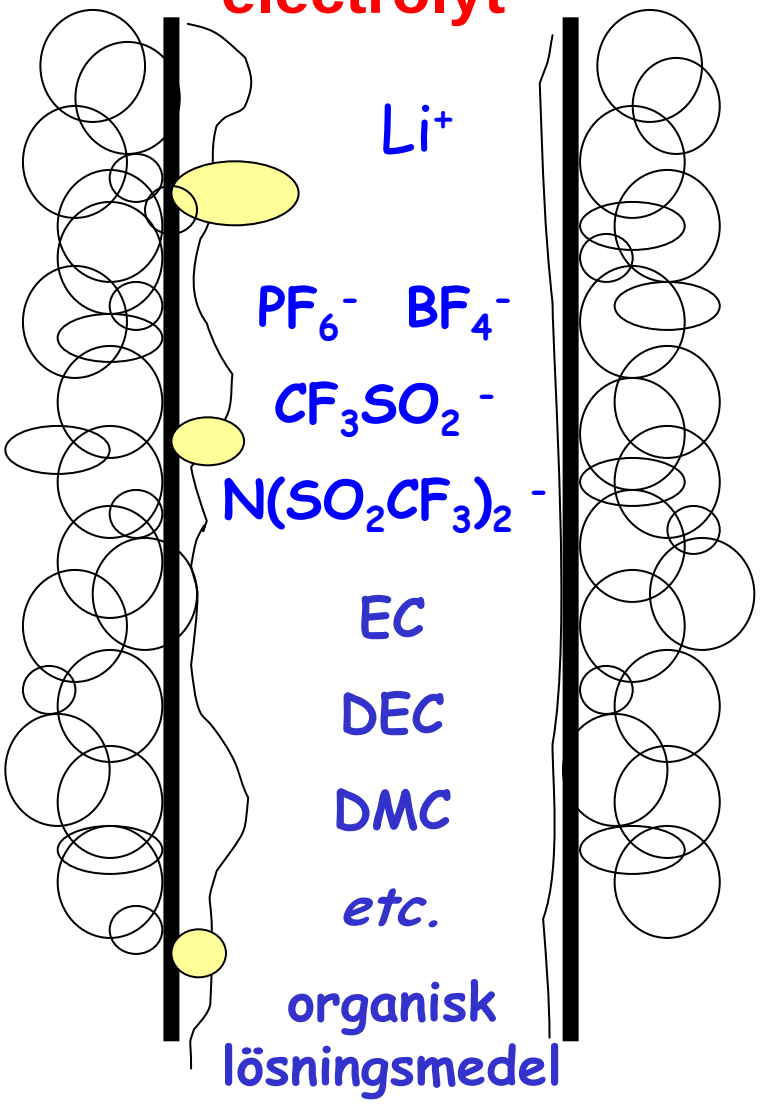
«Research in the field of batteries moves at glacier pace »

N.Y.Times: 2001

Li-jonbatteriet ger oss bästa möjlighet till uppskalning !
(det tar >20 år att ta fram ett helt nytt batterikoncept)



Olika batterimaterial . . .

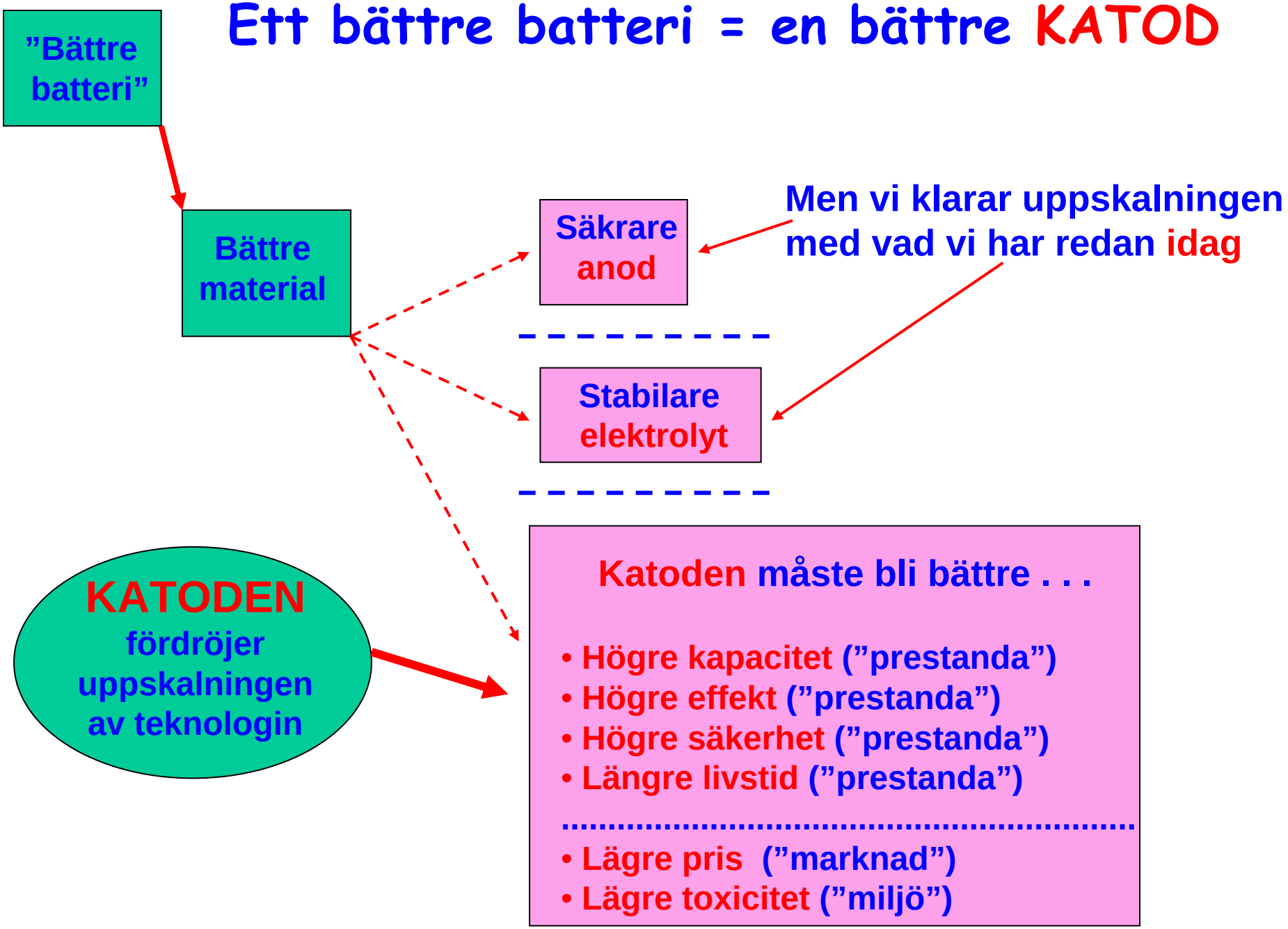


Möjliga vägar fram ?

1. Bättre bulk-material (*e.g.*, LiFeSiZE AB !)
2. Nanomaterial
3. Mikro-arkitekturer

1. Bättre bulk-material ?

Ett bättre batteri = en bättre KATOD



Better batteries

. . . esp. for EV scale-up

Better materials

Safer anodes

More stable electrolytes

We can **scale up** with what we already have at lower voltages, but:

* Cu/graphite sustainability !!!
* $LiPF_6$!!!!

The CATHODE is hindering the scaling up of the technology!

- Higher capacity ("performance") cathodes
- Higher power ("performance")
- Safer ("performance")
- Longer lifetime ("performance")

.....

- Lower cost ("market")
- More abundant materials ("market"/ "environment")
- Non-toxic ("environment")

Ett nytt HEV/P-HEV/EV katodmaterial ?
. . . från Uppsala

- Dagens mobiltelefon/laptop material
  - **$LiCoO_2$, $Li(Co,Ni)O_2$, $LiNi_{1-y-z}Co_yAl_zO_2$**

- **Större** batterier kräver **billigare** katodmaterial

$\Rightarrow \Rightarrow \Rightarrow$ **Fe-baserad material**

- $LiFePO_4$ (A123, *etc. idag*)
- **Li_2FeSiO_4 (litiumjärnsilikat)**

(Fe- och Si-oxider >10% av jordskorpan !)

