

ASTER



Analyse Systémique des Terres Rares
Flux et Stocks

Conférence de clôture
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The ASTER methodology and results for fluorescent lamp phosphors

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Presentation outline

1. Project objectives
2. Overview of methodology
3. Results for fluorescent lamp phosphors
4. Conclusions

1. Objectives of the ASTER project

- Explore, using MFA (Material Flow Analysis), flows and stocks of certain rare earths at the scale of the EU-27
- Build « Sankey diagrams » to visualize flows and stocks to help appreciate criticality and recycling potentials
- Develop innovation with respect to two specific aspects:
 - ✓ Account for “lithospheric stocks”
 - ✓ Account for “epistemic uncertainties” (related to the incomplete/imprecise nature of available information)

- Motivation

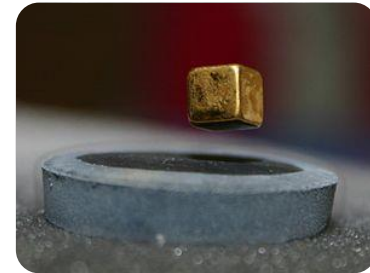
- ✓ REE flows and stocks have been studied mainly at a global scale
- ✓ A systemic analysis, associating both primary and secondary sources, is required for reliable decision-making regarding raw material management and policy-making
- ✓ MFAs can help identify potentials for recycling and also the complementarity between primary and secondary sources
- ✓ The issue of uncertainty treatment in MFA (as in LCA) is an important technical and scientific issue

- Primary focus: applications for which there exist recycling potentials

- ✓ Phosphor powders (Tb, Eu, Y)



- ✓ Permanent magnets (Nd, Pr, Dy)



- ✓ NiMH batteries (Nd, Pr)



- Main deliverables

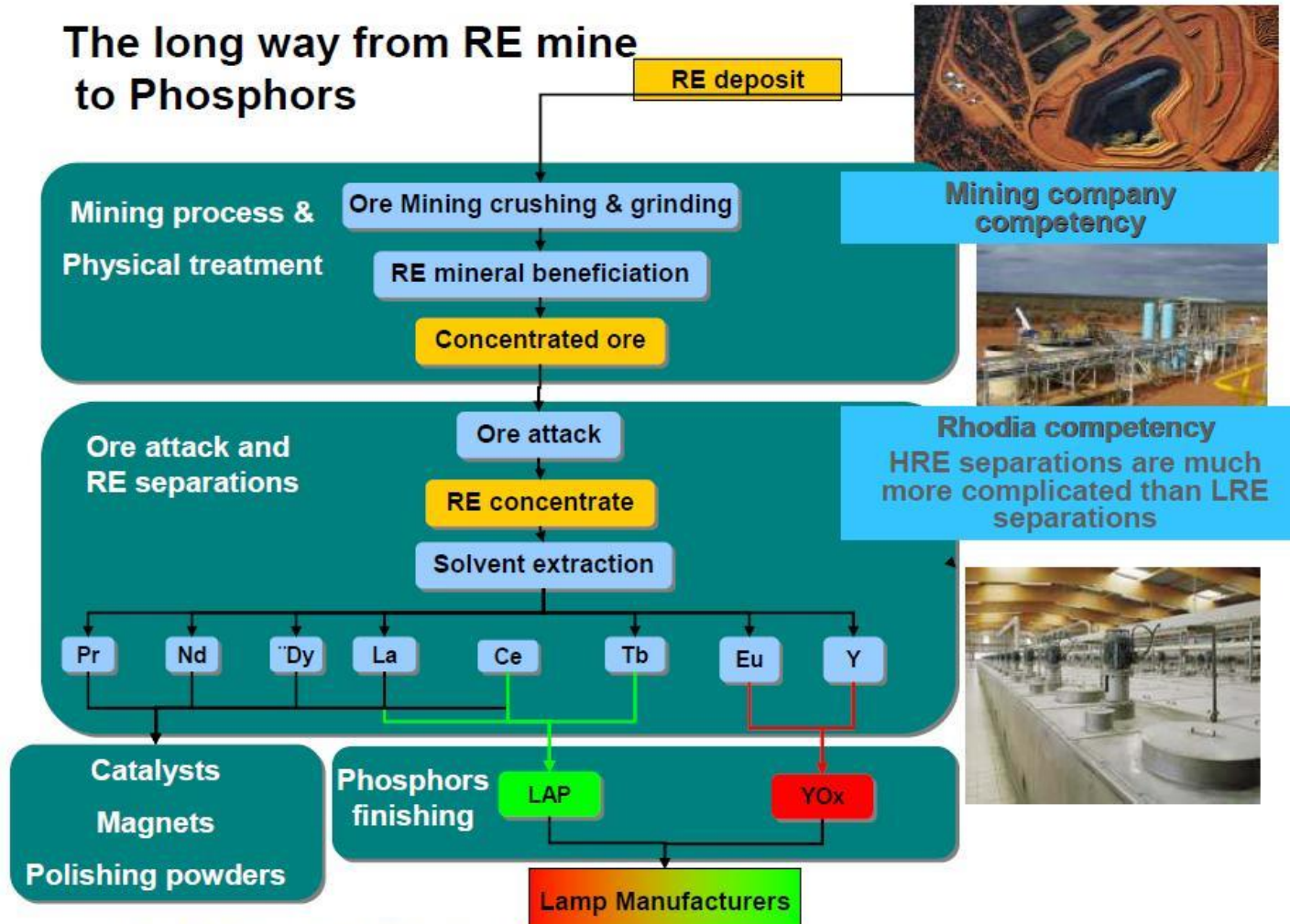
- ✓ Estimates of primary resource potentials in the EU (*see Tuduri et al. and Goodenough; this conference*)
- ✓ Sankey diagrams (*see also Planchon et al., this conference*)
- ✓ A methodology for data reconciliation in MFA with “epistemic uncertainties” (*see Dubois et al., this conference*)
- ✓ Prospective analysis of REE supply/demand trends at a 5-10 year horizon (*see Rollat et al., this conference*)
- ✓ Dissemination (web page, conferences, journals, etc.)

