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The Rare Earths Market

Equilibrium between demand and supply

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ASTER – Conférence de clôture – 23 Avril 2015

Special Chem

The challenges of a RE market forecast at the EU 28 boundary

- The recent history shows that the previous forecasts have failed
- All the forecasts are based on individual RE segments analysis forgetting the RE equilibrium issue
- The RE value chain is world wide and the tentative to do a European market analysis is more than a challenge

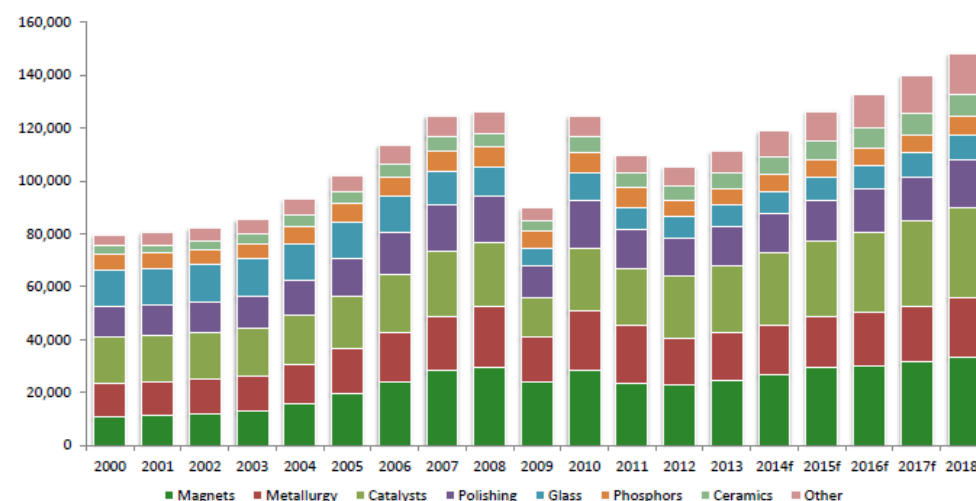
The failure of the previous forecasts

IMCOA 5th RE conference Nov 2009
Forecast Global demand of RE in 2014

<u>Rare Earth Oxide</u>	<u>REO Tonnes</u>	<u>Demand %</u>
Lanthanum	51,050	28.4%
Cerium	65,750	36.5%
Praseodymium	7,900	4.4%
Neodymium	34,900	19.4%
Samarium	1,390	0.8%
Europium	840	0.5%
Gadolinium	2,300	1.3%
Terbium	590	0.3%
Dysprosium	2,040	1.1%
Erbium	940	0.5%
Yttrium	12,100	6.7%
Ho-Tm-Yb-Lu	200	0.1%
Total	180,000	100%

Roskill 10th RE conference Nov 2014

World: Rare earths consumption by end-use, 2000 to 2018 (t)



The difficult issue of REE equilibrium

- The individual REE « equilibrium » constraint is a key characteristic of the RE business

Rare Earths Properties	Applications	RE
Magnetics	Magnets	Nd, Pr, Dy, Tb
Electric - H2 storage	NiMH Batteries	La, Ce, Pr, Nd
Catalysis	Cars depollution	Ce, La, Nd
Catalysis	Petrochemical industry	La, Ce, Pr, Nd
Phosphors	Lighting TV –Display	La, Ce, Eu, Tb, Y
Polishing Powders	Glass – Flat screens	Ce, La, Pr