De gamla grekernas grundelement:
"Earth-Air-Fire-Water" !

LiFeSiZE

. . . an Uppsala University spin-off Company

Goal: **We develop Fe-based cathodes for Li-ion batteries for large-scale applications (transport and sustainable energy storage)**

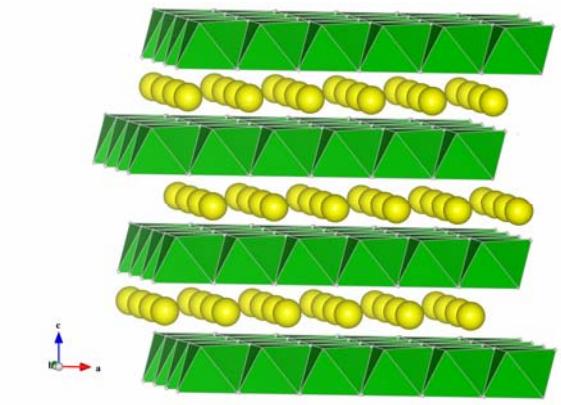
. . . an inestimably large - but tough - market !

- **develop a CHEAP green synthesis method for Li_2FeSiO_4 (”LFS”)**
- **produce/sell Li-ion battery cathodes based on LFS**

Common Li-ion battery cathode materials

a) Layered:

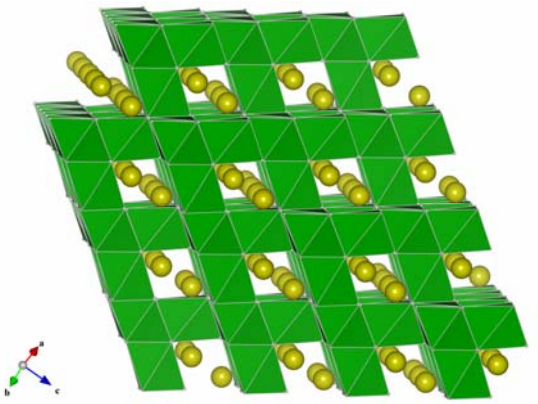
$LiCoO_2$ -> $Li_{0.5}CoO_2$: ~3.9V, ~140 mAh/g



- Instability ?
- Solution:doping

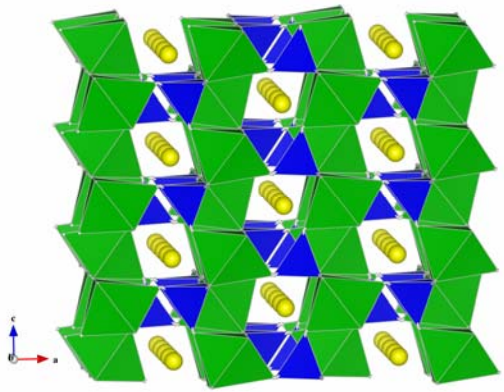
b) Spinels:

$LiMn_2O_4$ -> Mn_2O_4: ~3V or ~4.0V, 148 mAh/g



c) Olivines:

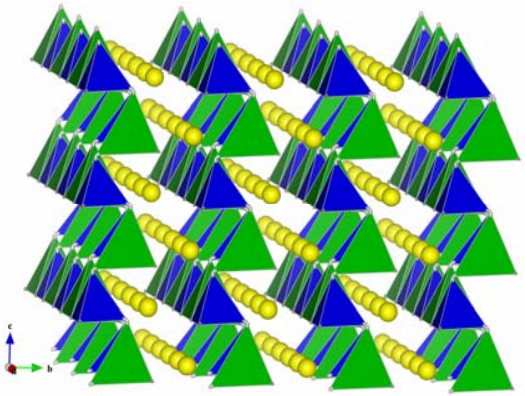
$LiFePO_4$ -> $FePO_4$, ~3.6V, ~170 mAh/g



- Poor electronic conductivity !
- Solutions:
  - doping
  - nano-coating
  - nano-sizing

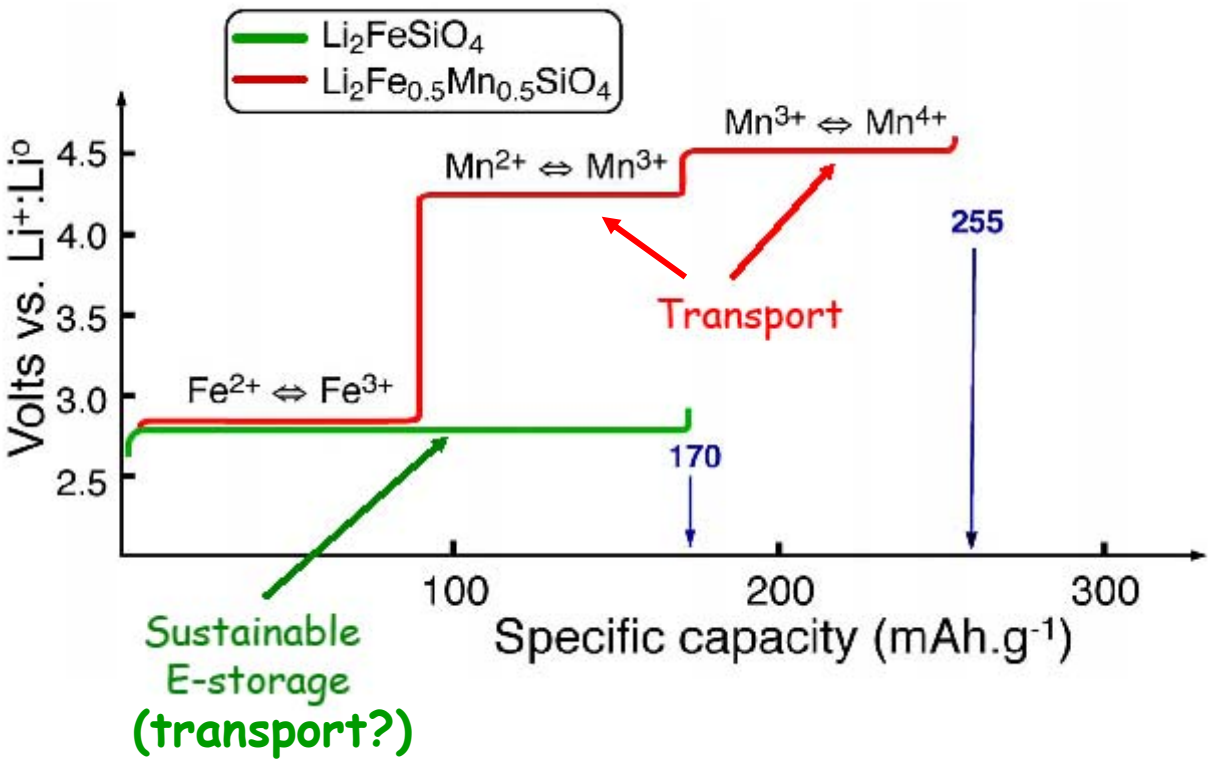
d) Orthosilicates

Li_2FeSiO_4 -> $LiFeSiO_4$, ~2.85V, ~ 170 mAh/g



Extract >1 Li to give higher capacity at higher voltage . . .
. . . the "Holy Grail" of the Li-ion battery?

