3rd Int. Congress on
Advanced Battery Technology

Future Availability of Lithium – Does Recycling Help?

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Institute for Technology Assessment and Systems Analysis

Li

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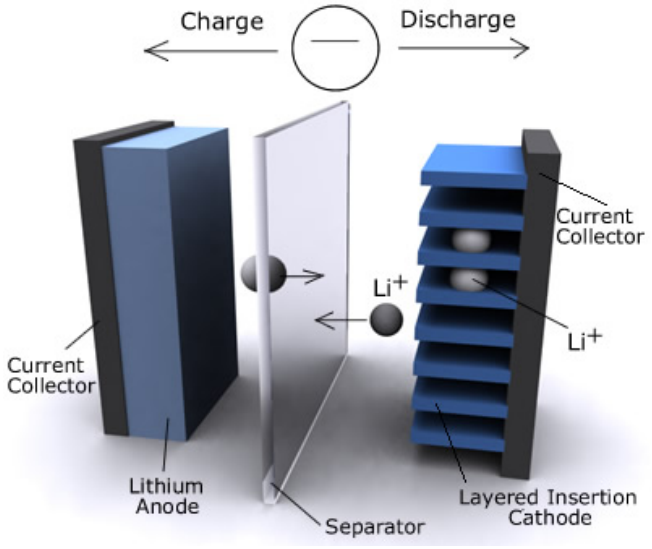
New and Emerging Technologies

Li-Batteries



- Li
- Co
- Ni
- Mn
- Ti

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Question: Enough Li in the future?

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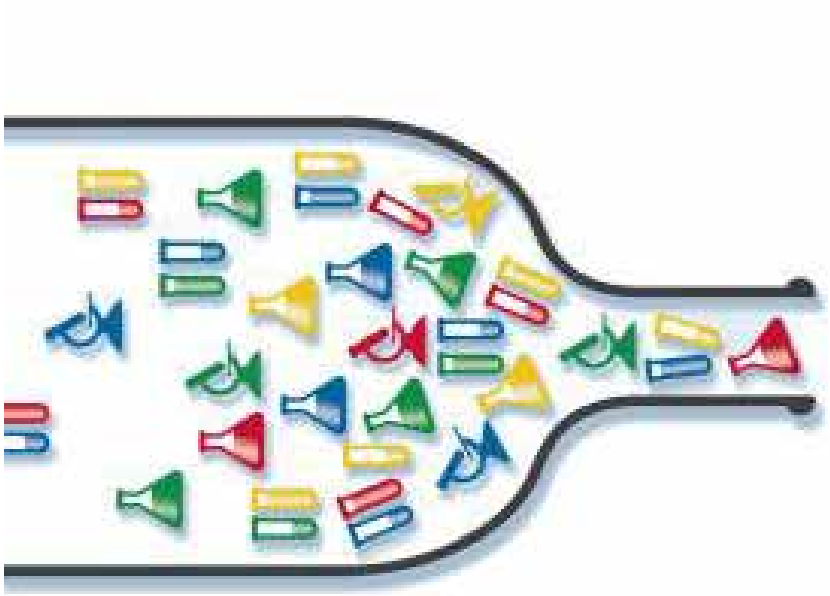
Availability of Lithium - a Bottleneck for Li-Ion Batteries (Emerging Key Technologies)?



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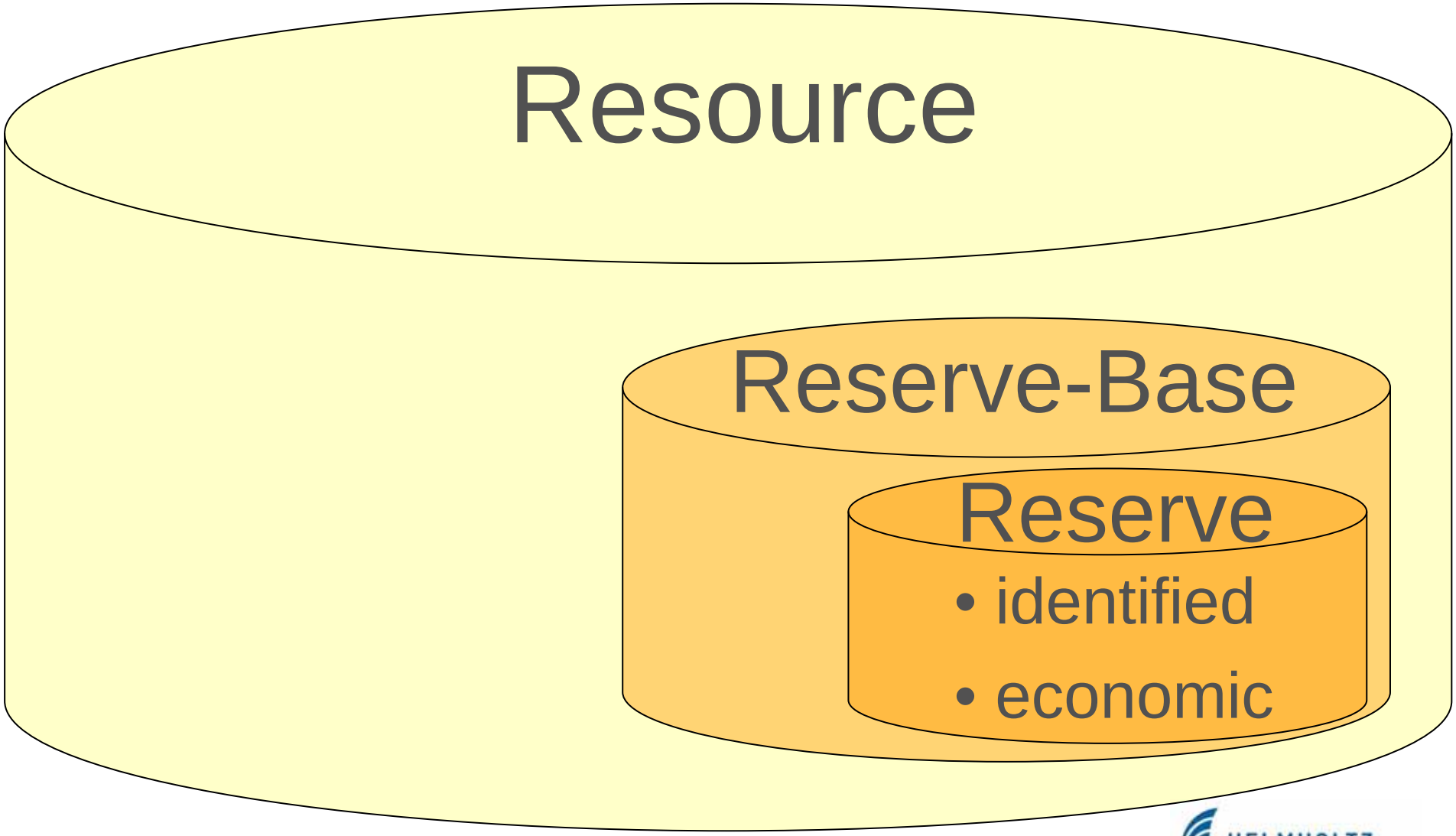
Availability of Lithium
Basic Questions

- Lithium Reserves and Resources?
- Consumption (past, present, future)?
- Recycling?