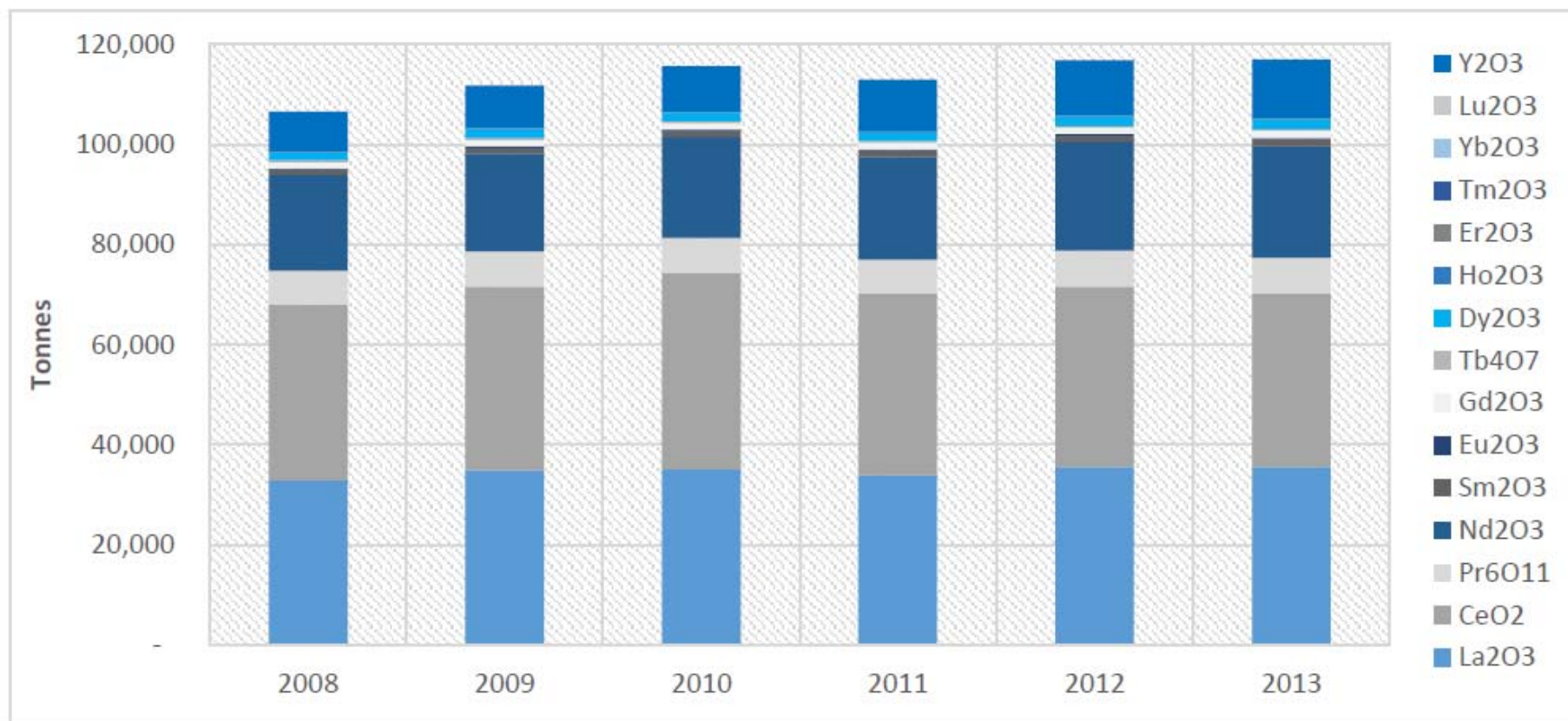
➤ ***Individual REE have their own lifecycle on the market but they are linked in the raw materials with a limited flexibility.***
Processing costs are significantly impacted by REE without market and the Magnet market cannot bear all the surplus costs

The RE market today and tomorrow

The view of the market analysts

Adamas Intelligence, October 2014

The historical evolution of the RE market



The RE ww market has been quite stable in volume between 2008 and 2013

The world wide RE market evolution: a global growth dominated by magnets needs

Data from Adamas

- A global CAGR of 3.9% between 2014 and 2020
- Magnets are the main driver (CAGR of 7%)



This situation will increase the discrepancy of the demand between the RE and some RE with high content in the ores (La Ce) or with high value (Eu) will be in excess.

How the RE market can be totally modified by a technology change

- 1. The magnet market and the strategy of wind turbines producers**
- 2. The phosphor market and the penetration of LED**