2. Overview of methodology

- Data mining: multiple data sources
 - ✓ Assessment of RE exploration project data, analysis of existing deposits and occurrences,
 - ✓ Statistical data EUROSTAT, GTA, Roskill, USGS, etc.
 - ✓ Yearly reports of companies (hard disk drives, windpower generators, portable phones, lamps, etc.)
 - ✓ Scientific papers (compositions, proportions of components in products, etc.)
 - ✓ ...
- Comparison with previously-published data
- Data reconciliation (*see Dubois et al., this conference*)
- Consistency verification with industry experts

- Knowledge regarding production processes

The long way from RE mine to Phosphors



Alain Rollat – Phosphor Summit 2012/03/21 – How to satisfy the Rare Earths demand

- Information on compositions

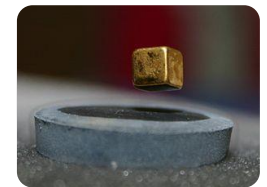
- ✓ Phosphors

Powder	La ₂ O ₃ (%)	CeO ₂ (%)	Eu ₂ O ₃ (%)	Tb ₄ O ₇ (%)	Y ₂ O ₃ (%)	Proportion in the Trichrom. mix (%)
1	-	-	2.5	-	-	33.0
2	-	14.9	-	8.1	-	8.4
3	39.2	21.4	-	10.7	-	15.0
4	-	-	6.1	-	93.9	43.6