Reserve / Resource



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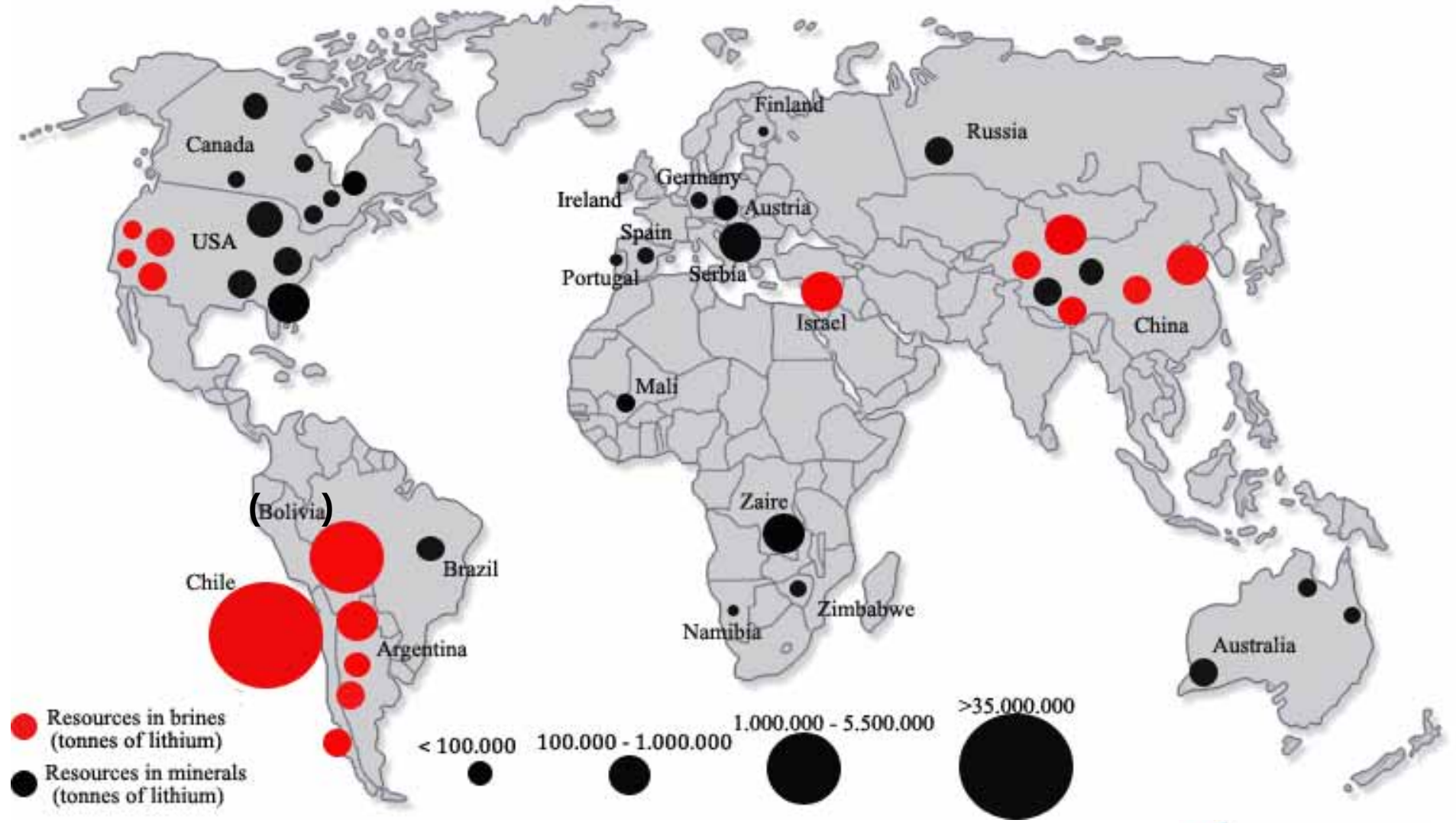
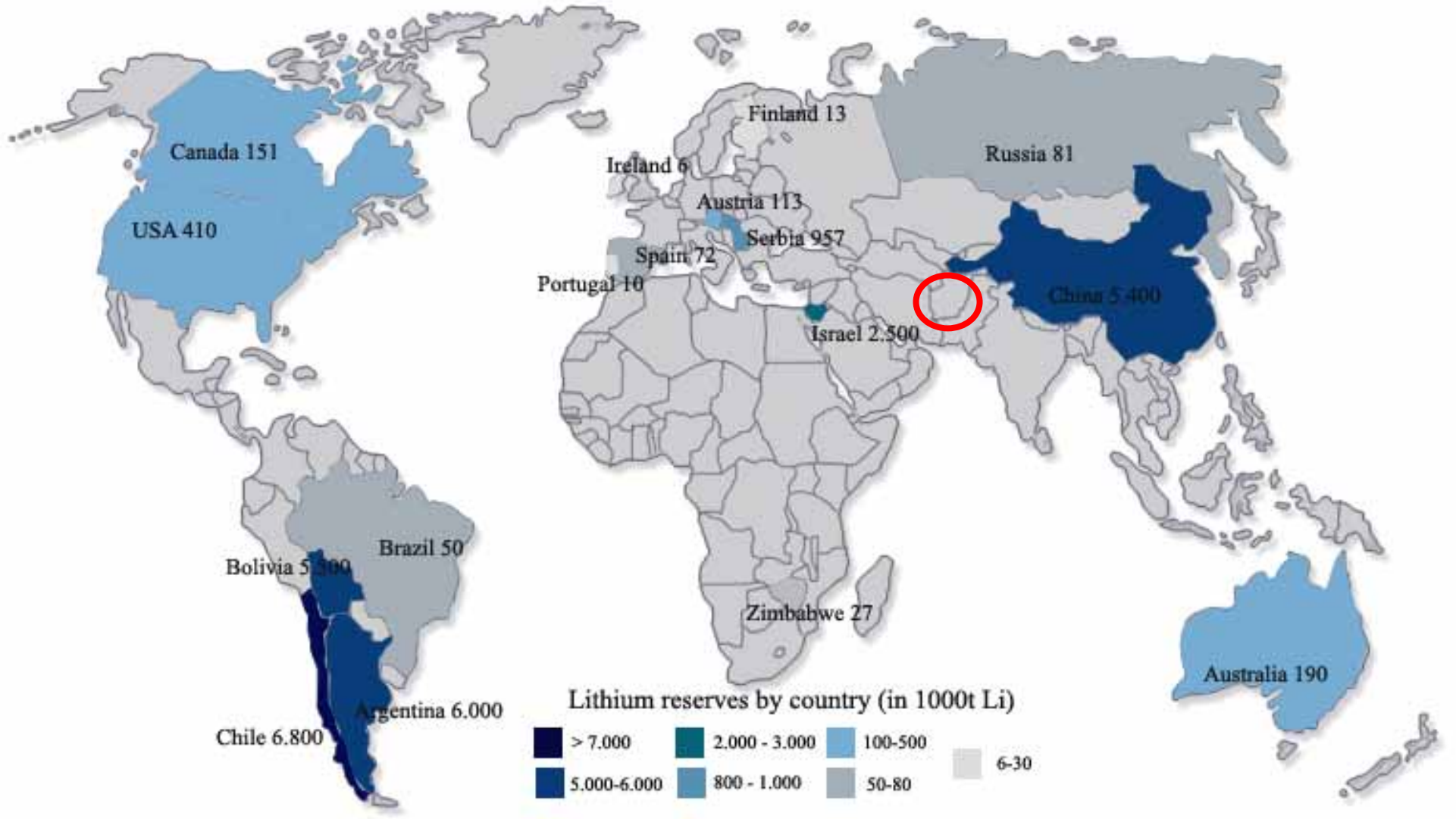
The Case of Lithium – World Resources



Source: Yaksic & Tilton 2009 and others

The Case of Lithium – World Reserven



Source: USGS 2010, Haber 2009 and others

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World Li Resources/Reserves

Source	Lithium content *(metric tons)*			
	Reserves	Reserve base	Resources	Reserves & Resources
USGS 2009	4,100,000	11,000,000	13,760,000	
Roskill 2006	4,100,000	11,000,000	13,000,000	
Roskill 2009 (cit. by Chemetall 2009 (online))	30,000,000			
Tahil 2007	6,800,000	15,000,000		
Tahil 2008	4,000,000		17,380,000	
Yaksik & Tilton 2008 (cit. in Evans 07/2008)				35,000,000
Evans 2008b				30,120,000
Evans 2008a	20,266,400		8,723,700	28,500,000
Evans 1978				10,600,000
Kogel et al. 2006 (based on data from Evans 1978)	2,536,200		10,647,100	
Garret 2004	16,915,400			
Hochschwimmer 2004	9,357,000			
Will 1996	7,000,000	14,000,000		
Solminihac 2009 (representative of SQM)	18,786,399*[1]		56,359,196*[1]	
Haber 2009 (representative of Chemetall)	28,400,000		28,400,000	
FMC 2009	16,077,964*[1]			

*[1] Figures for lithium are calculated from LCE (lithium carbonate equivalent) considering a general conversion factor of 5.323

Source: Weil, Ziemann, Schebek 2009

Recoverable Lithium?

Recovery rate Lithium (Yaksic & Tilton 2009)

- Minerals (pegmatites): 50%
- Minerals (hectorites): 50%
- Brines : 45%

Resources in Germany („little hope“)

Erzgebirge, Sachsen

- > 50.000 t Lithium
- Economic ?

Zinnwaldit

(Fluor, Chlor, Lithium, Bor, Beryllium)

Resources/Reserves in Bolivian („big hope“)

Salar de Uyuni, Bolivian

- 5.500.000 t Lithium
- Economic?

Problems (in comparison to Chile):

- Lower Li concentrations
- Higher magnesium content
- Higher annual precipitation

„Freiberger Kegel“
Lithium extraction in Salar de Uyuni

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BUSINESS + POLITICS

Pentagon 'Discovers' Huge Lithium Deposit in Afganistan

U.S. Identifies Vast Riches of Minerals in Afghanistan

Tyler Hicks/The New York Times

A bleak Ghazni Province seems to offer little, but a Pentagon study says it may have among the world's largest deposits of lithium.

By JAMES RISEN
Published: June 13, 2010

WASHINGTON — The United States has discovered nearly $1 trillion in untapped mineral deposits in Afghanistan, far beyond any previously known reserves and enough to fundamentally alter the Afghan economy and perhaps the Afghan war itself, according to senior American government officials.

NYDailyNews.com
DAILY NEWS

Afghanistan mineral deposits worth potentially $1 trillion, according to U.S. geologists

BY Sean Alfano
DAILY NEWS STAFF WRITER

Monday, June 14th 2010, 7:26 AM

14. Juni 2010, 13:30 Uhr

WELT ONLINE

In den Nachrichten: WM 2010 | Walter Mixa | Hannelore Kraft | Vuvuzela

12:04 | GOLD, KUPFER, LITHIUM

Rohstoffe mit Billionen-Wert in Afghanistan entdeckt

Lithium, Gold, Kupfer, Eisen

Afghanistan sitzt auf gigantischen Bodenschätzen

Zur Abwechslung können die USA Positives aus Afghanistan berichten: US-Geologen haben Gold-, Kupfer-, Lithium- und Eisenvorräte entdeckt, die einen Billionen-Wert haben sollen. Das Pentagon spricht von "atemberaubenden Möglichkeiten".

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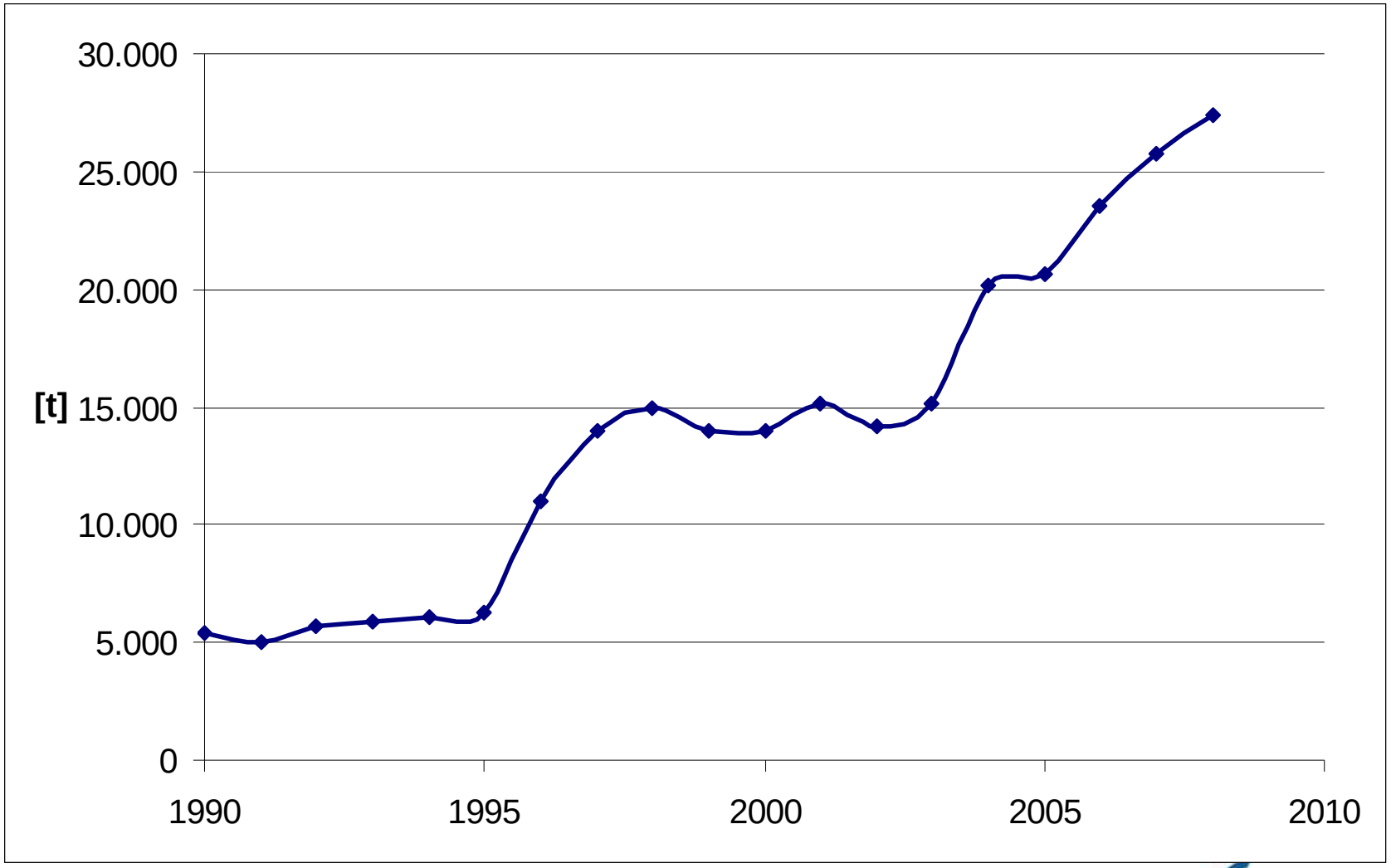
Availability of Lithium
Basic Questions

- Lithium Reserves and Resources?
- Consumption (past, present, future)?
- Recycling?