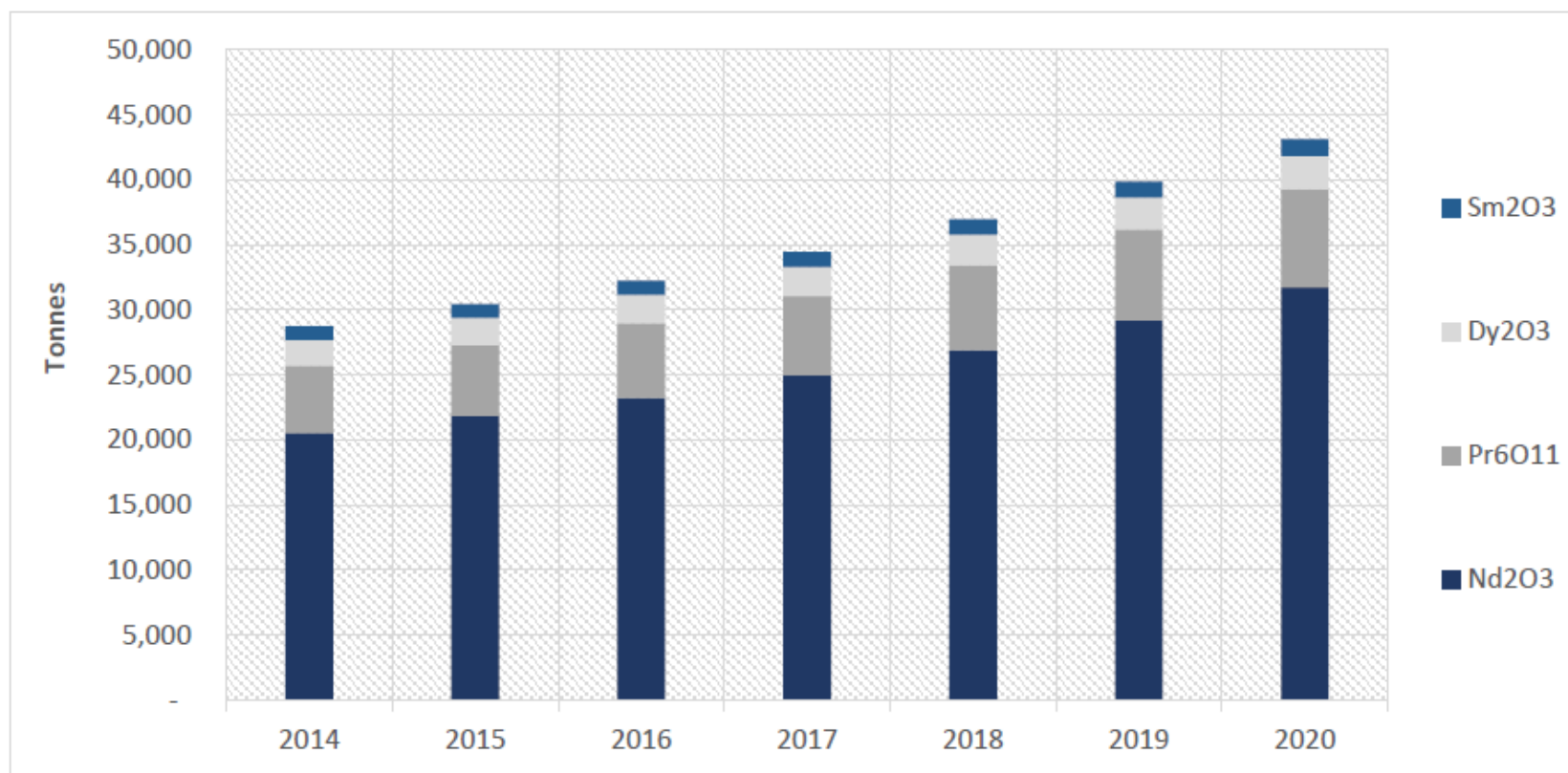
How the RE market can be totally modified by a technology change

The Magnet case

The magnet market – Adamas forecast October 2014

In October 2014 Adamas forecasted an increase of RE demand for magnets from 30kT in 2015 to 42kT in 2020 with a quite stable composition of Dy of around 9%.

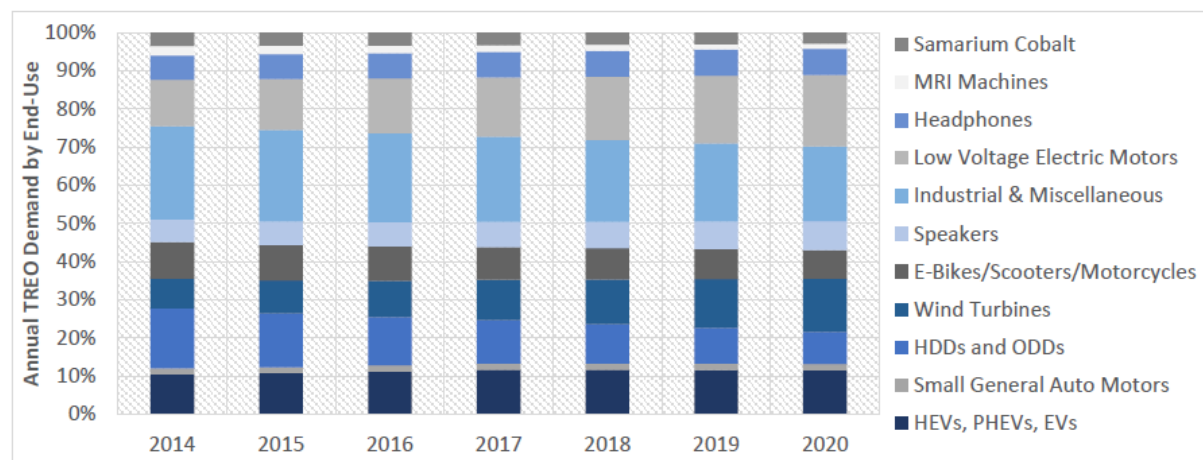
Figure 176: Forecasted REO demand for permanent magnets from 2014 through 2020