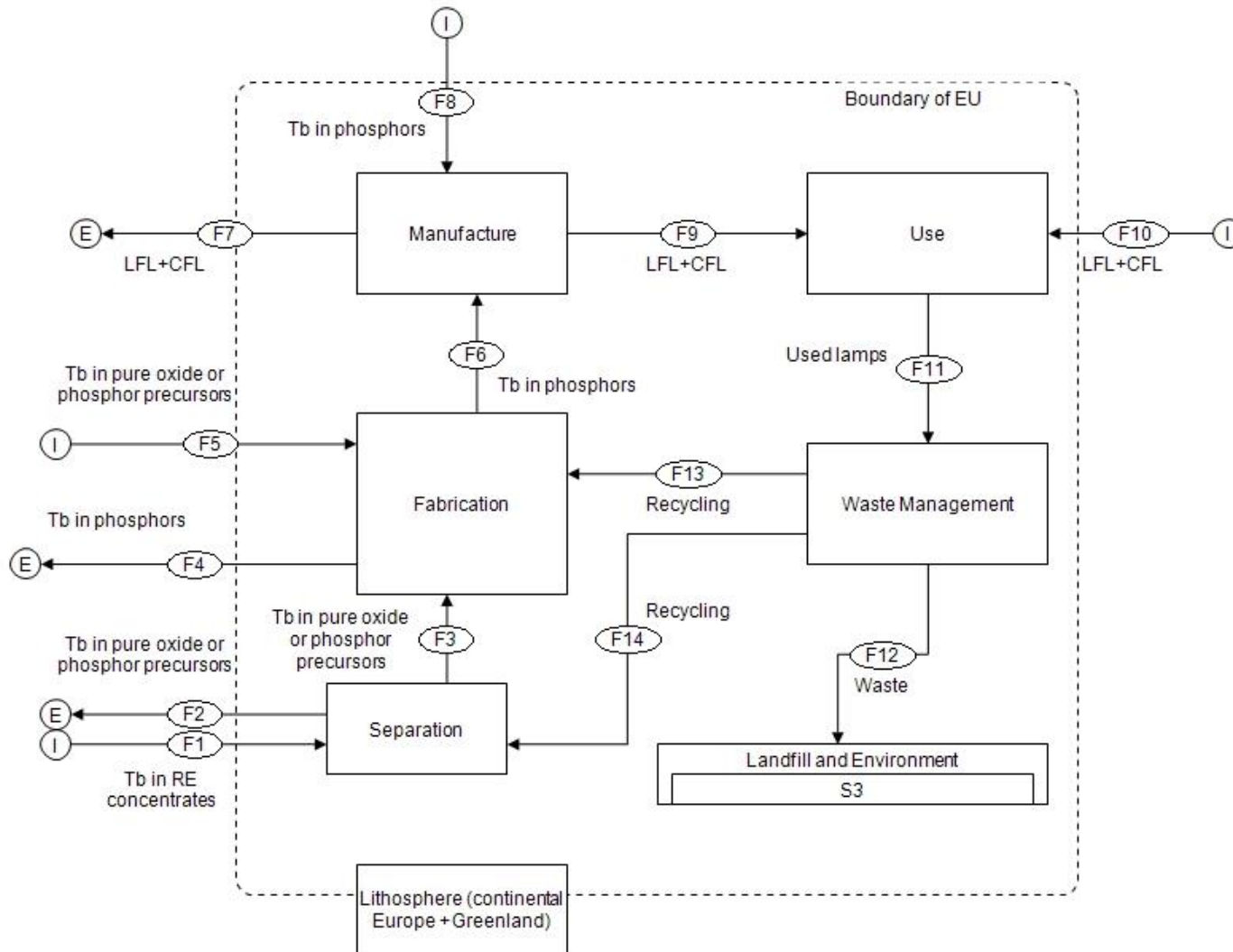
- ✓ Permanent magnets and NiMH batteries

Application	La (%)	<u>Ce</u> (%)	<u>Pr</u> (%)	<u>Nd</u> (%)	Tb (%)	<u>Dy</u> (%)
<u>NdFeB magnets</u>	-	-	5	20	1	5
NiMH batteries	45.1	24.3	4.2	10.3	-	-