***e.g.*, for x = 0.5**

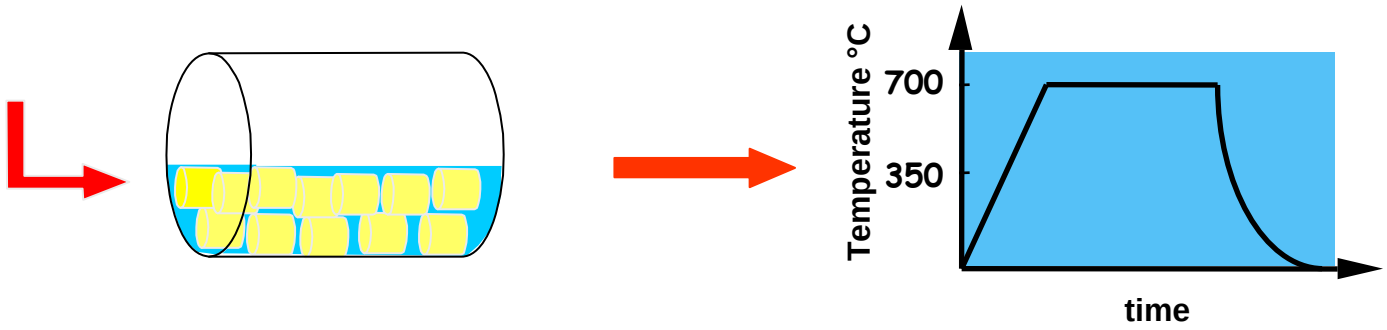


$$Li^{+2}(Fe^{2+}_{1-x}Mn^{2+}_{x})SiO_4 \Rightarrow Li^{+}_{1-x}(Fe^{3+}_{1-x}Mn^{4+}_{x})SiO_4 + \underline{(1+x)Li^+} + \underline{(1+x)e^-}$$

" a 1.5-electron reaction"

Li_2FeSiO_4 synthesis

Solid-state synthesis:



Ball-milling

e.g., $FeC_2O_4 \cdot 2H_2O$ + Li_2SiO_3
+
C-precursor

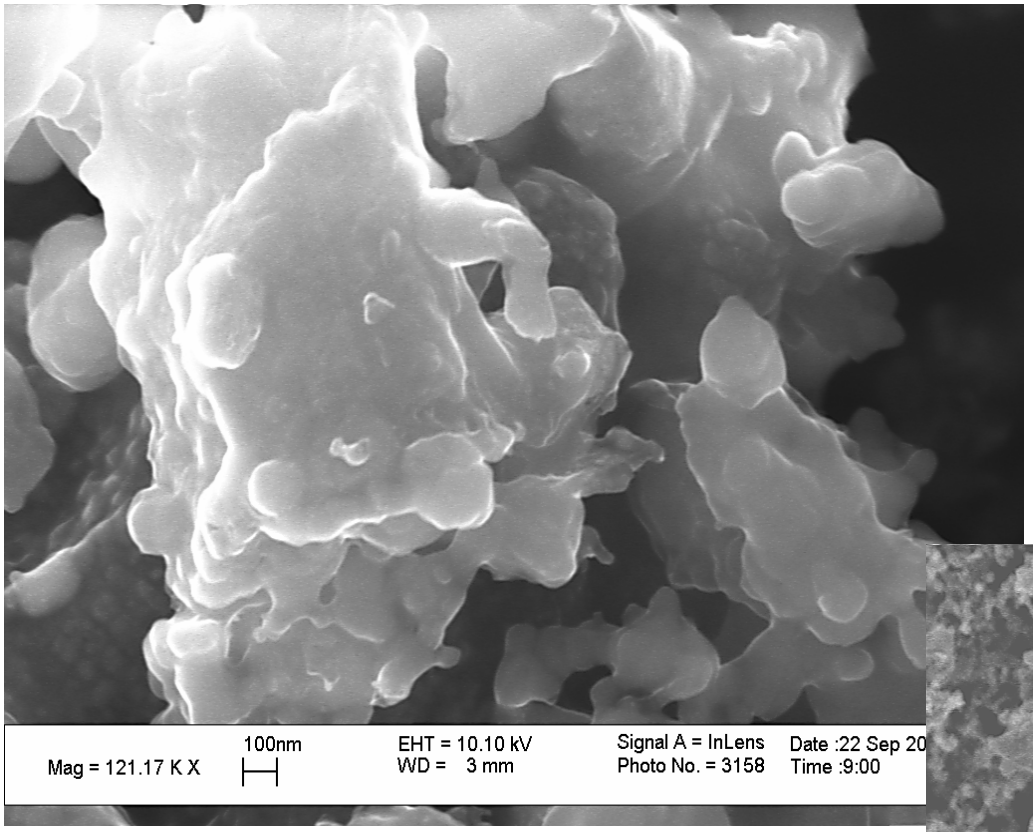
Heat treatment

700°C in a CO/CO_2 gas flow (20 h)

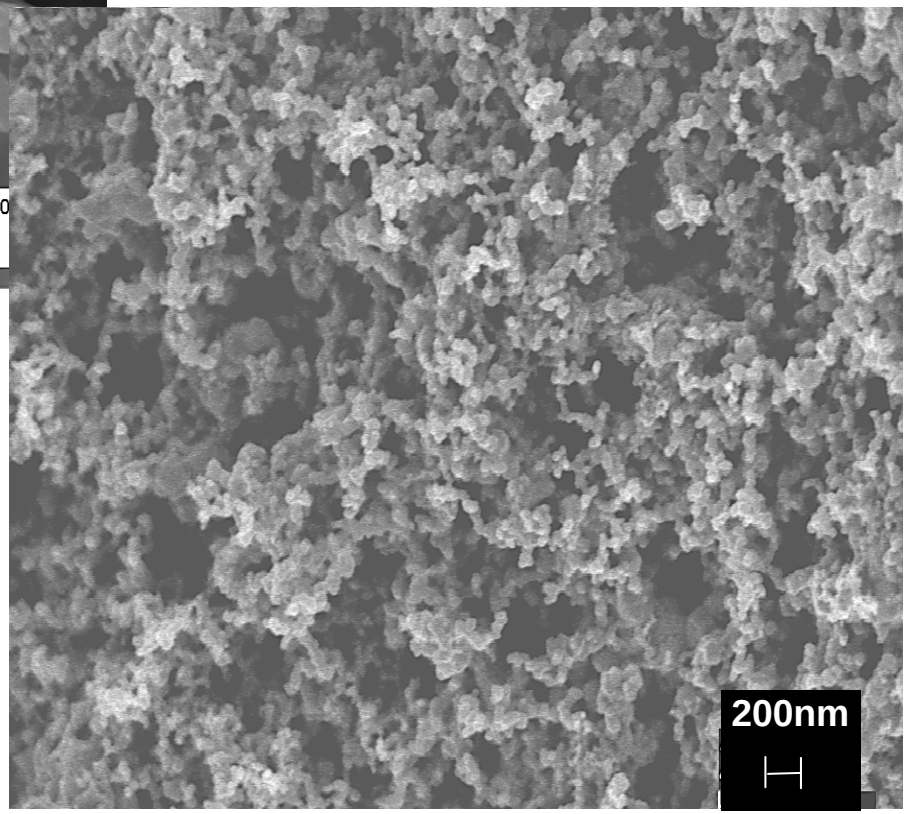
BUT:

Solgel, wet chemical and hydrothermal process routes also result in "useable" active materials

SEM picture of Li_2FeSiO_4 after ball-milling for 12h: 85 mAh/g

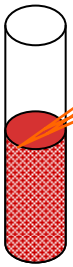


SEM picture of Li_2FeSiO_4 after 2 months mixing/grinding: 125 mAh/g



A cheap, fast microwave-assisted process ?

CEM Focused Microwave™ synthesis system



Quartz vessel

Mixture of reagents:
LiAc, Fe(Ac)2, TEOS,
Solvent: TEG

Microwave heating

300°C, 15 min

Drying

150°C, 4 h
(vacuum)

XRD,SEM
TGA,
EC test…

Li_2FeSiO_4 ?

Ball-milling, 2h
w/ acetone

acetone evap.