Rem: The Dy content is necessary to increase the Curie T° .

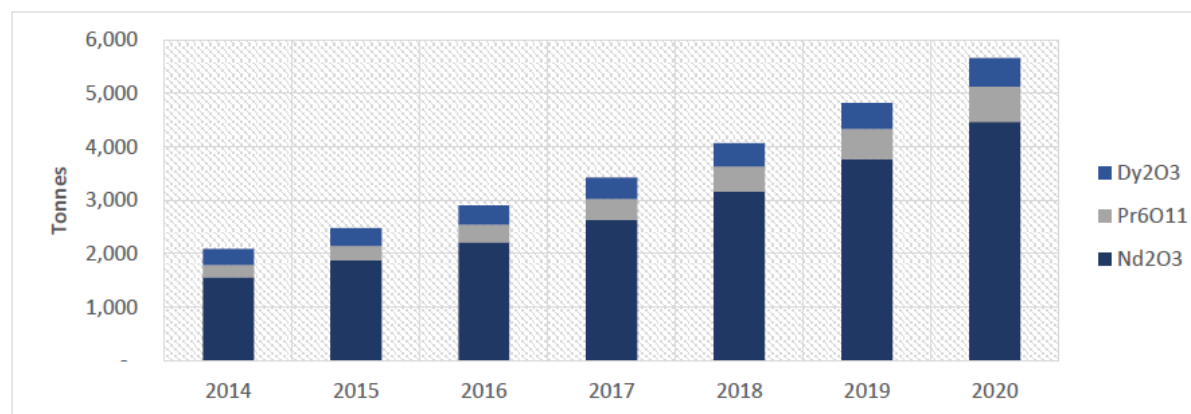
The magnet market – Adamas forecast October 2014

Figure 177: Forecasted REO demand for permanent magnets by end-use from 2014 through 2020



...leading to an overall RE consumption growth for wind turbines from 2100t in 2014 to 5670t in 2020 (including 540t of Dy) .

Figure 184: Forecasted REO demand for wind turbine generators from 2014 through 2020