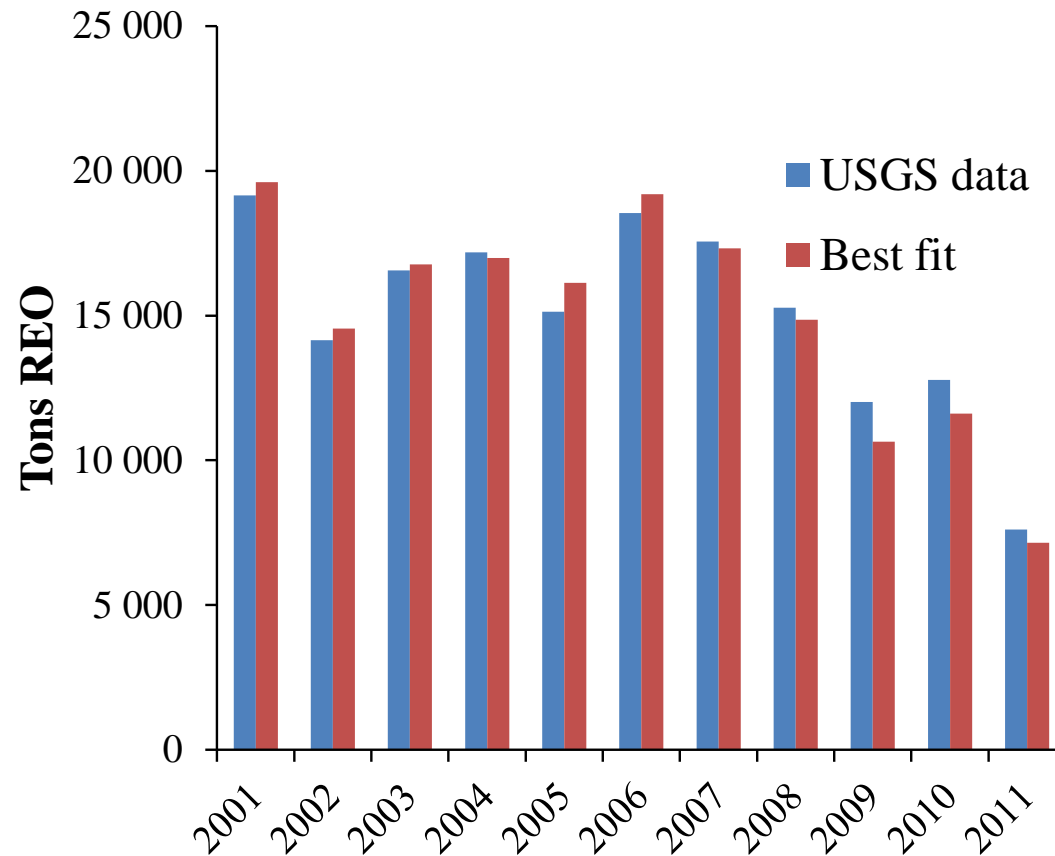
- MFA: system and boundaries

Tb



- Disaggregation of EUROSTAT data
 - ✓ Difficulty: lack of specificity of HS custom codes with respect to rare earths
 - ✓ For raw materials, 4 codes :
 - 2805 30 10 Intermixtures or interalloys of rare-earth metals, scandium and yttrium
 - 2805 30 90 Rare-earth metals, scandium and yttrium (excl. intermixtures or interalloys)
 - 2846 10 00 Cerium compounds
 - 2846 90 00 Compounds, inorganic or organic, of rare-earth metals, of yttrium or of scandium or of mixtures of these metals (excl. cerium)
 - ✓ Same codes as those considered in Öko-Institut (2011)
 - ✓ We perform a correction for post-2008 Austrian data

- ✓ Need to convert these data (tons compounds) into tons REO
- ✓ Conversion factors: obtained through best-fits to USGS data



- Conversion factors

- ✓ 280530 : 1.2
- ✓ 284610 : 0.67
- ✓ 284690 : 0.72

- ✓ Next: disaggregation into individual REOs (see Goonan, 2011)
- ✓ Need: consumption of REOs by market sector in EU (%)

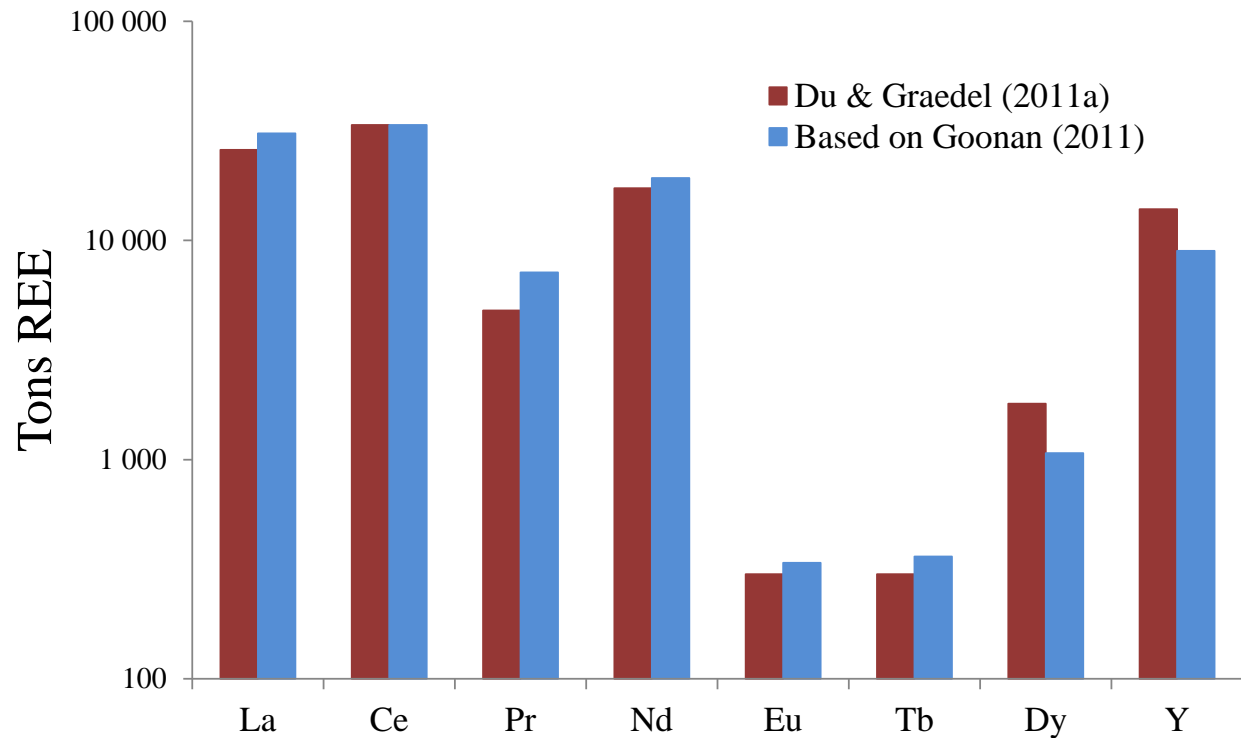
Magnets	Alloys	Automotive catalysts	Fluid catalytic cracking	Polishing powders	Glass additives	Phosphors	Ceramics	Other
3.6	12.0	26.3	15.6	6.6	18.0	6.0	6.0	6.0