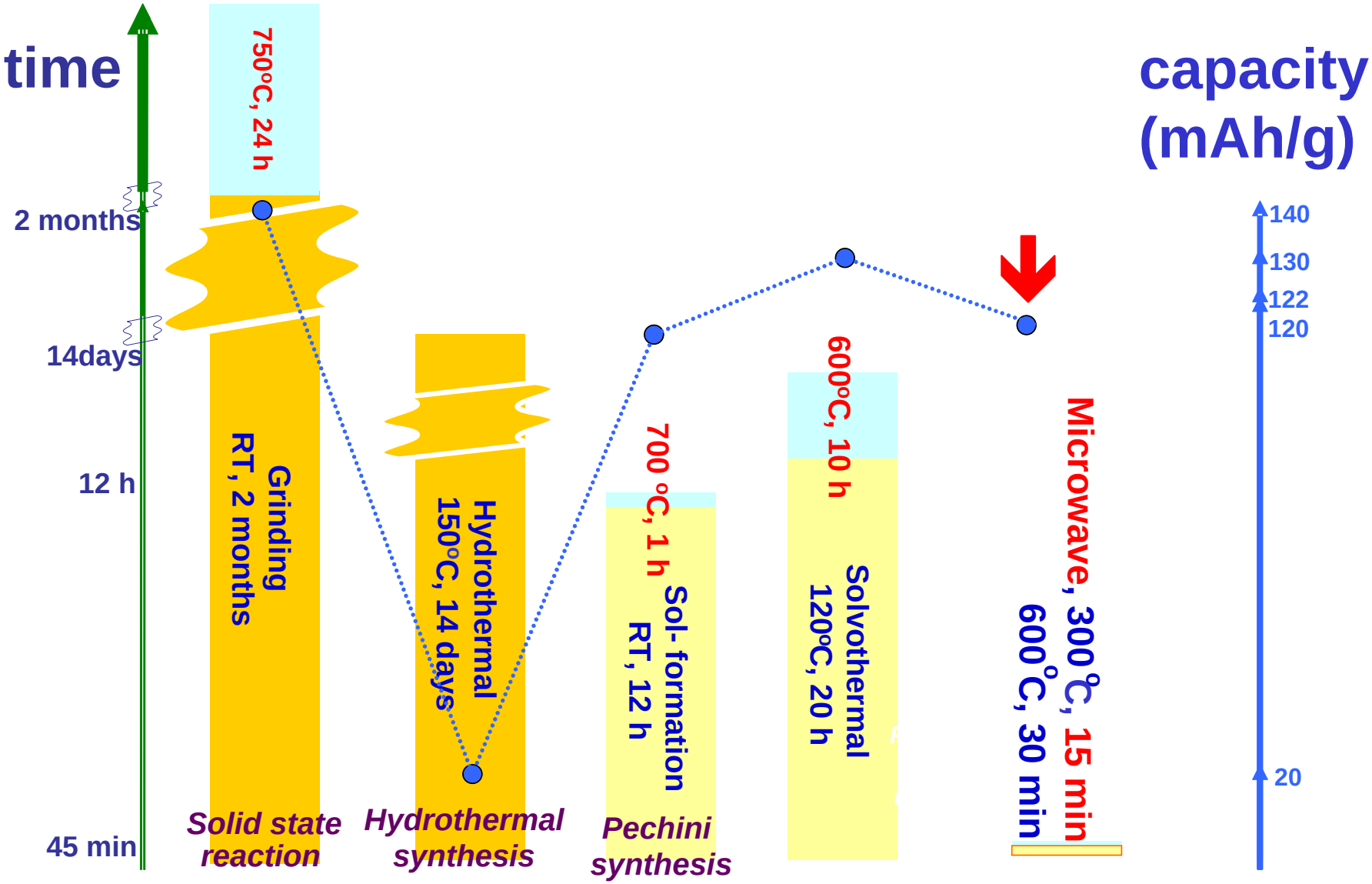
Ball-milling, 2h
w/ acetone
w/ 20 wt% sucrose

acetone evap.

Post heat-treatment

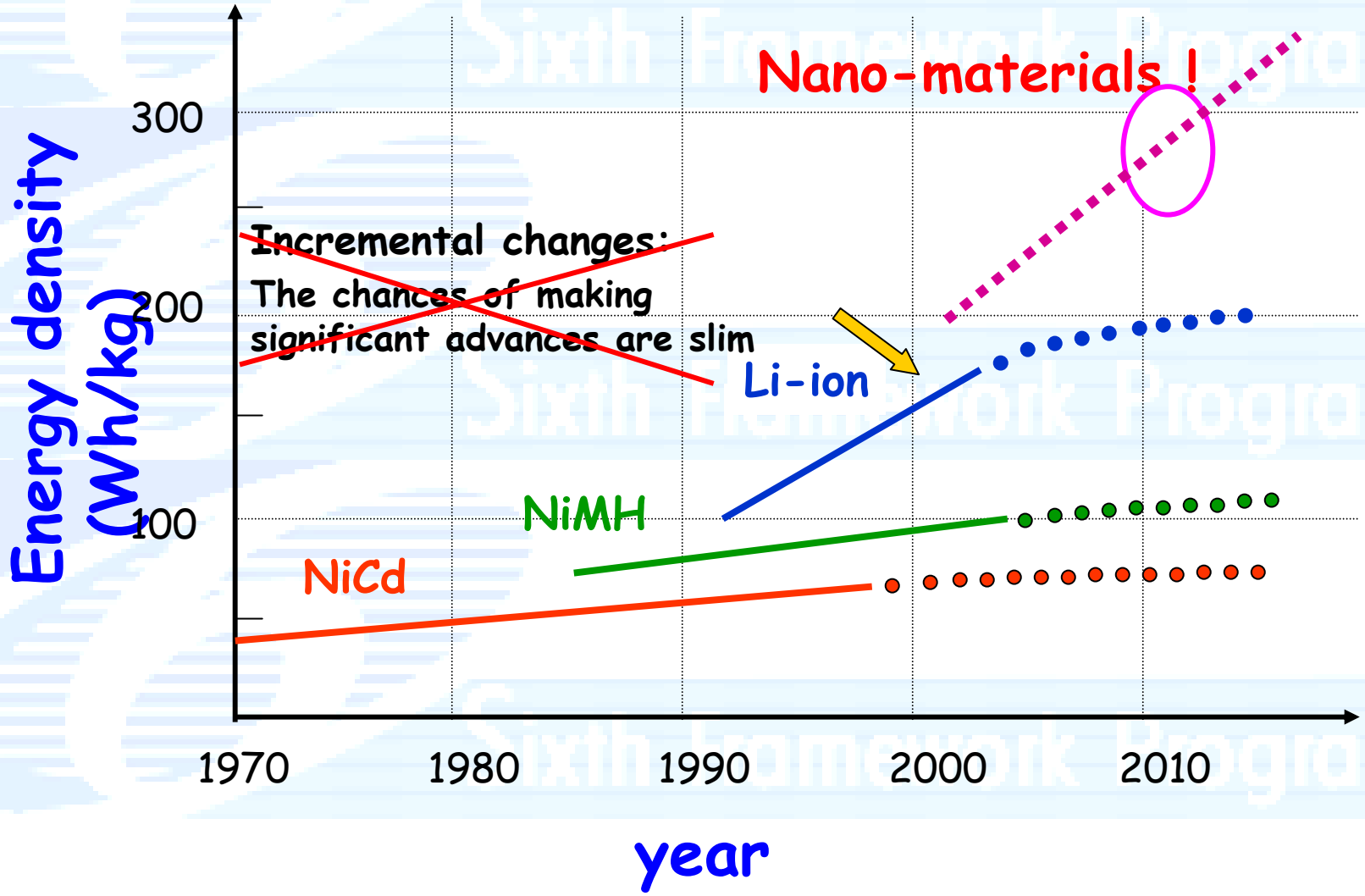
600°C, 30 min
(10°C/min)
N_2 flow (100 ml/min)

Shorter, cheaper synthesis methods



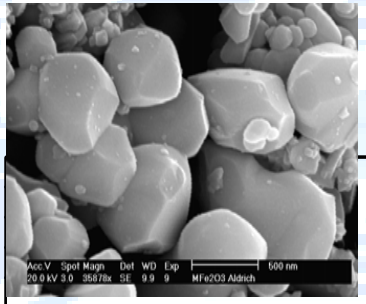
2. Nanomaterial ?

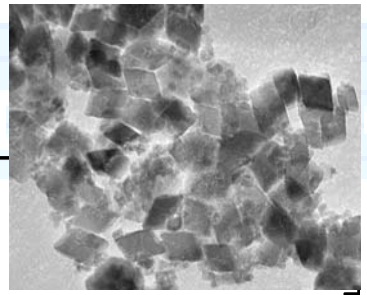
Nano-materials ?