Production of Lithium



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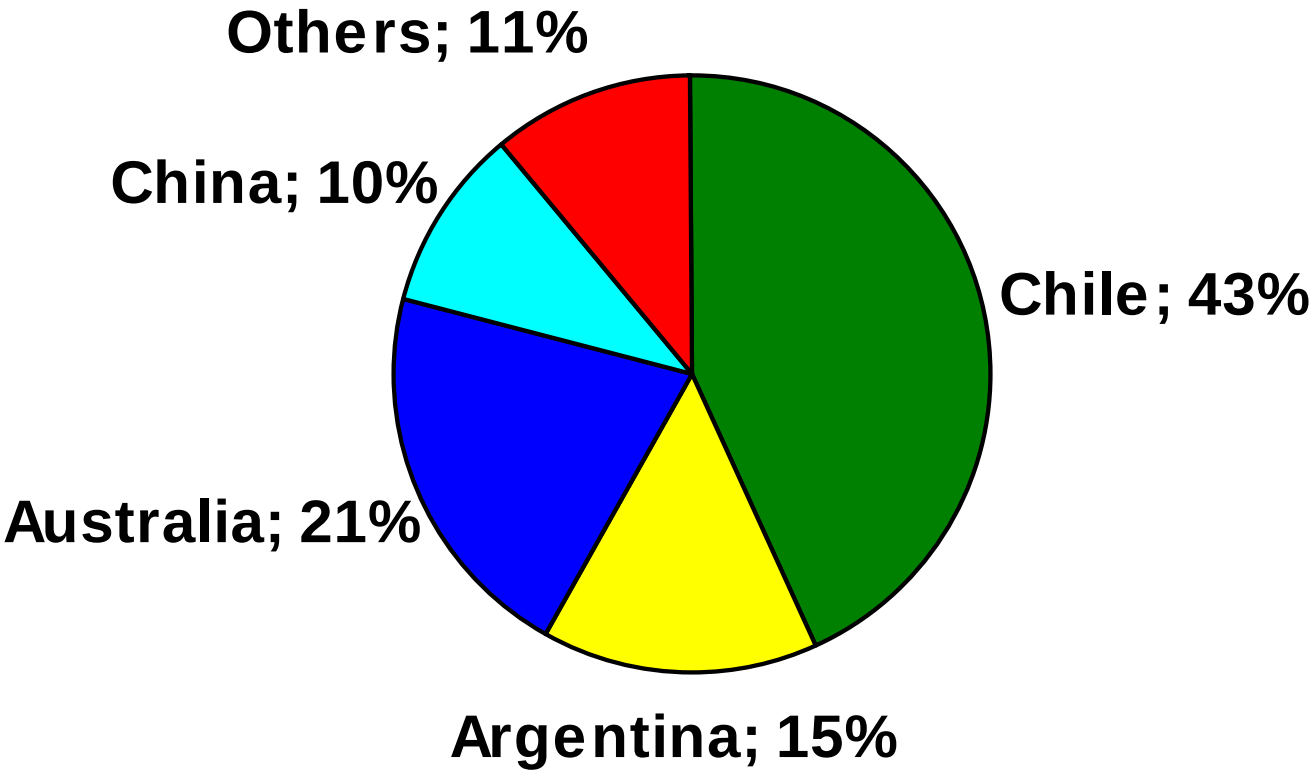
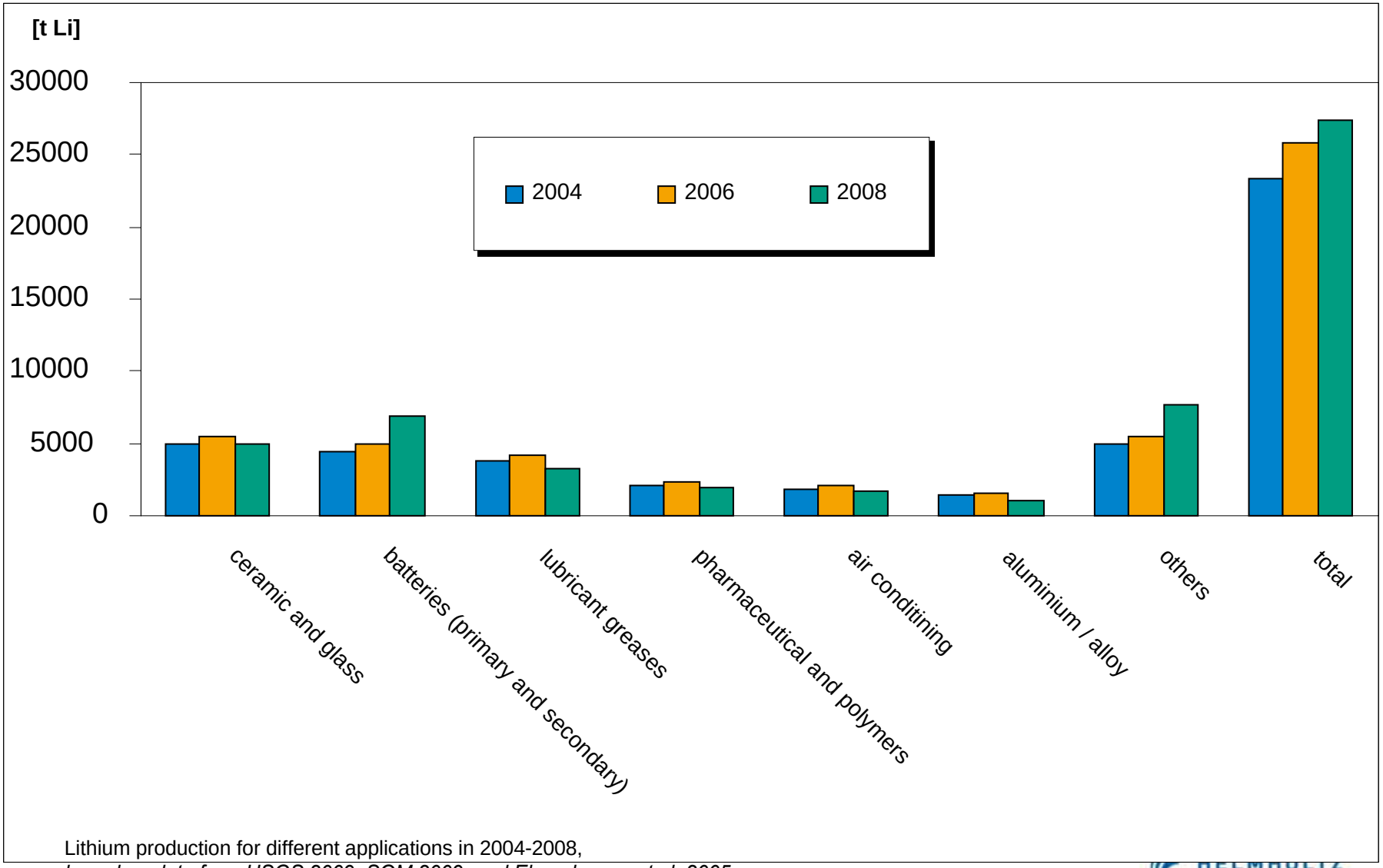
Lithium Production