- ✓ REO distribution by application (modified LYNAS 2010)

	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Y	Other
Magnets			16.1	64.5				3.2	16.1		
Battery Alloys	52.5	31.0	4.0	11.0						1.5	
Metal alloys	25.4	53.1	5.5	16.0							
Auto catalysts	4.8	90.4	2.0	2.9							
Petroleum refining	89.6	10.4									
Polishing powders	30.5	66.0	3.5								
Glass additives	23.4	67.3	1.0	2.9						2.1	3.3
Phosphors	10.3	7.9				6.1		4.0		71.6	
Ceramics	16.2	12.0	5.9	11.4						54.6	
Other	18.4	39.5	4.0	14.4	1.9		0.9			20.9	

- Verification: application to global rare earth consumption (Du & Graedel, 2011)

2007
global
consumption



Not shown: Gd and Sm. Data suggest:
mine production >> utilization => stockpiling
(Du & Graedel MFAs for Gd, Sm ?...)

- Application to EUROSTAT data yields: 12 550 tons REO imported in 2010
- Consistent with other sources:



RARE EARTH OXIDES (REO)

3

Key Consumer

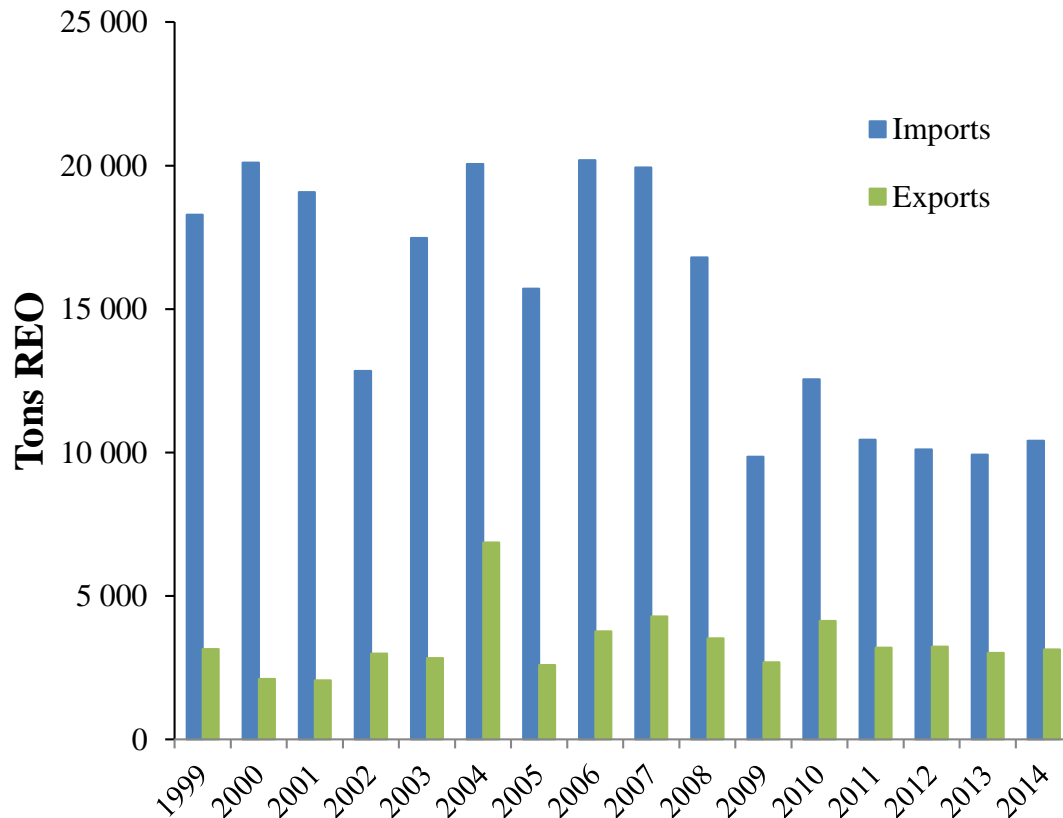
Estimated consumption by country in 2010