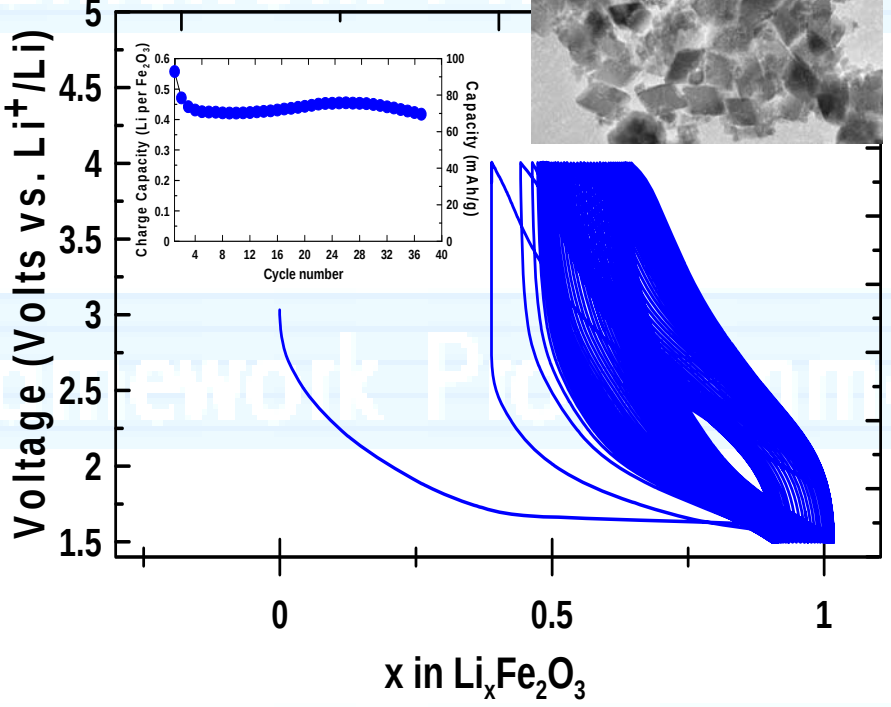


Particle-size: cathode material

bulk-Fe_2O_3 vs. nano-Fe_2O_3



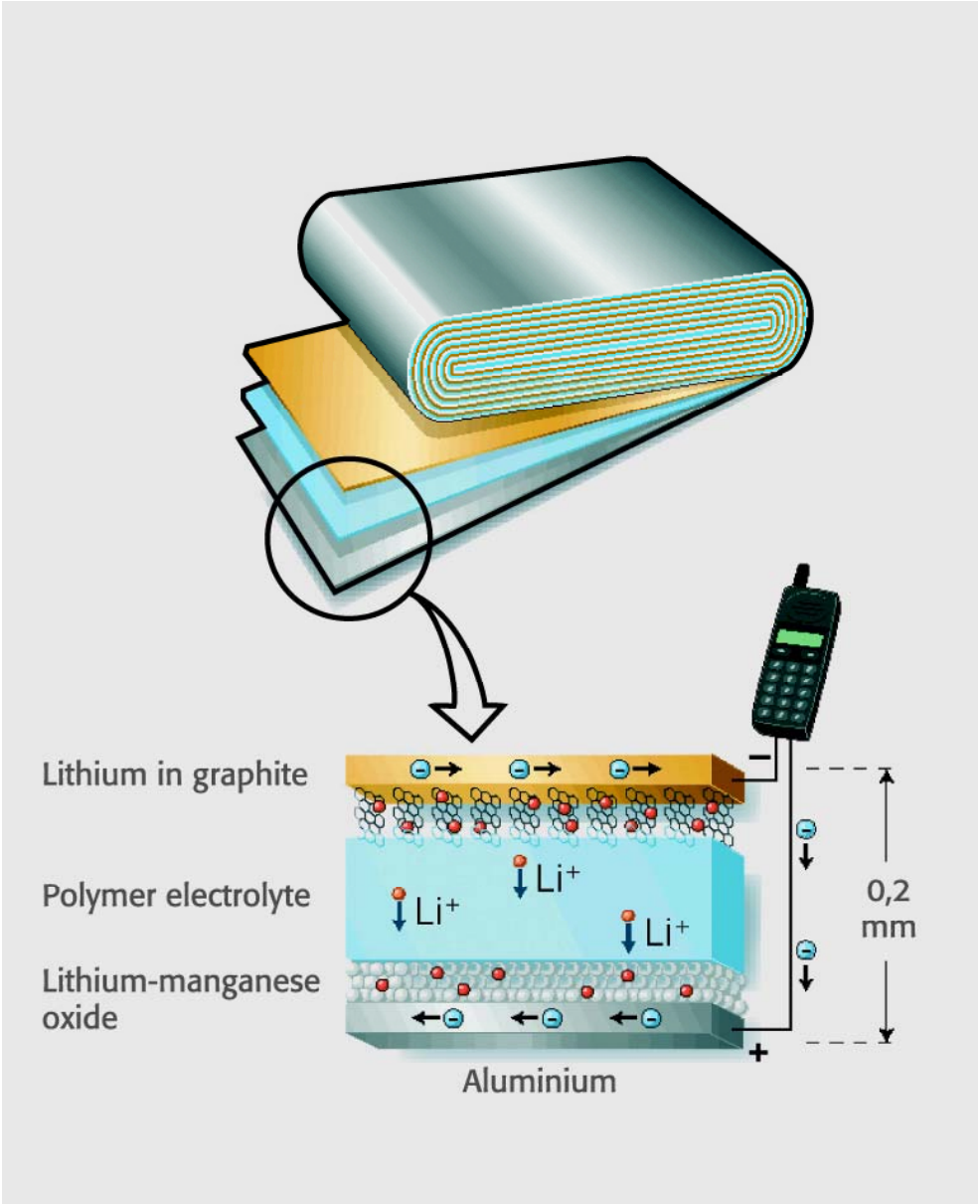




Larcher *et al.* *J. Electrochem. Soc.*, 150 (2003) A133-A139.

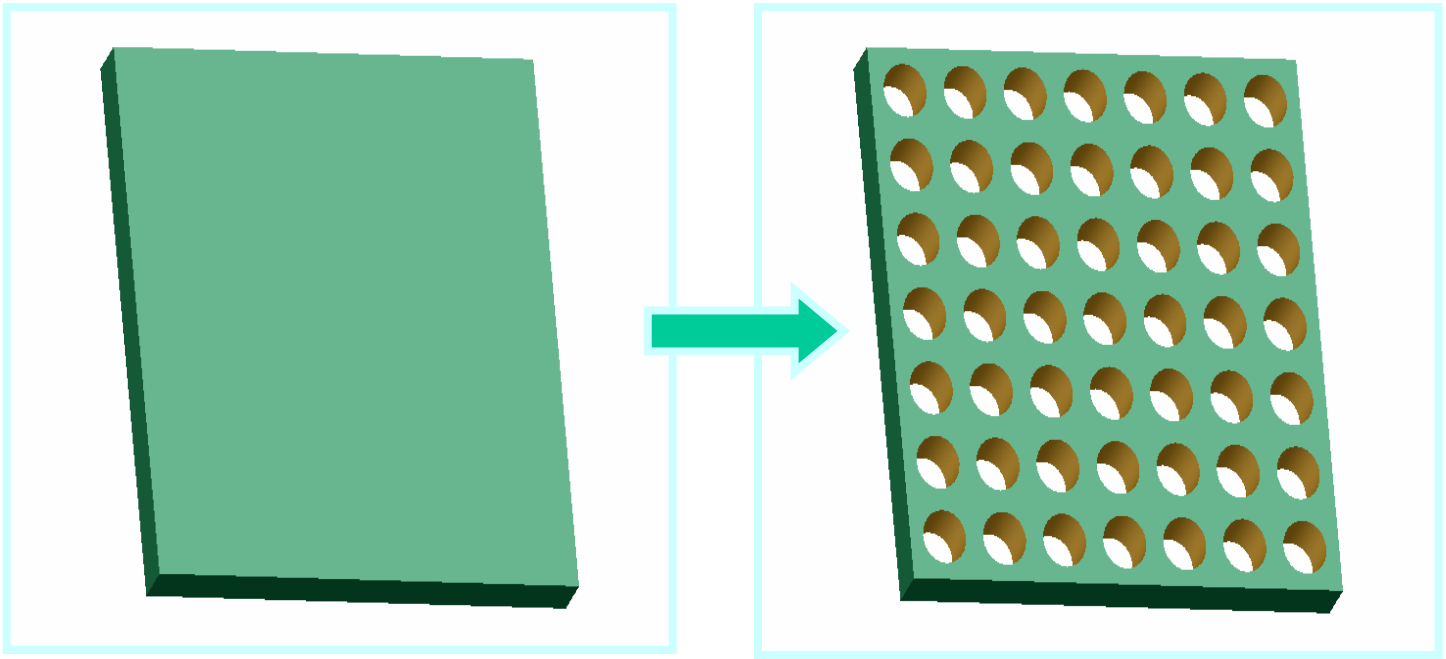
3. Mikro-arkitekturer?