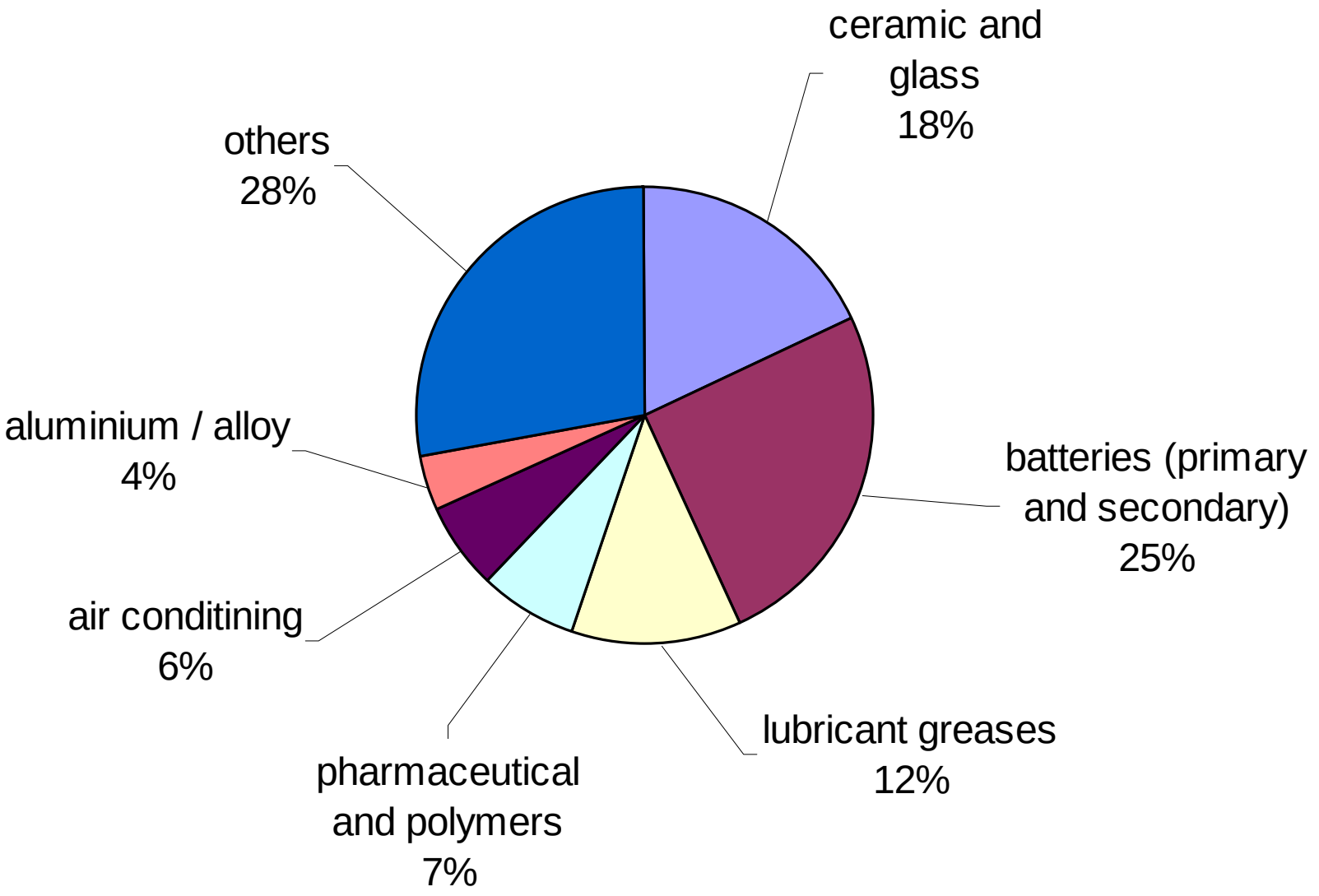
SQM 2009

Lithium Production and Use



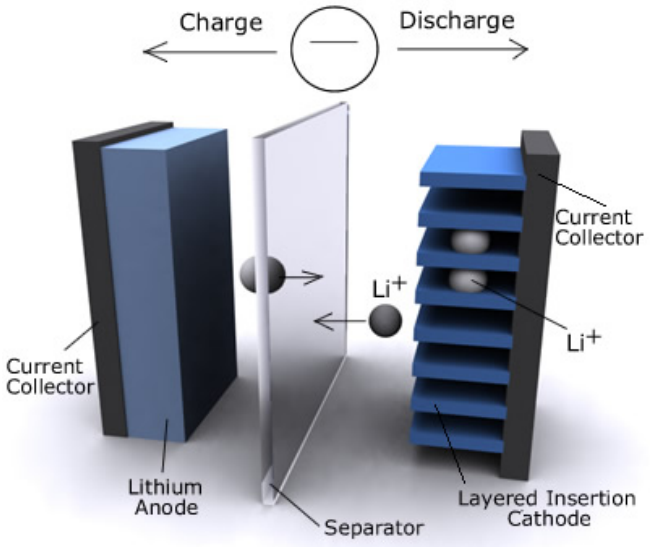
Lithium production for different applications in 2004-2008,
based on data from USGS 2009, SQM 2009, and Ebensberger et al. 2005

Application fields of Lithium 2007 „Basic demand“



Future Consumption?

Lithium-Batteries for Electric Vehicles



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Li-Ion secondary batteries

High Energy Battery (Full EV)

- Max. Energy Density ~ 0.2 kWh/kg
- Max. Peak Power Density ~ 0.5 - 1.3 kW/kg

High Power Battery (Hybrid)

- Max. Energy Density ~ 0.08 kWh/kg
- Max. Peak Power Density ~ 3 kW/kg

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Quelle: Deutsche Bank Studie

EVONIK

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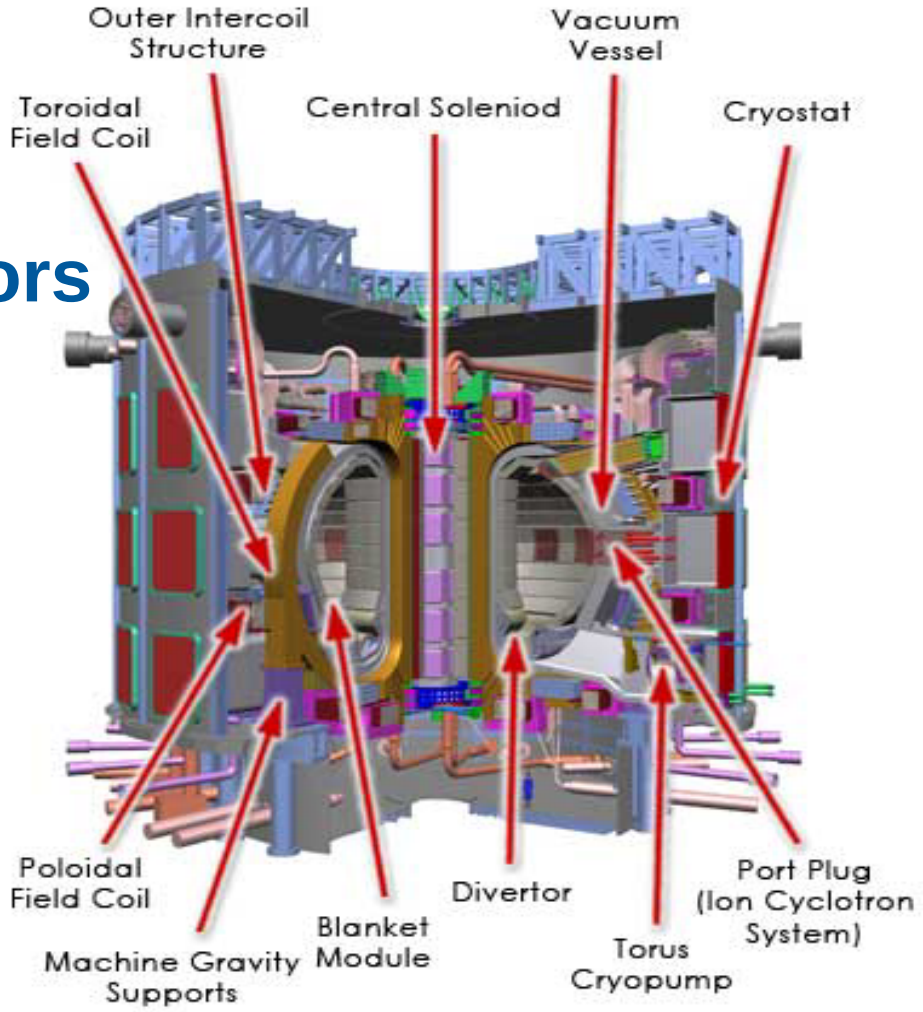
Ressource Competition
Future Technologies

Lithium for Fusion Reactors

for tritium production:

$$^{6}Li + n \rightarrow {}^{4}He + T + 4.78\ \text{MeV}$$



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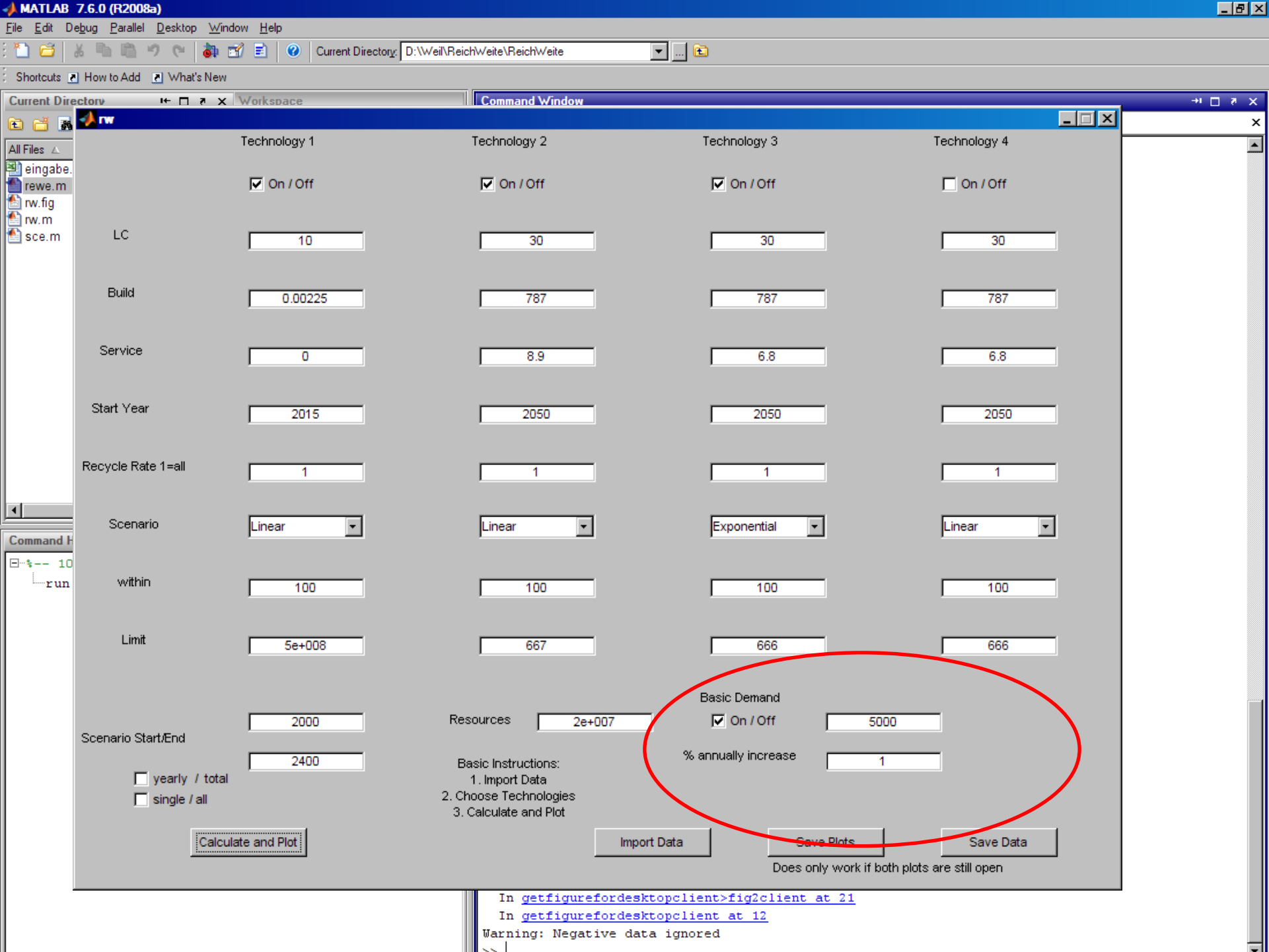
Three considered „technologies“

- „Basic demand“ technologies: glass, ceramic, aluminium production, aluminium alloy, grease, medicine, primary battery, rechargeable batteries for cell phone and laptop
- New technology: Li-Batteries for EV
- Future technology: Fusion reactors