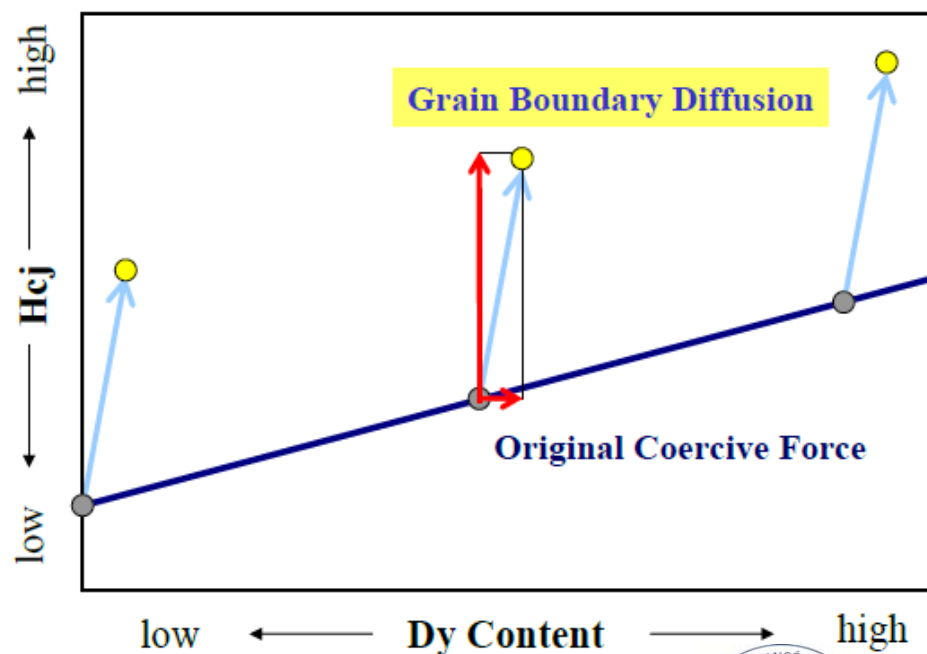
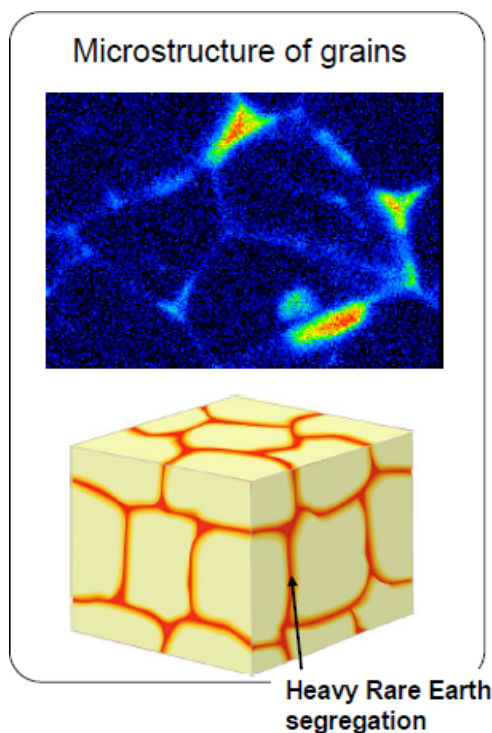


The magnet market - How to reduce the Dy consumption: The strategy of the magnet maker

Dy is necessary to increase the Curie temperature. The target of the magnet makers is to understand how to decrease the Dy content by keeping the same Curie temperature



The Relation between Coercive Force Enhancement and Dy Content

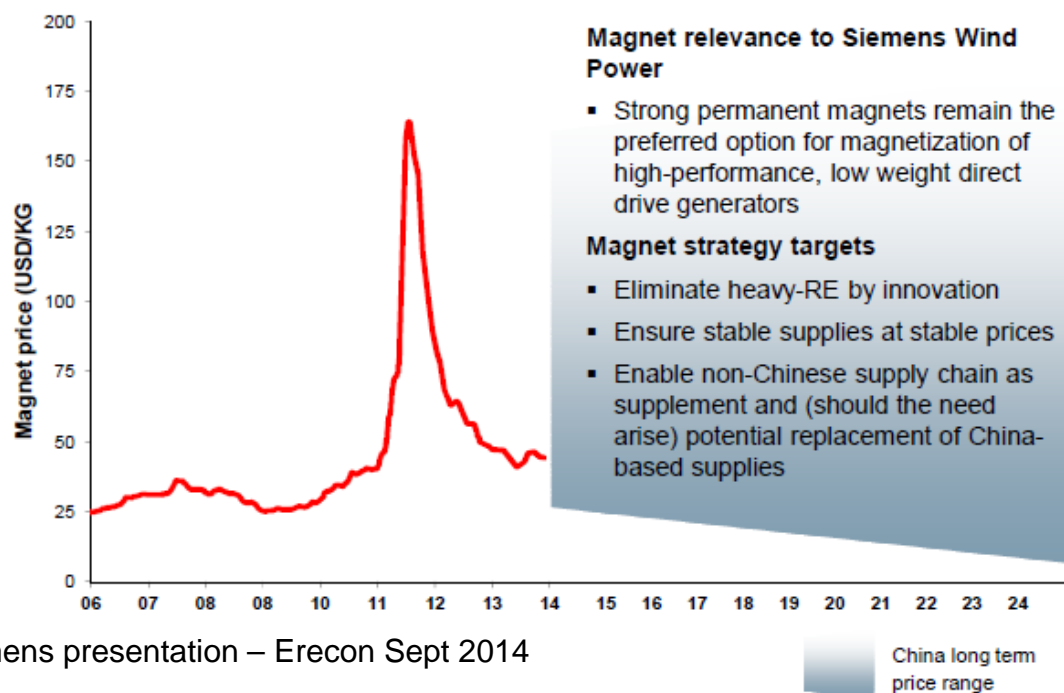


The magnet market - How to reduce the Dy consumption: The strategy of the end user

Siemens intends to be the 1st producer for off shore wind turbines (with a 6MW generator). In Sept 2014 Siemens announced that the permanent magnets used in their new generators will be totally free of Dy by using a cooling system.