Today's rechargeable Li-ion battery



2D !

A basic MB design principle: Perforated substrates with high aspect-ratio give higher electrode surface area-to-volume ratio



The geometric **Area Gain** (A.G.) per given substrate footprint

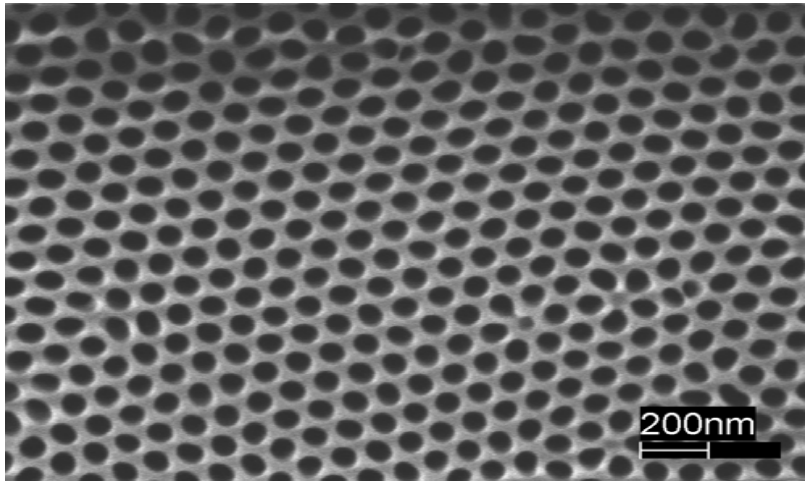
d-diameter

s-interhole spacing

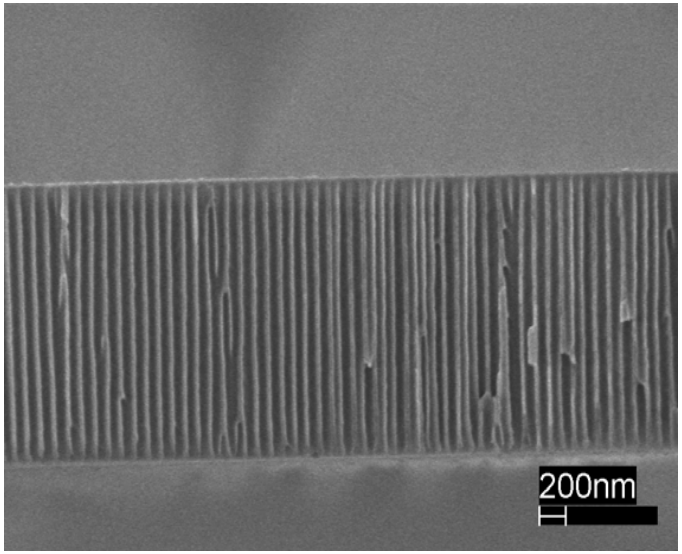
t-substrate thickness

$$A.G. = \frac{\pi d}{(d+s)^2}\left(t - \frac{d}{2}\right) + 2$$

Porous alumina as a template for nano-electrodes