MATLAB 7.6.0 (R2008a)
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Shortcuts How to Add What's New
Current Directory
Workspace
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rewe.m
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Technology 1
Technology 2
Technology 3
Technology 4
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LC
10
30
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Build
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Service
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8.9
6.8
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Start Year
2015
2050
2050
2050
Recycle Rate 1=all
1
1
1
1
Scenario
Linear
Linear
Exponential
Linear
within
100
100
100
100
Limit
5e+008
667
666
666
Scenario Start/End
2000
2400
yearly / total
single / all
Resources
2e+007
Basic Instructions:
1. Import Data
2. Choose Technologies
3. Calculate and Plot
Basic Demand
On / Off
5000
% annually increase
1
Calculate and Plot
Import Data
Save Plots
Save Data
Does only work if both plots are still open
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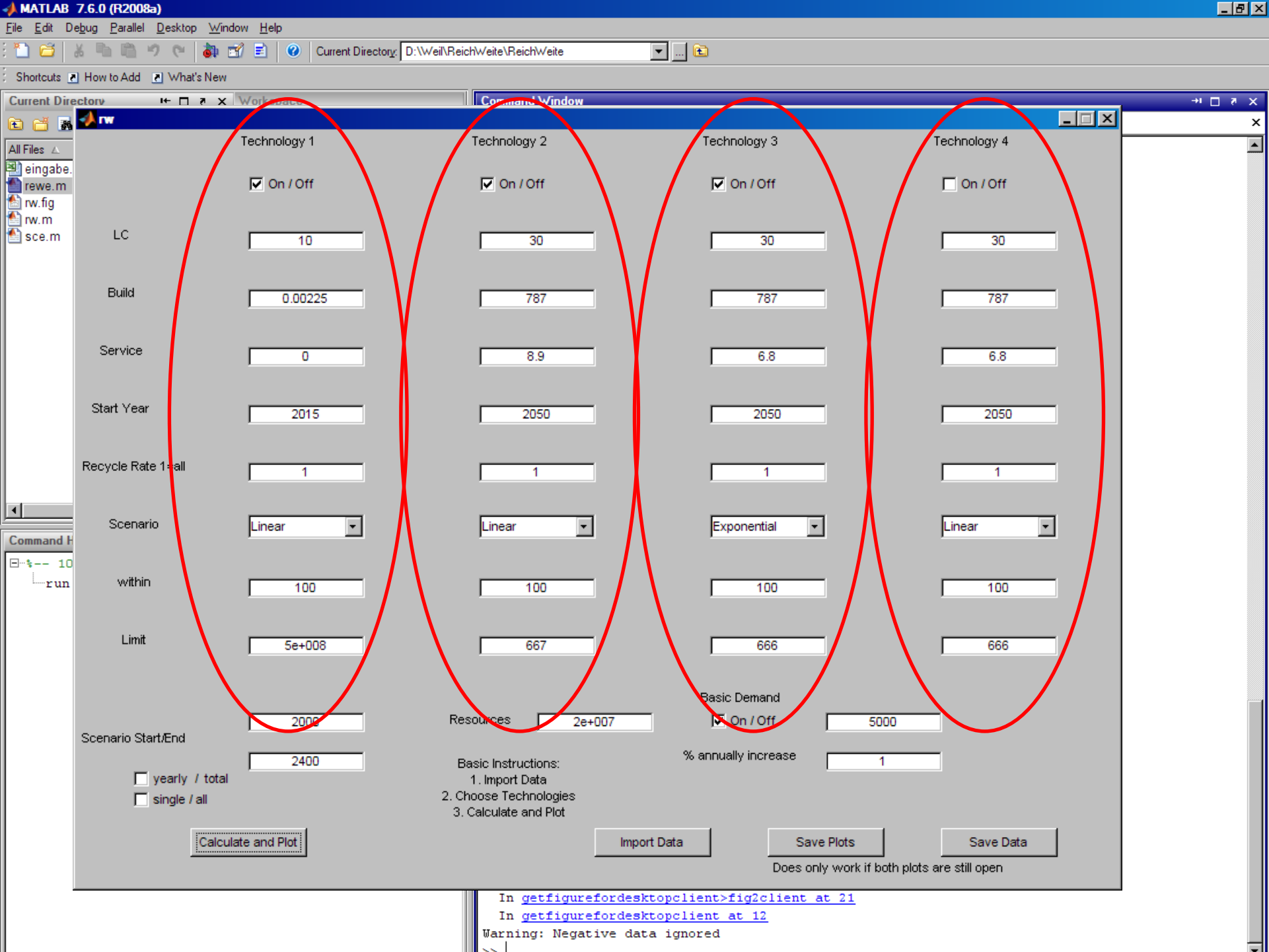
Warning: Negative data ignored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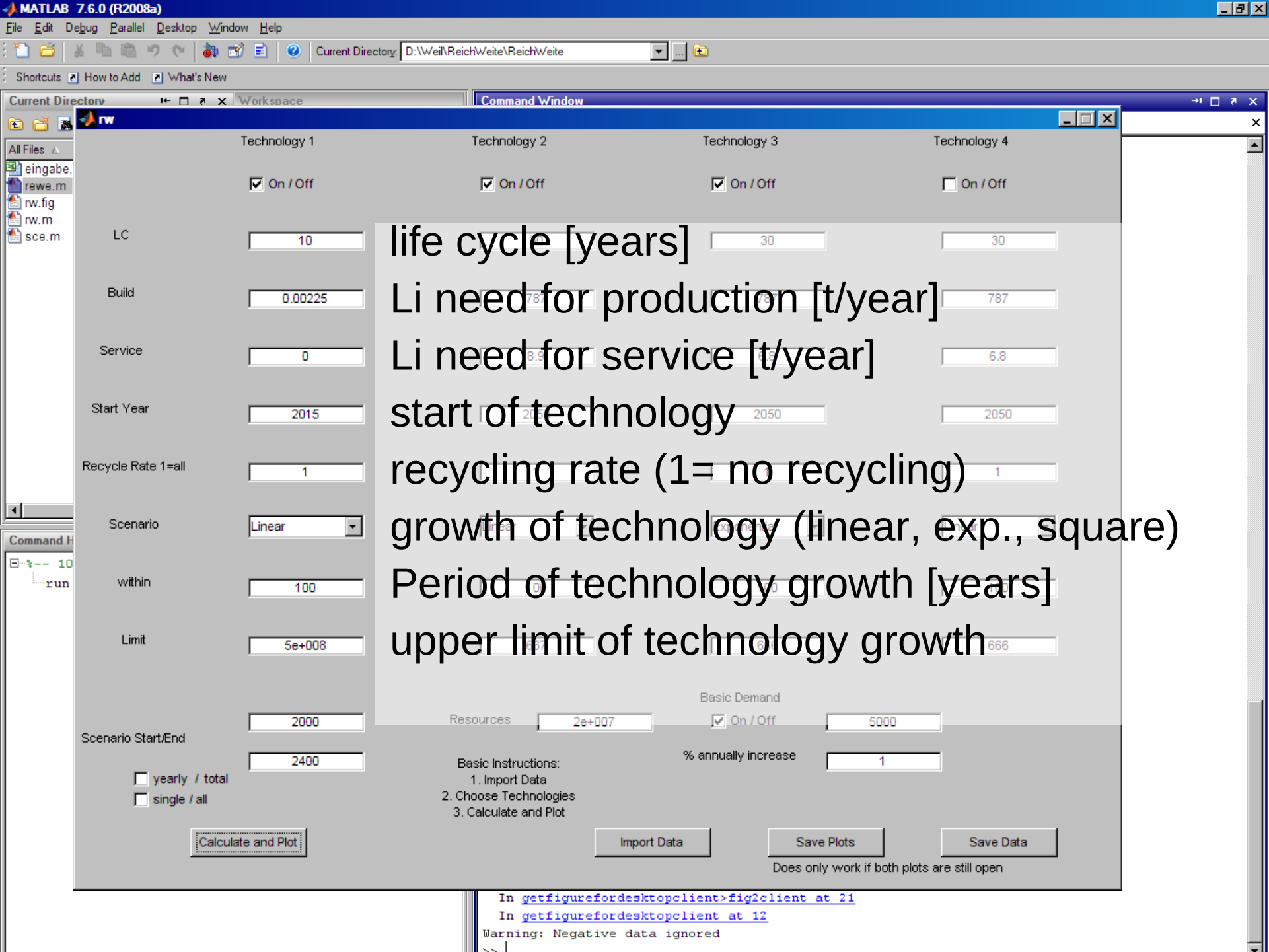


life cycle [years]

Li need for production [t/year]

Li need for service [t/year]

start of technology

recycling rate (1= no recycling)

growth of technology (linear, exp., square)

Period of technology growth [years]

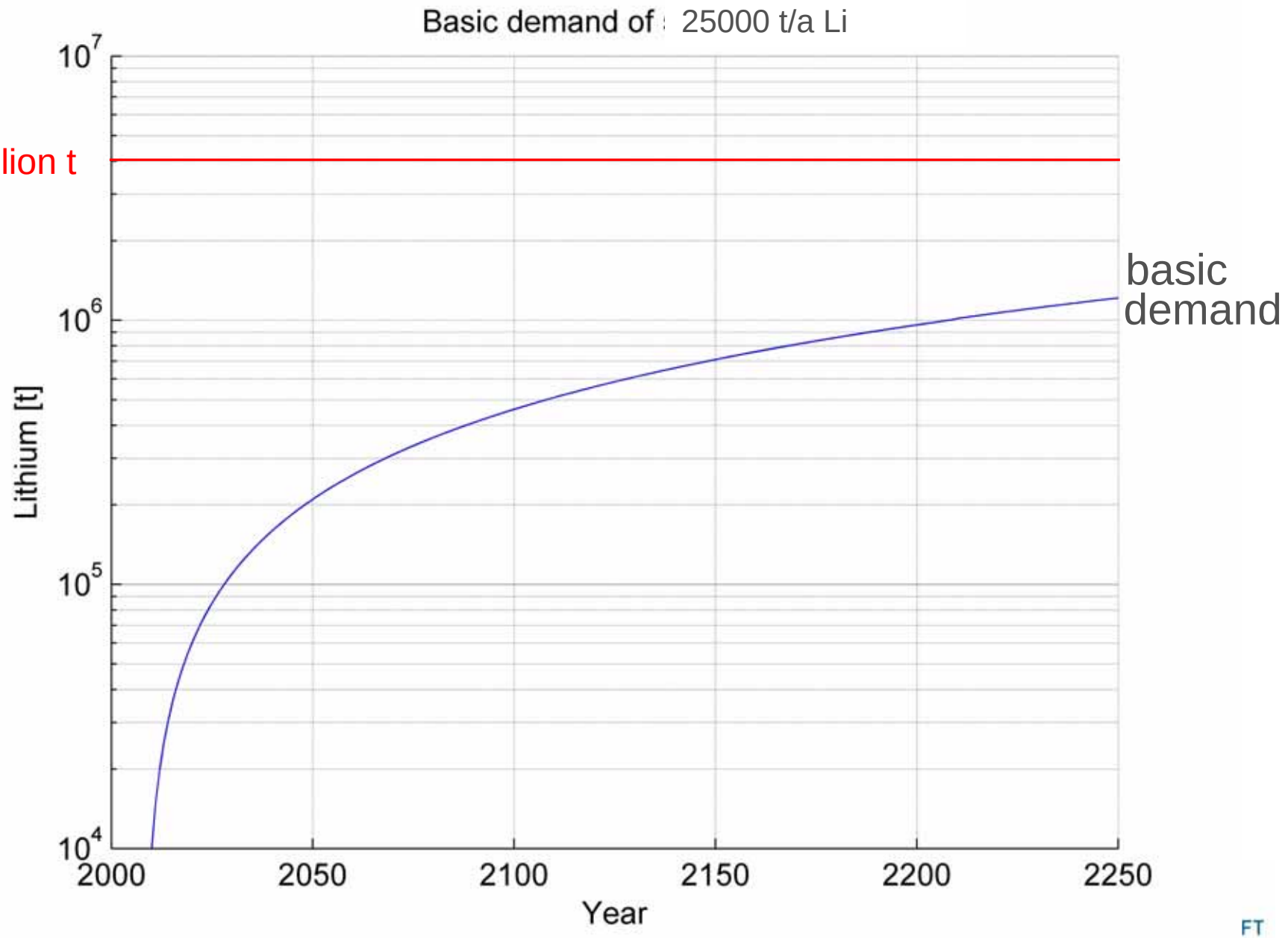
upper limit of technology growth

Scenario 1

Basic demand

(glass, ceramic, aluminium production, aluminium alloy, grease, medicine, primary battery, rechargeable batteries for cell phone and laptop)