**NdFeB Magnets -
Price Stability for upcoming 10 Years required**

SIEMENS



Siemens presentation – Erecon Sept 2014

How the RE market can be totally modified by a technology change

The Phosphor case

By 2013 Phosphors were the 2nd RE market in value

	2008	2011	2013
Overall RE market	1867 M\$	7891 M\$	3021 M\$
RE Phosphors market	473 M\$	1838 M\$	616 M\$
%Phosphor/overall	25%	23%	20%

Adamas October 2014

In 2013 the RE value in Phosphors still accounted for 20% of the global RE market. More than 95% of the RE phosphors are used in the CFL and LFL

- How much this figure will be modified by the penetration of LEDs?
- What can be the consequence on the global RE market?

The penetration of LED is much faster than previously expected

People have a very positive attitude towards LED lighting. This is not particularly the case for fluorescent lighting

LFL lighting

- Slow start
- Greenish color
- Difficult to dim
- Long life
- Contains hazardous Hg
- Good energy saving
- Traditional, smart

LED lighting

- Instant ON
- Pleasant good looking lighting
- Easy dimming
- Endless life
- Free of hazardous materials
- Great energy saving
- Modern, responsible

Penetration of LED: Product Innovations

Low cost tubes with fairly good performance

- LED spots focused on where light is needed
- Elimination of diffusor, heat sink and reduction of the number of LEDs



Penetration of LED: Cost improvement

The industry is on a very steep learning curve

=> Lumens per USD was 50 in 2009 and will reach 1500 in 2015

Dies:

- Wave 1
Shift from high power LED to mid power LED with improved lm/\$ performance
- Wave 2
Shift from Korean mid power LED supply to low cost Chinese supply



Lamps:

- Continuously improving designs
 - Heat management
 - Optimized components
 - Life time sacrifices
- Continuously improving processing



The RE in Fluorescent lamps and LED or the end of life

	YEO $\text{Y}_2\text{O}_3\text{:Eu}$	LAP / CAT $\text{LaPO}_4\text{:Ce,Tb}$ $\text{MgAl}_{11}\text{O}_{19}\text{:Ce,Tb}$	BAM $\text{BaMgAl}_{10}\text{O}_{17}\text{:Eu}$
Representative Linear blend (4100K)	50%	40%	10%
Representative CFL blend (2700K)	70%	30%	



REE wt%	Y	Eu	Tb
Blend	40%	2%	4%

	YAG $\text{Y}_3\text{Al}_5\text{O}_{12}\text{:Ce}$	CASN $\text{CaAlSiN}_3\text{:Eu}$
LED Representative blend	80%	20%



REE wt%	Y	Eu
Blend	44%	2%

Ref: GE presentation: RE conf Singapore Nov 2014

- Use of REE (Y, Eu, Tb) is 15 to 20 times higher in Fluorescent lamps than LED for equivalent lumen output, even higher if you include LRE (La & Ce)
- The life time of a Fluo lamp is 10 000h to 25 000h
- The life time of LED lamp is 40 000h to 50 000h

	Fluorescent	LED
Output (lumens/unit)	3000	100
Phosphor (g/unit)	2	0.002
% REE in Phosphor (Y, Eu, Tb)	46%	46%
Mfg yield (%)	95%	50%
Lumens/g of REE (Y, Eu, Tb)	3000	54000

The positioning of EU28 in the RE value chain

The position of EU28 in the global RE value chain

	Situation in 2015		
	EU actors	EU production	WW production
Mining	None	0	160 kt REO
Separation	Solvay (France) Silmet (Estonia)	# 6 kt REO	160 kt REO
Metals	LCM (UK) Silmet (Estonia)	# 500t RE	#50 kt RE
Magnets	Vacuum Schmelz (Germany + Finland)	# 500 tRE	25 to 30 kt RE
Batteries NiMH	Small producers	< 100 tRE	#15 kt RE
Phosphors	Osram (Ger) LWB (Ger)	300 to 500 tREO	6 kt REO

EU 28 has a very weak position in all the RE value chain from Mining to advanced materials. But European industry is a key consumer of components containing RE, especially magnets (automotive, electronic and renewable energy industries)

The position of EU28 in the global RE value chain

EU 28 has a very weak position in all the RE value chain from Mining to advanced materials.