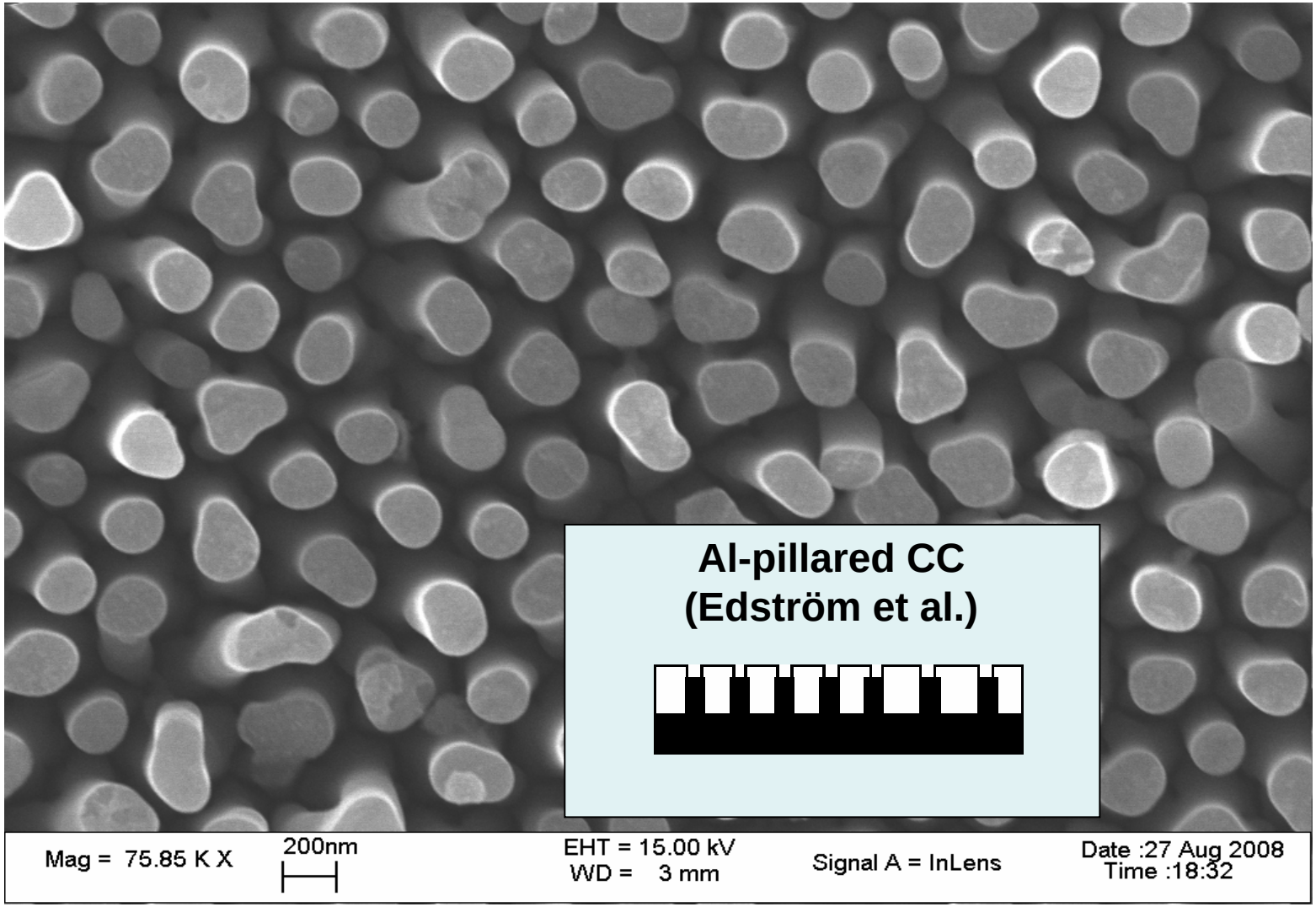
Along the pores

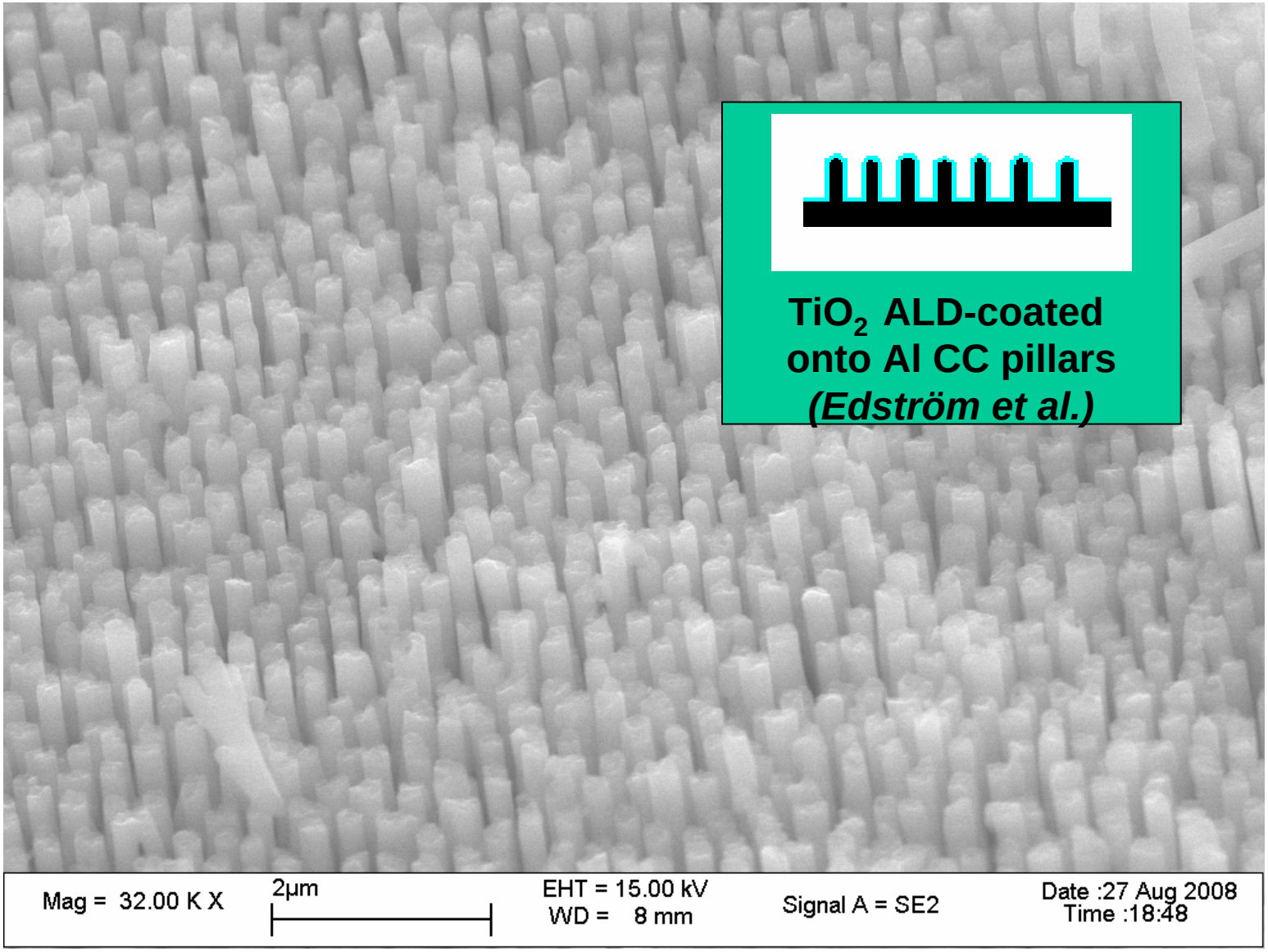


From the side

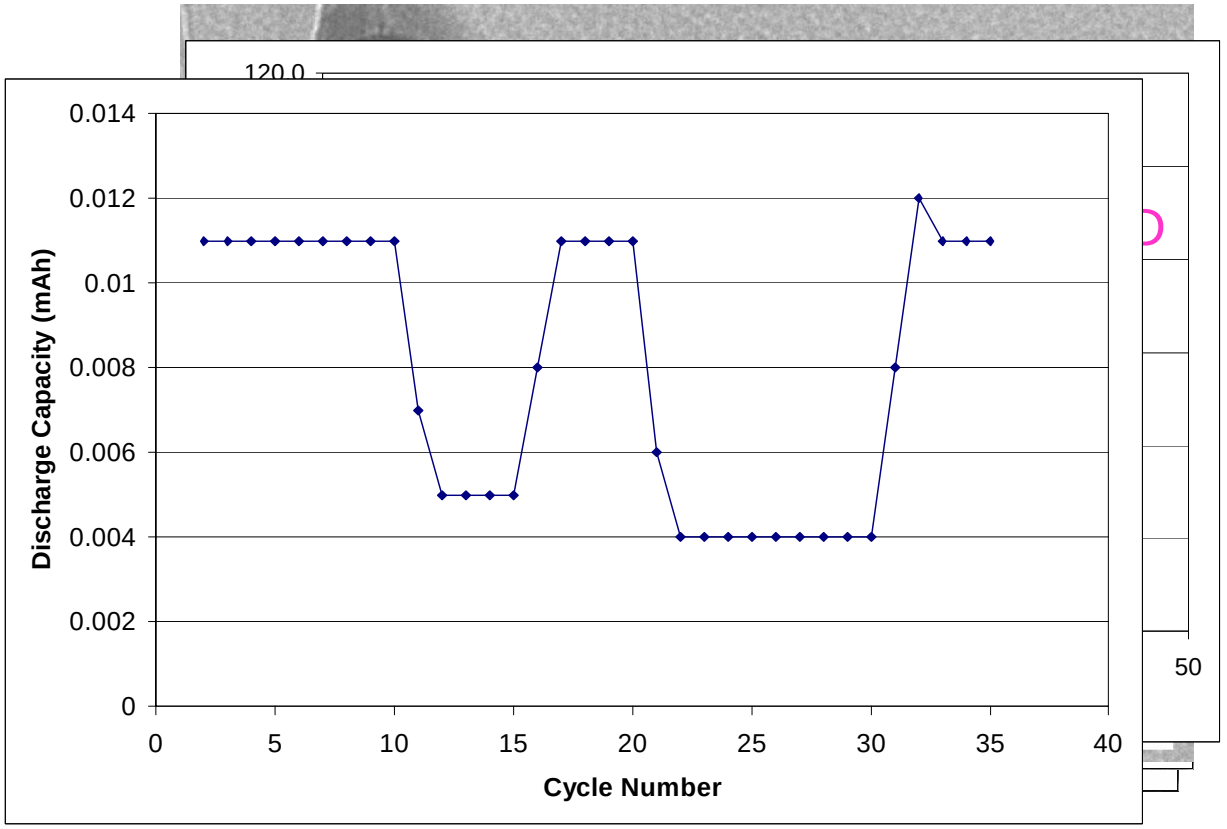
.... for "3D-microbatteries" (3D-MB:s)!!

Johansson, Boman *et al.* (Materialkemi/UU)


Al-pillared CC
(Edström et al.)
Mag = 75.85 K X
200nm
EHT = 15.00 kV
WD = 3 mm
Signal A = InLens
Date :27 Aug 2008
Time :18:32


TiO_2 ALD-coated
onto Al CC pillars
(Edström et al.)
Mag = 32.00 K X
2µm
EHT = 15.00 kV
WD = 8 mm
Signal A = SE2
Date :27 Aug 2008
Time :18:48