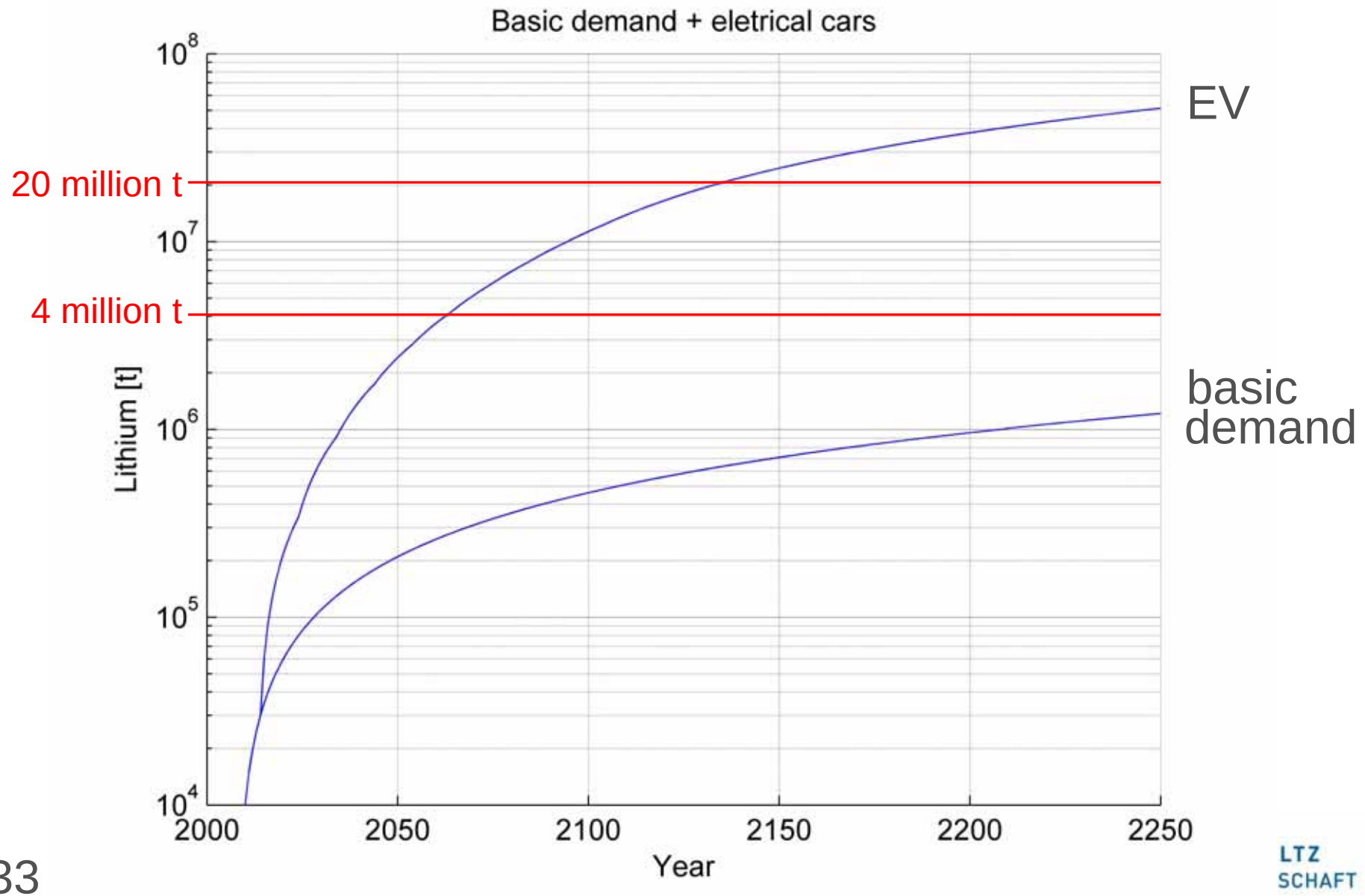
- 25000 t/year
- growth +3%/year
- starts 2008
- no Li recycling


Basic demand of 25000 t/a Li
4 million t
basic demand
Lithium [t]
Year
10^7
10^6
10^5
10^4
2000
2050
2100
2150
2200
2250

Scenario 2

Basic demand + electric vehicles

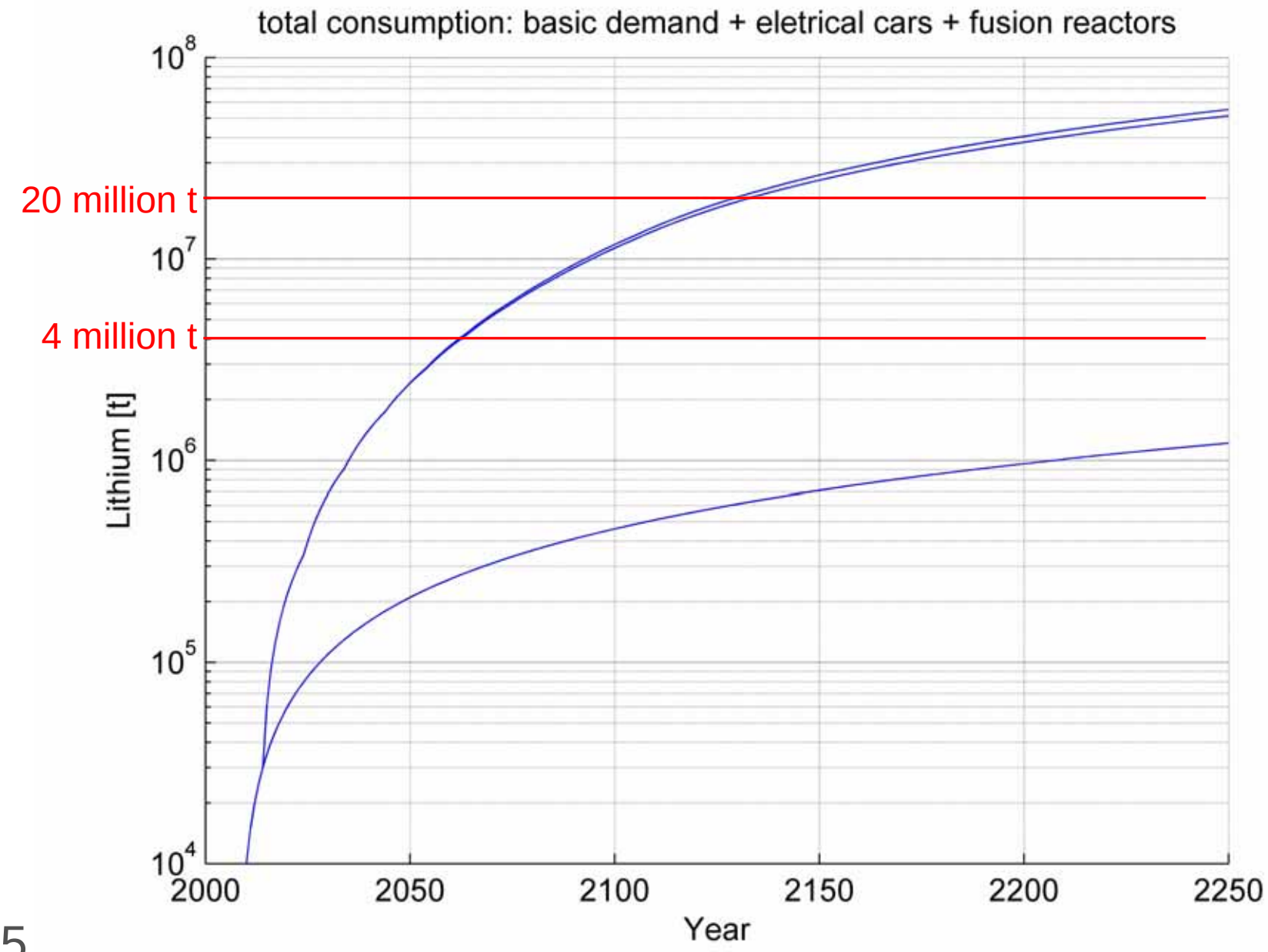
- 500 million electric vehicles in 100 years (with Li batteries), ~ 50% of present existing cars
- mass production of EV starts 2015
- exponential growth
- 50% Hybrid (1-3 kWh), 50% full EV (10-25 kWh)
- 0.3kg Li/kWh (0.15-1.5 kg)
- lifetime vehicles and Li batteries: 10 years
- no Li recycling


Basic demand + eletrical cars
EV
basic demand
20 million t
4 million t
Lithium [t]
Year
10^8
10^7
10^6
10^5
10^4
2000
2050
2100
2150
2200
2250