Country/Region (REO production)	t REO	Share [%]
China	75,000	60
Japan & SE Asia	25,000	20
USA	15,000	12
others (incl. Europe)	10,000	8

- Difference could be due to AU correction ($\approx 3\ 000$ t REO in 2010)

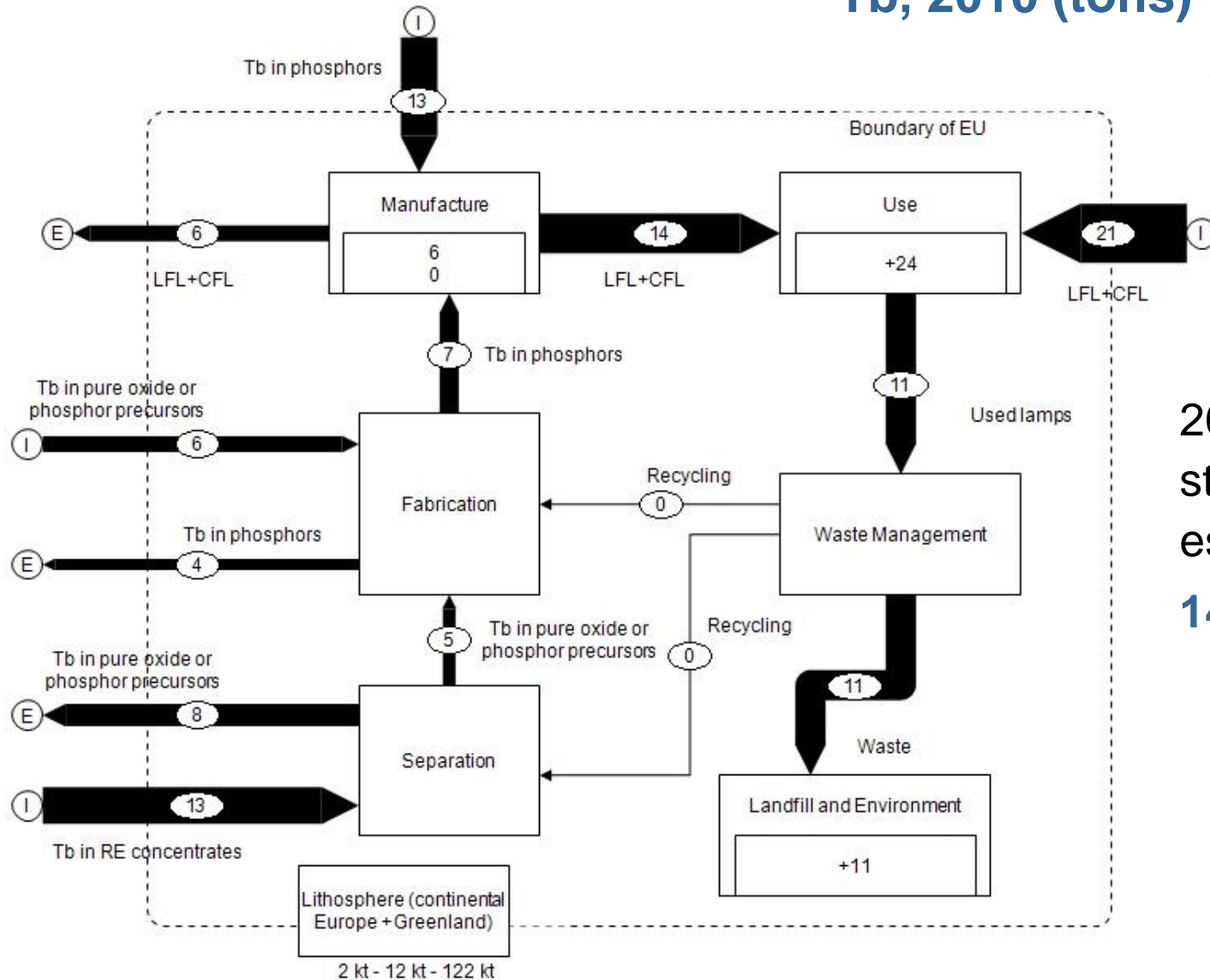
3. Results for fluorescent lamp phosphors

- Histories of European REO imports and exports
 - ✓ Sharp drop in 2008 interpreted as effect of economic crisis