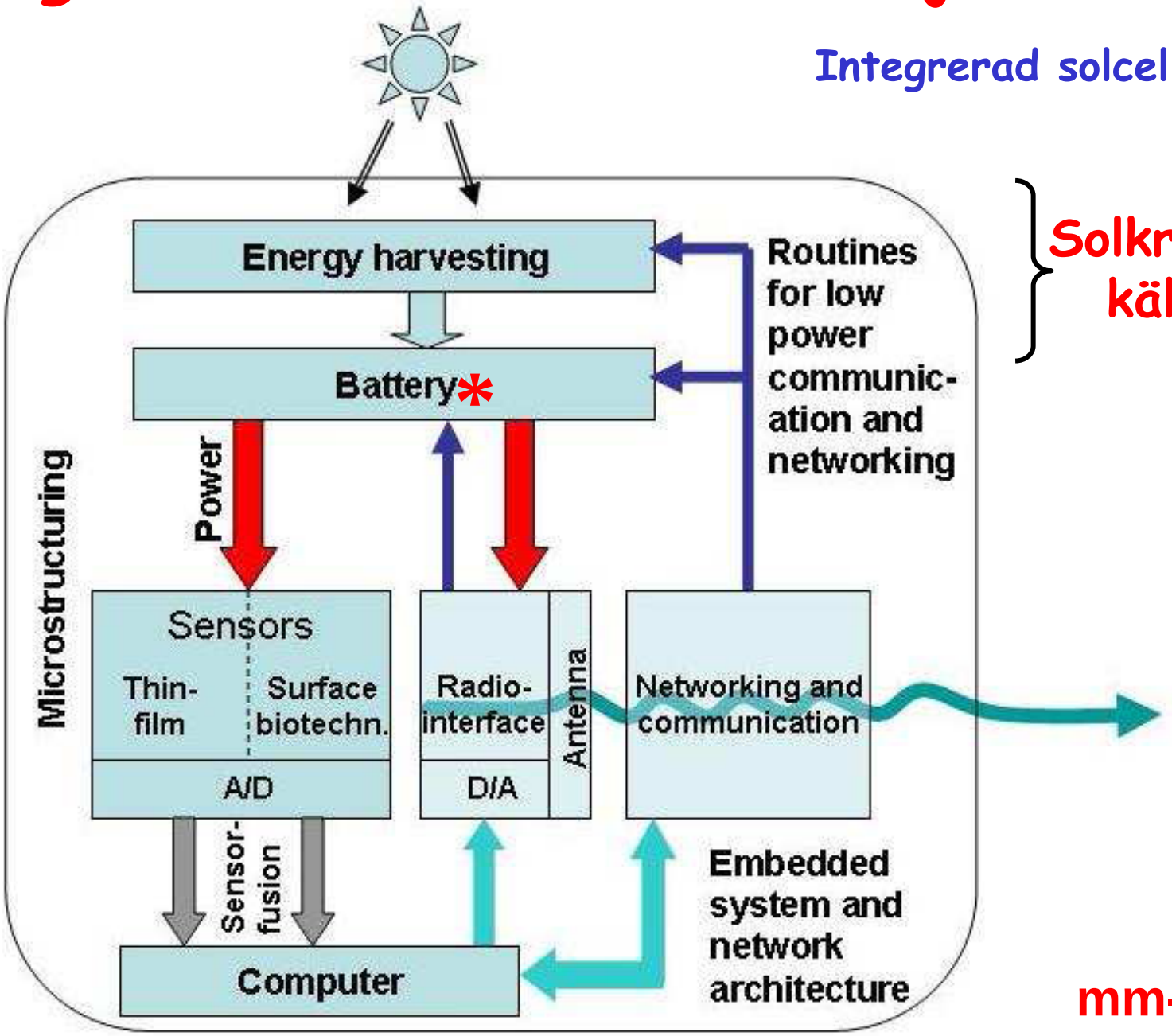
Result:



→ Complete coverage of the nanostructured CC
→ Good cycling stability

e.g., "Smart dust" - för miljöbevakning

Integrerad solcell/3D-MB



Solkraft källa

mm-kuber !

Att sammanfatta . . .

Portable/on-board electrical energy demands will continue to increase over the coming decades:

- **Portable communications:**
  - more laptops, PDA's, cellular phones, video cameras, power tools, and integrated applications like PDA's with a cellular phone.

- **(Hybrid?) electric cars, scooters, bicycles:**
  - motivated by higher gasoline costs and the need for a "greener" environment.

These will all need better batteries of different types . . .

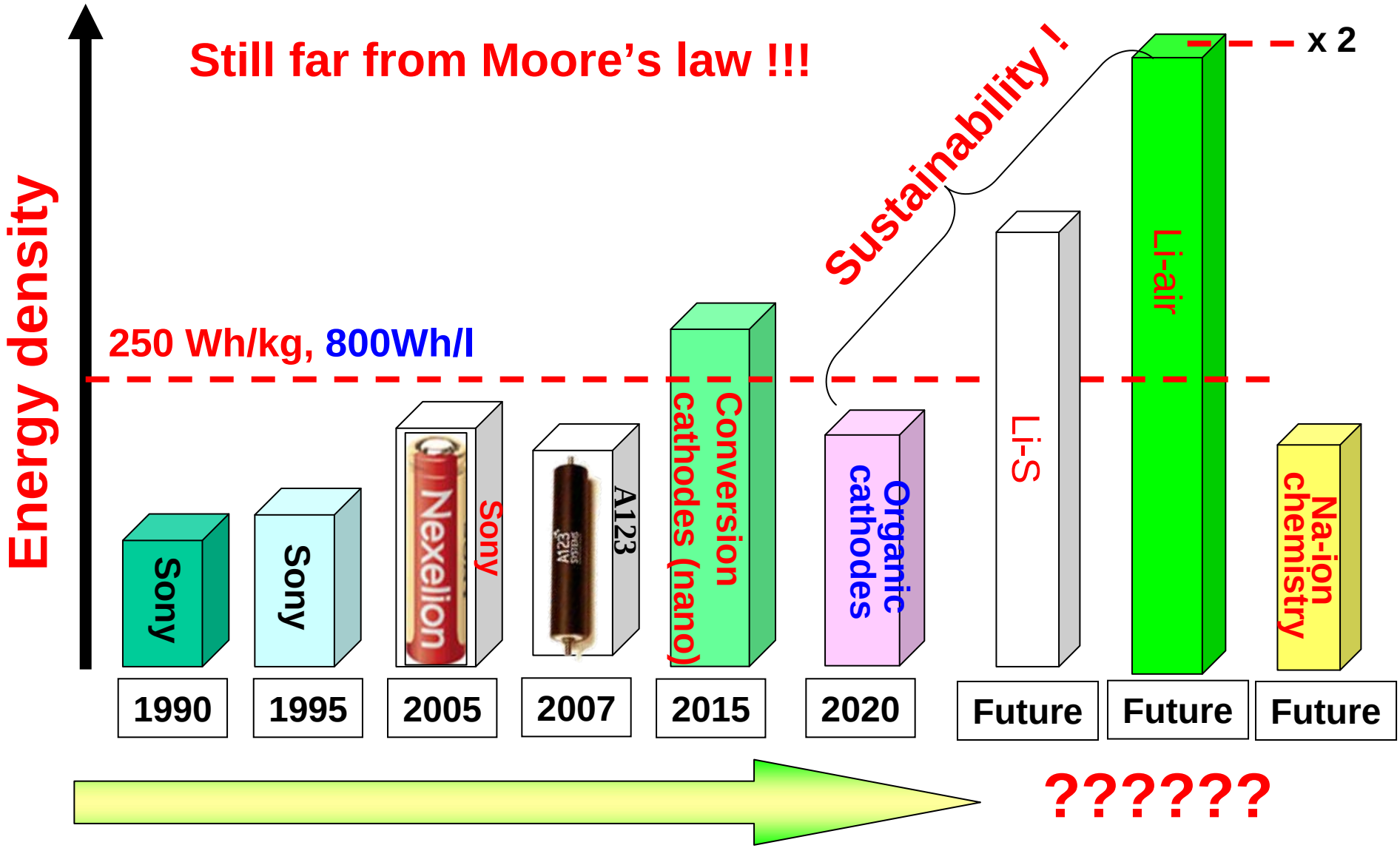
PROBABLE TECHNOLOGICAL TRENDS IN BATTERIES OVER THE NEXT 10-20 YEARS . . .

- More hybrid systems - integrating the advantages of different devices, *e.g.,* battery + supercapacitor, battery + fuel cell, primary + rechargeable cell, *etc.*

- Li-ion technology will penetrates new applications, esp. with larger Li-ion batteries replacing other technologies.

- No dramatically new "battery chemistries" yet – but new battery engineering will soon emerge.

The development of Li-ion batteries over the next 20-30 years



Vi har knappast kommit igång, spec. i den stora-batteri världen . . .

. . . 2030:s batterier kommer säkerligen att vara bättre än dagens på alla sätt !

Tack för mig !

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