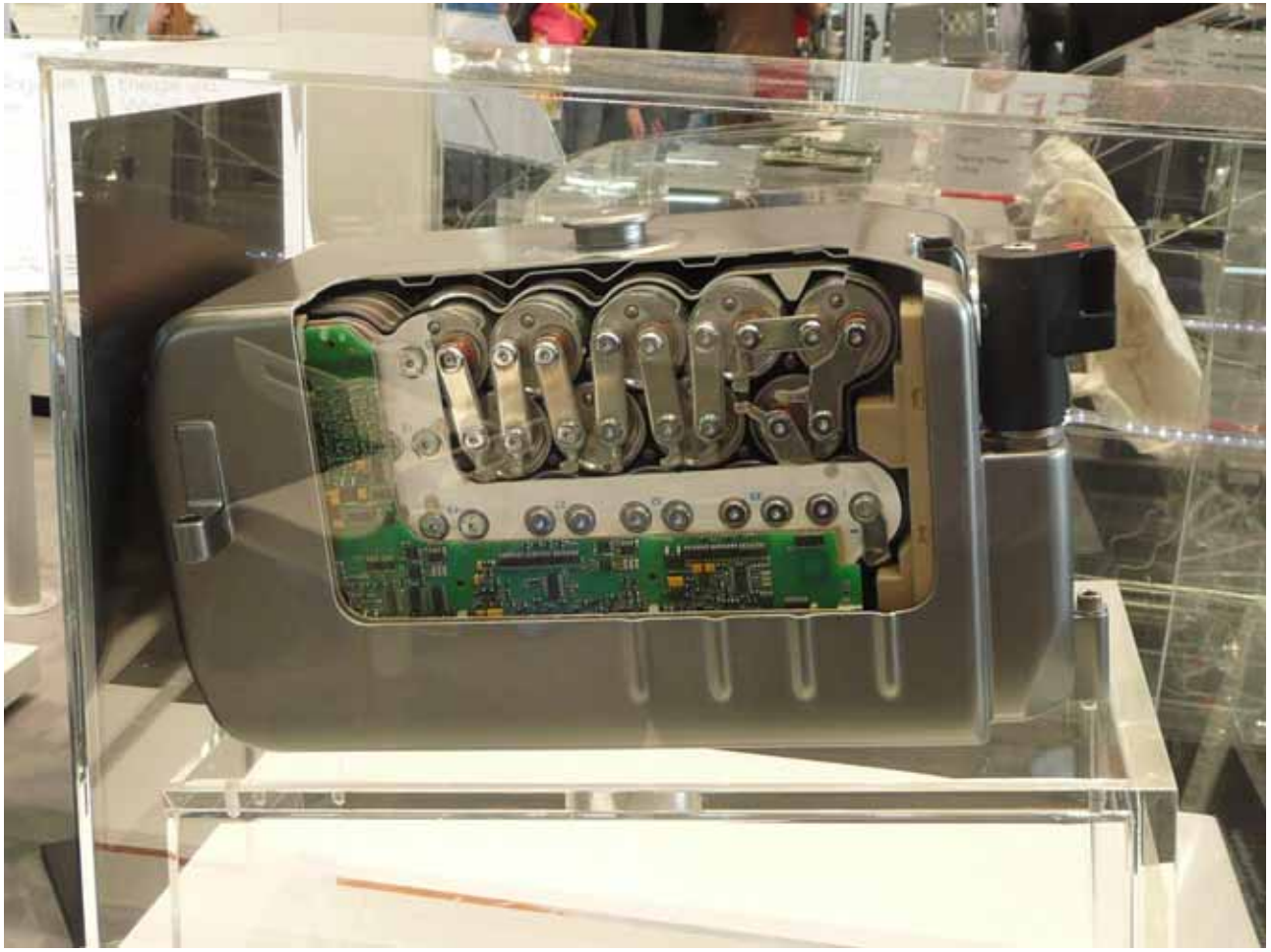
Scenario 3

Basic demand+electric vehicles+fusion reactors

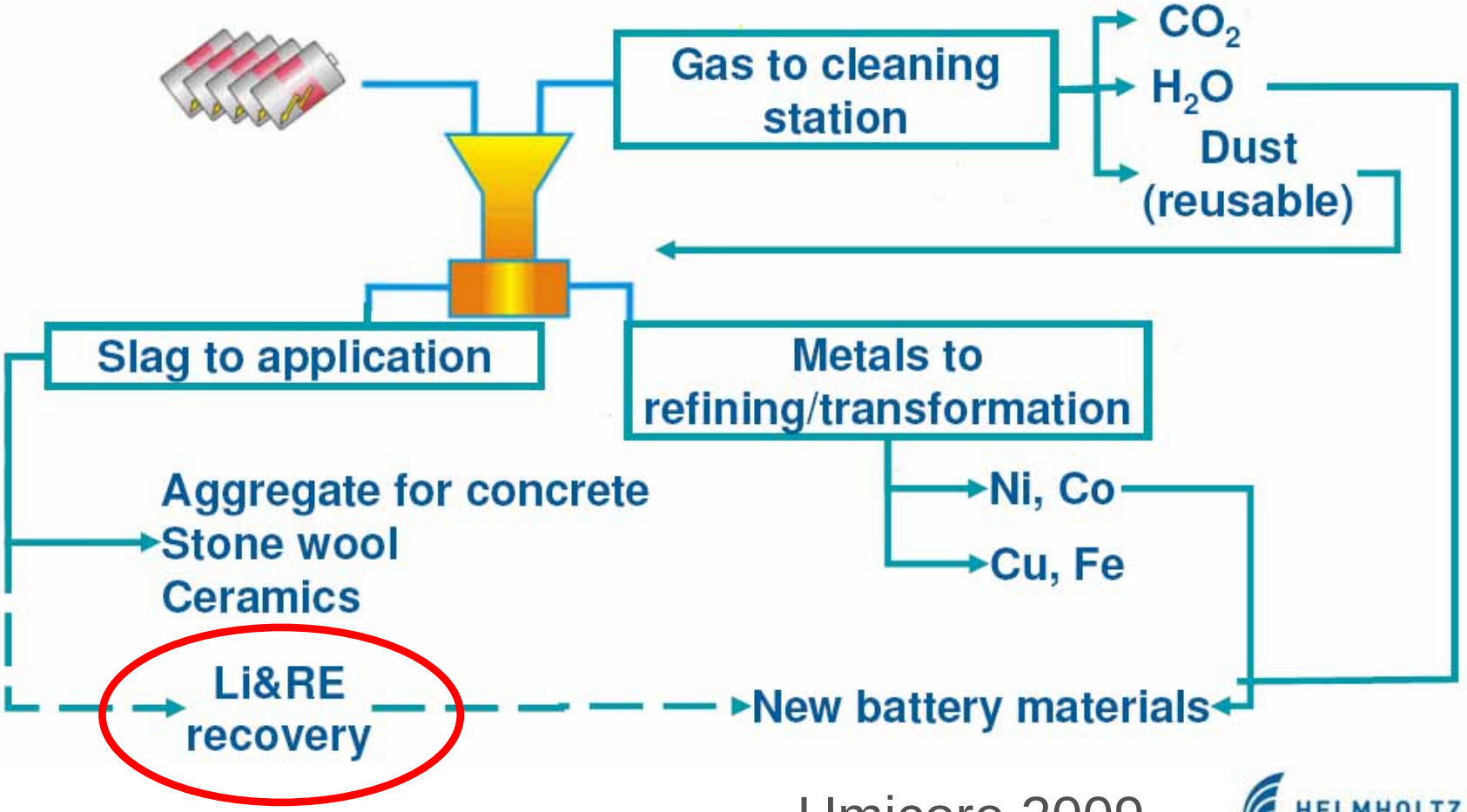
- 1000 GW in 100 years (~ 667 fusion reactors)
- 790 t Li/ reactor (blankets) and 9 t Li/reactor and year
- lifetime fusion reactors: 30 years
- fusion reactors starts with energy production 2050
- no Li recycling


total consumption: basic demand + eletrical cars + fusion reactors
20 million t
4 million t
Lithium [t]
10^8
10^7
10^6
10^5
10^4
2000
2050
2100
2150
2200
2250
Year

Recycling



The Umicore recycling process for Batteries



Umicore 2009

Li-Ion battery

Dismantling

→ electronics, steel casing

Battery cells
(anode, cathode, electrolyte, separator, protect casing)

Total discharge
against fire and explosion hazard

Deactivation
of lithium metall

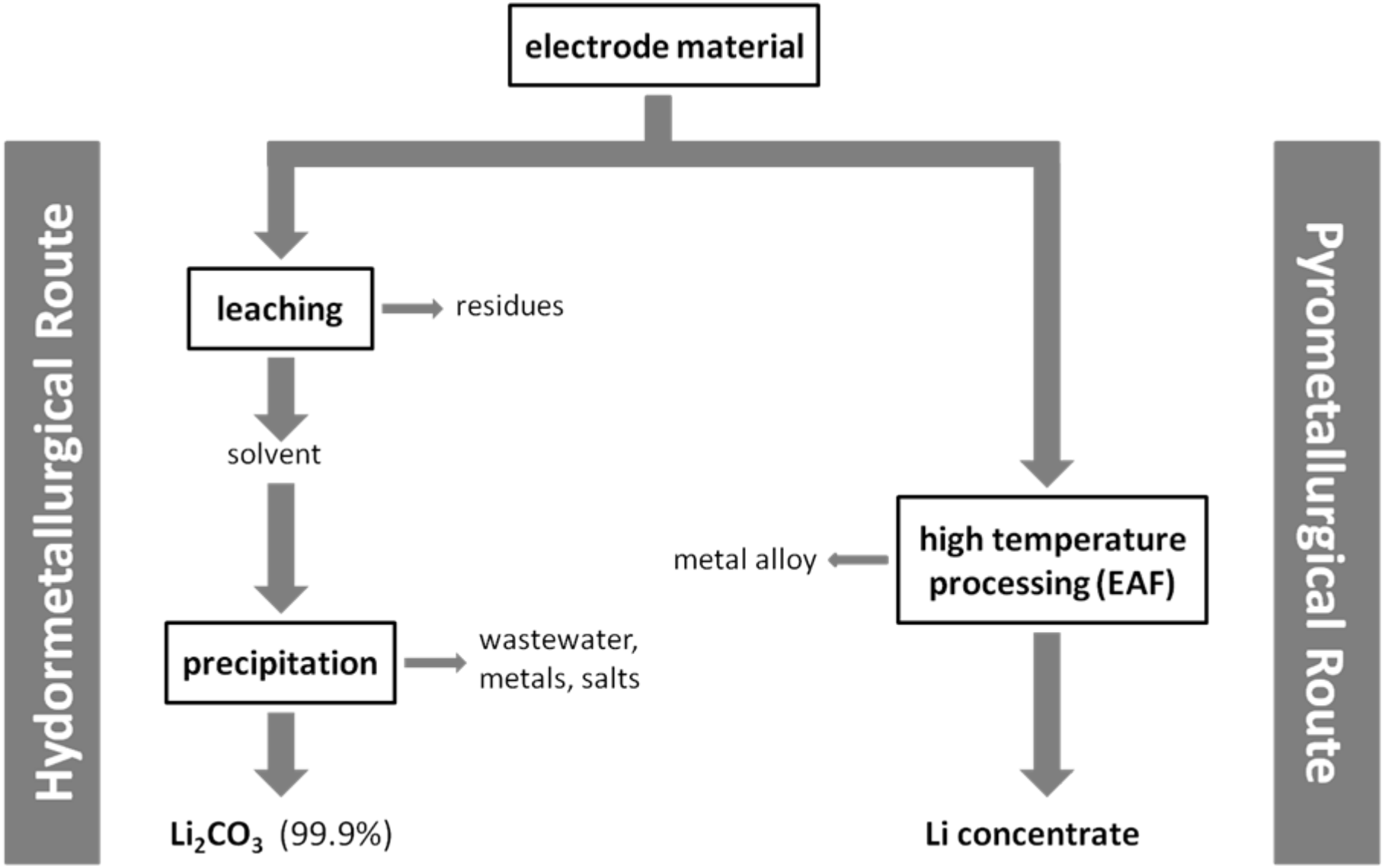
Destillation

→ electrolyte (recycled by a deep frozen condenser)