But European industry is very dependent on components containing RE, especially magnets (automotive, electronic and renewable energy industries)

The example of car industry

Figure 63: DBe global car production forecasts 2012-2018

Production (millions)	2012	2013	2014	2015	2016	2017	2018
Europe	19.3	18.7	19.4	20.2	21.1	22.1	22.9
Greater China	18.6	20.4	22.6	24.8	26.6	28.1	29.2
Japan/Korea	13.9	12.9	12.6	12.6	12.1	12.2	12.3
Middle East/Africa	1.7	1.8	2.1	2.2	2.4	2.5	2.5
North America	15.4	16.1	16.3	17.0	17.6	17.7	17.8
South America	4.3	4.5	4.8	5.3	5.5	5.8	6.0
South Asia	8.2	8.6	9.7	10.6	11.4	12.0	12.4
Total	81.5	83.1	87.5	92.6	96.7	100.3	102.9
% growth	6.0%	1.9%	5.3%	5.9%	4.4%	3.7%	2.6%

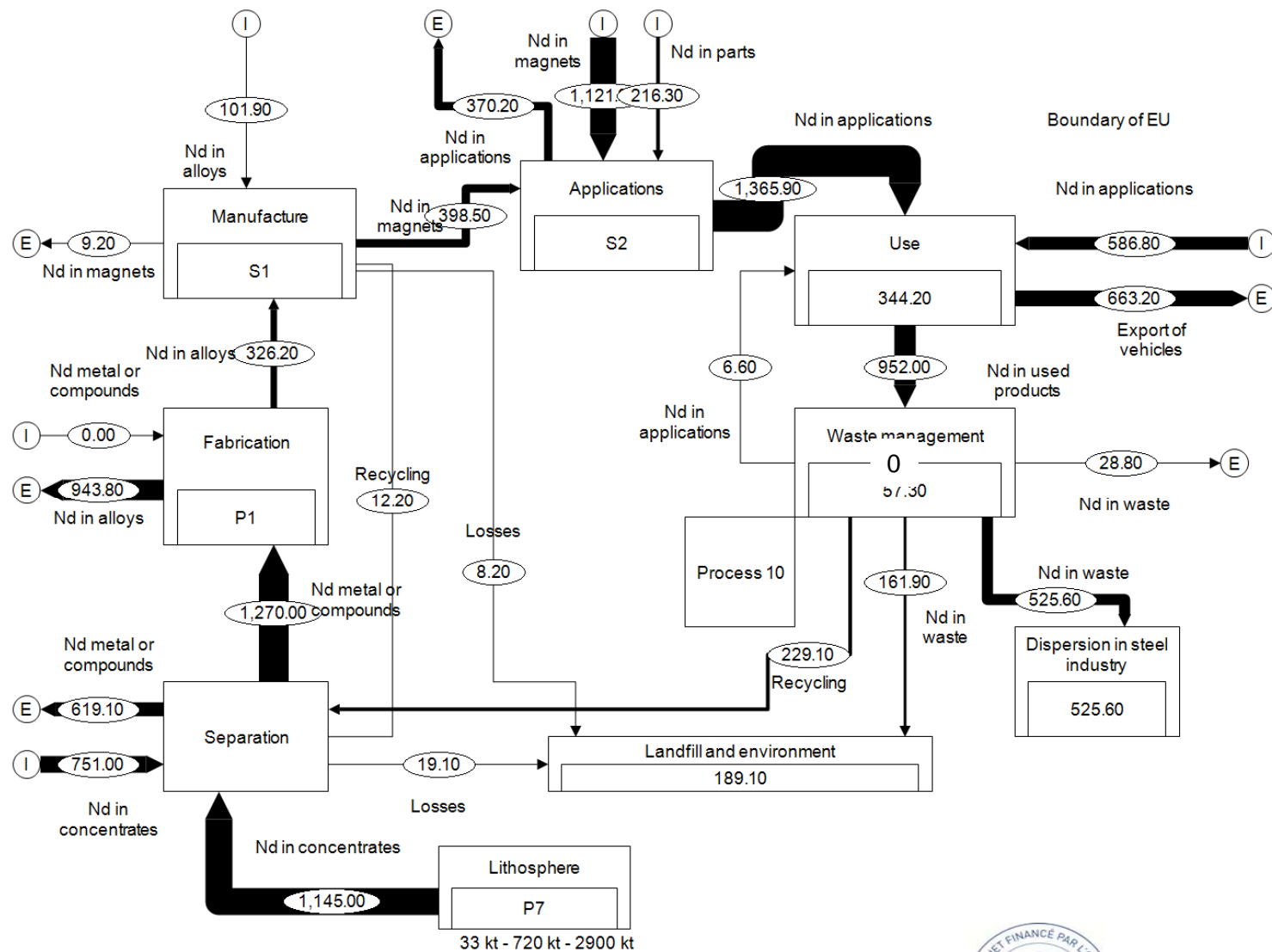
Source: Deutsche Bank

The position of EU28 in the global RE value chain