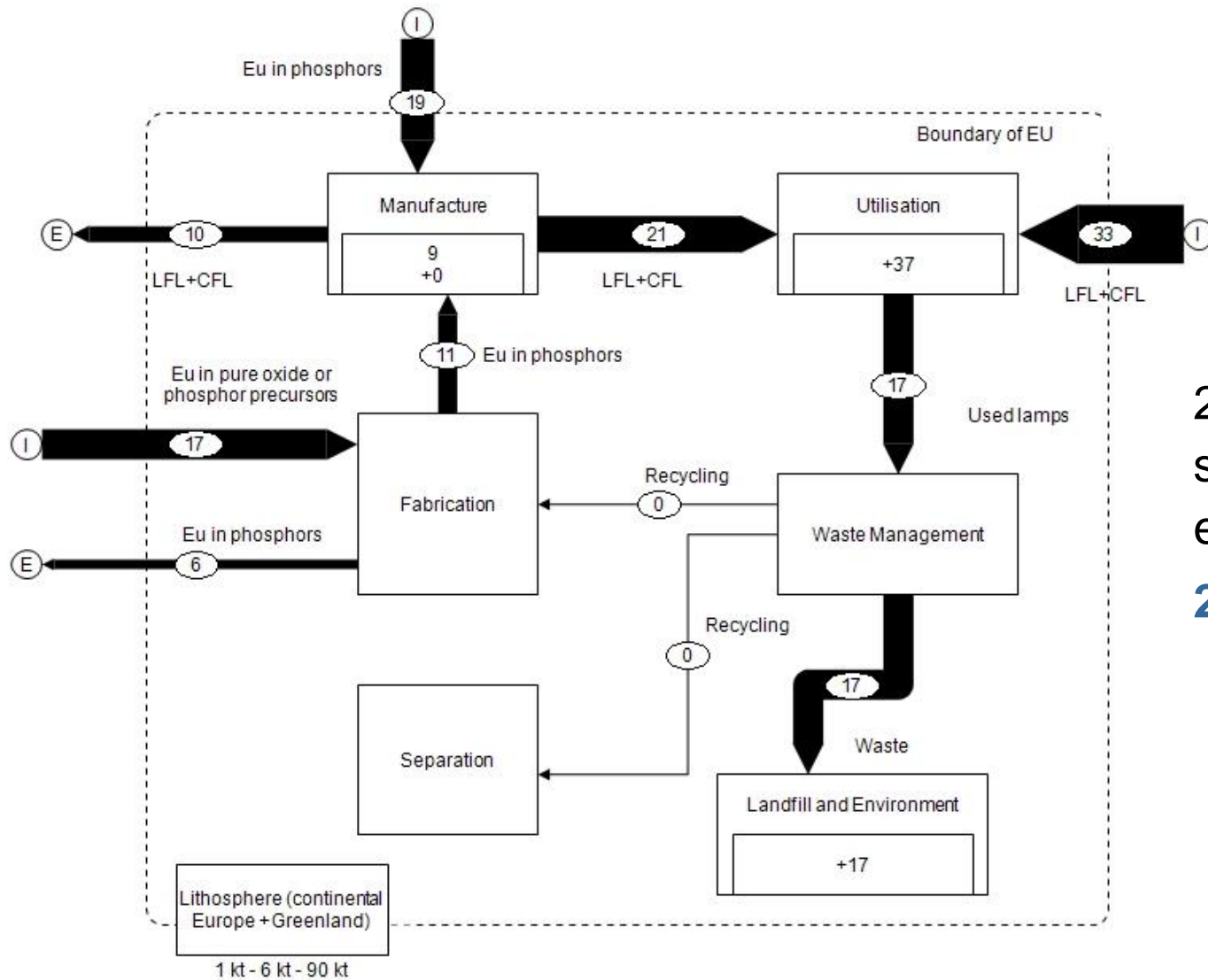
- SANKEY diagrams for phosphors

Tb, 2010 (tons)