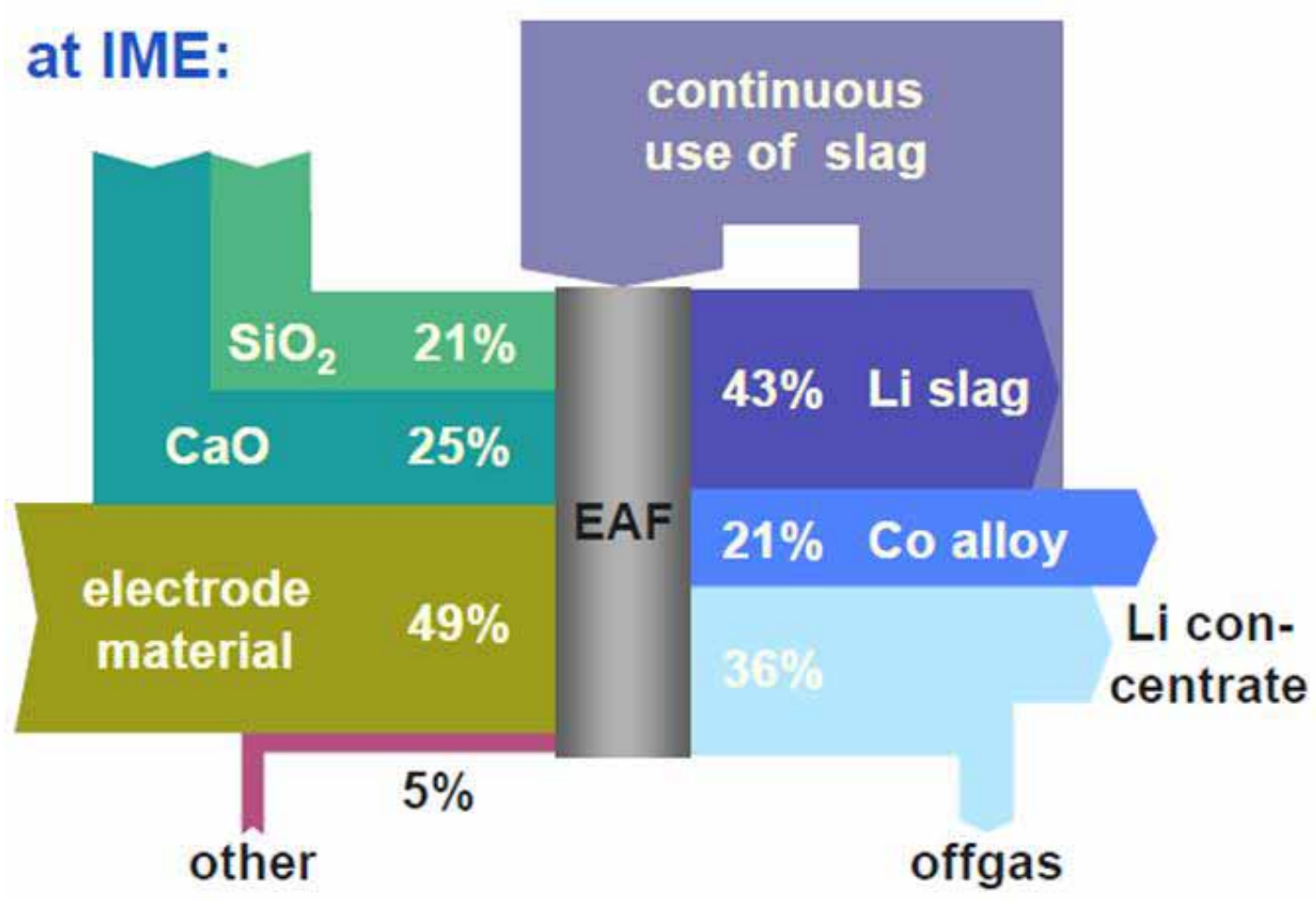
Conditioning
1. Pyrolisis to delete organic components (binder, separator)
2. Comminution

→ metal fraction (Cu, Al) → e.g. copper recycling company

Electrode material



ACCUREC GmbH / RWTH Aachen



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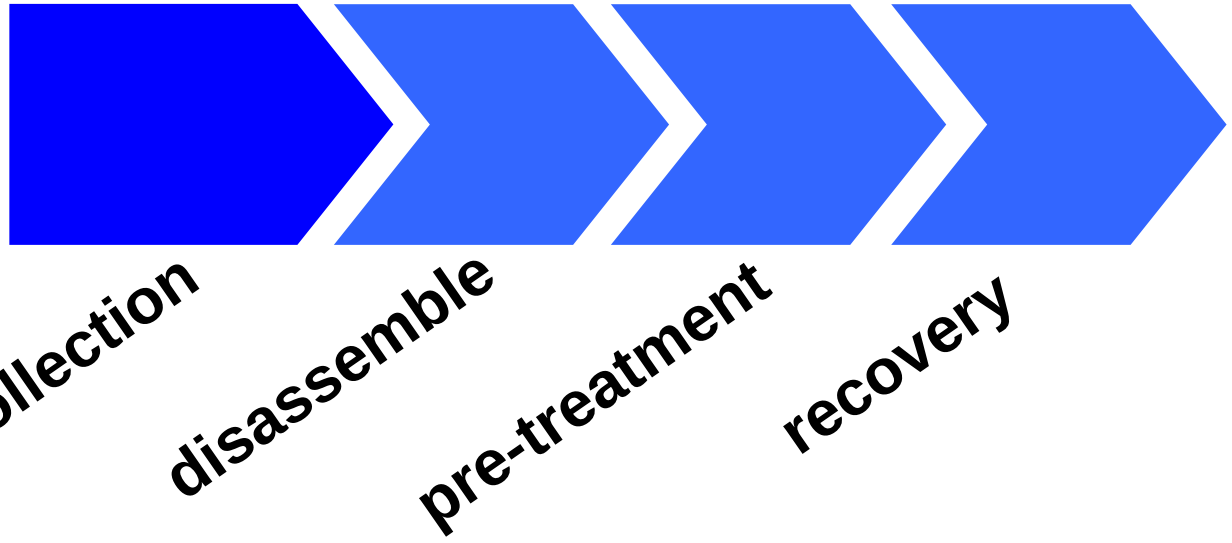
Lithium recycling rate
- Example -

90% X 90% X 90% X 70% = 51%



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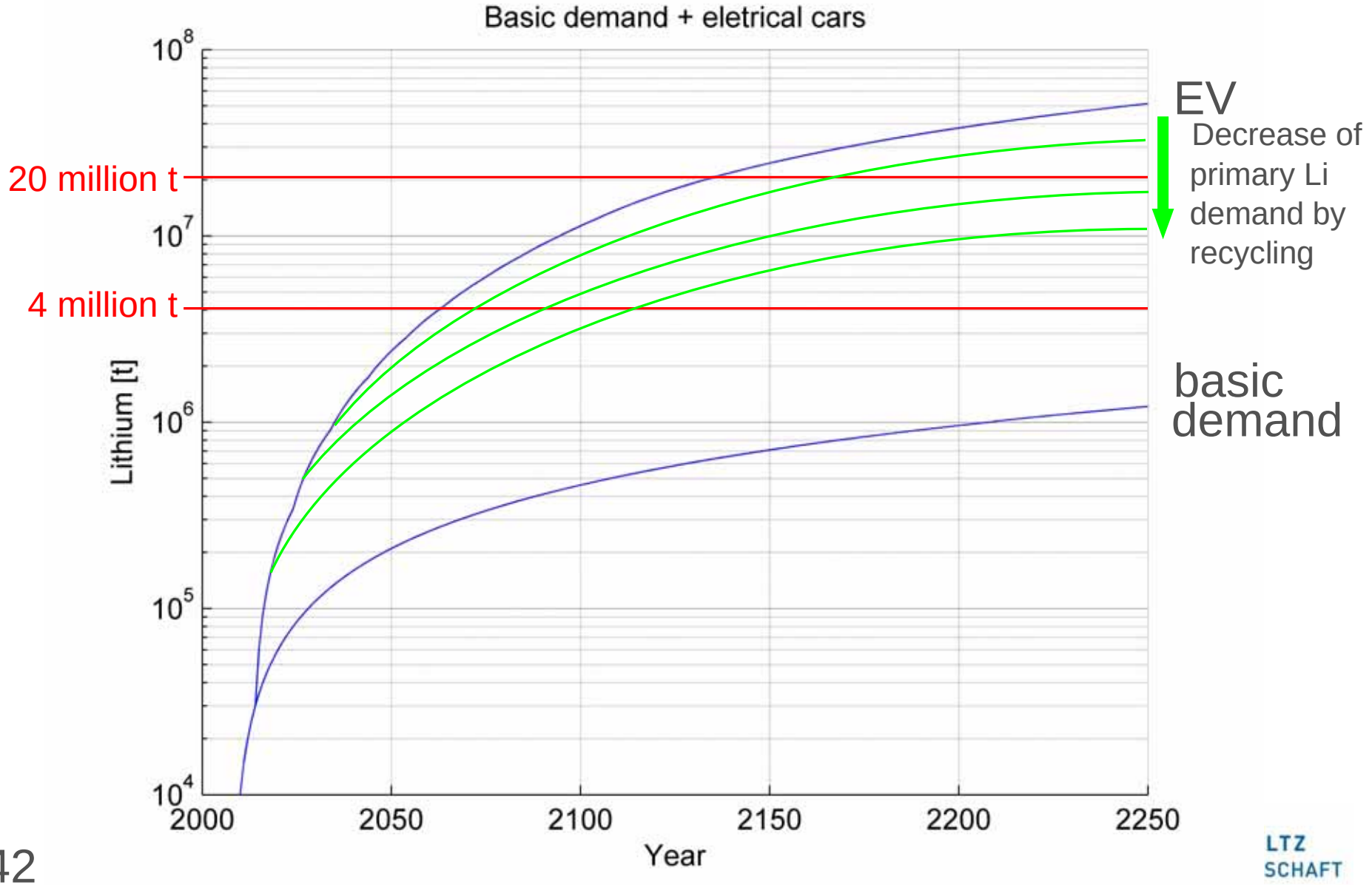
Effect of Lithium Battery Recycling



Summary

Mayor Li reserves and resources are concentrated in only a few countries

Present consumption pattern do not endanger confirmed reserves of Li

The production of Li-Ion batteries could significantly decrease Li reserves, as far as EV (with Li-Ion batteries) reach a high market penetration

Recycling could decrease significantly the use of primary Li and the dependency on imports