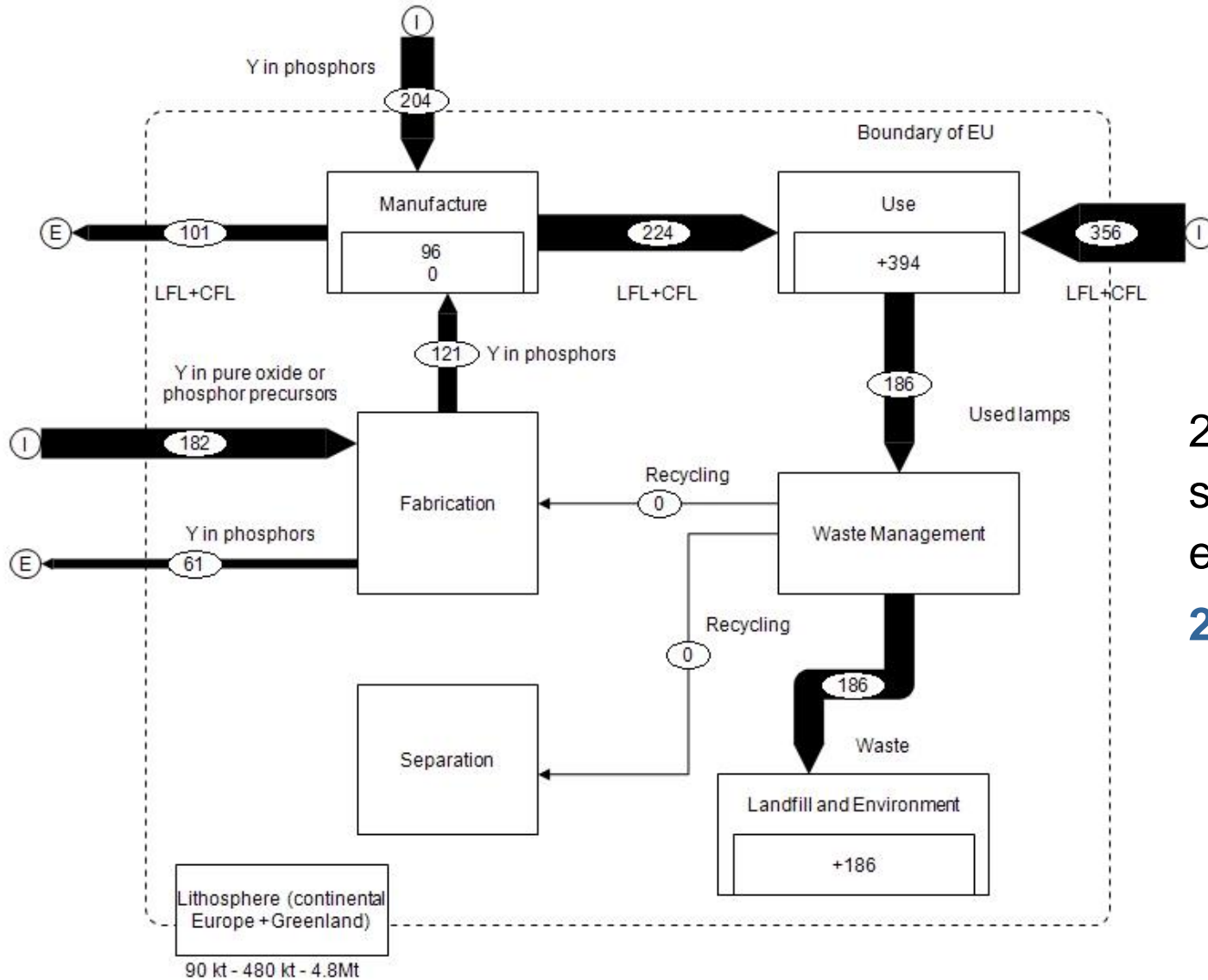
2010 in-use stock estimate:
140 tons

Eu, 2010 (tons)



2010 in-use stock estimate: **210 tons**

Y, 2010 (tons)



2010 in-use
stock
estimate:
2300 tons

4. Some conclusions

- ASTER results provide a global vision of flows and stocks of certain REEs along the value in the EU
- Flows into-use of Tb, Eu, Y in fluorescent light phosphors are $\approx 35, 54, 580$ tons/yr resp. for 2010
- In-use stocks of Tb, Eu, Y are estimated as 140, 210, 2300 tons resp.
- Results suggest that if one mining project in Europe should enter production (Norra Kärr?), there will be a strong influence on the balance between supply and demand for HREEs in EU (*see Rollat et al., this conference*)
- Production of primary sources will benefit secondary sources (recycling) due to the increase of treatment capacities (primary limiting factor is separate collection)

- Pressure on the supply of fluorescent light phosphors is expected to decrease in coming years, due to development of LEDs
- Further work is focused on:
 - ✓ Improving MFA consistency (e.g. time evolution of compositions)
 - ✓ ASTER « products »: reconciliation tool
 - ✓ Dissemination of results
- Approach associating both 1^{ary} and 2^{ary} raw materials in MFA could be extended to other critical metals (In, Ga, Ge, Nb, Ta, W, ...?)

Thank you for your attention

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