Potential evolution

	Situation in 2015		Evolution of EU28 production 2015 -> 2020	
	EU actors	EU/WW position	Scenario 1	Scenario 2
Mining	None	0%	Norra Karr (Sweden)	No new mine
Separation	Solvay (France) Silmet (Estonia)	3 to 5%	Increase	Stable
Metals	LCM (UK) Silmet (Estonia)	1%	Increase	Decrease
Magnets	Vacuum Schmelze (Germany + Finland)	1 to 2%	Increase	Increase
Batteries NiMH	Small producers	< 1%	Stable	Stable
Phosphors	Osram (Ger) LWB (Ger)	6 to 9%	Decrease	Decrease

An example of prospective MFA: The case of Magnet with scenario 1



ASTER – Solvay Spec Chem

24/04/2015

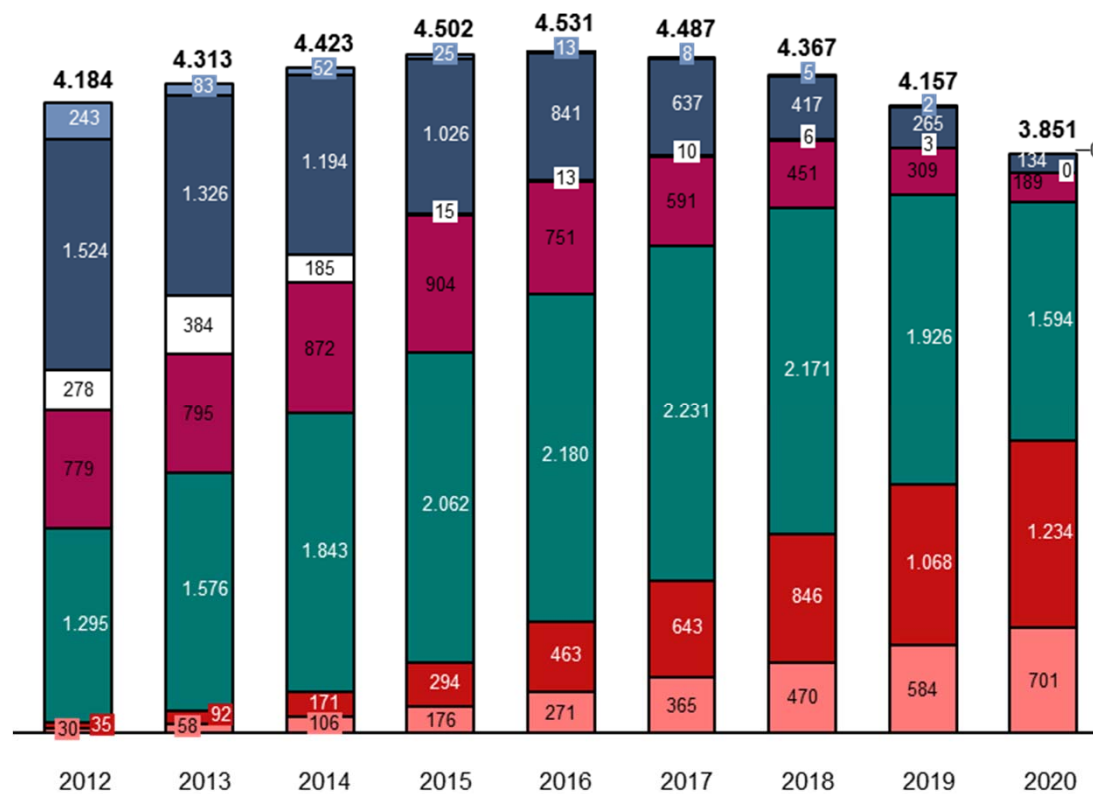


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**Thanks for your
attention**

Linear lamps market forecast - World wide market / LFL



- 2016 LED market share = **16%**
- 2018 LED market share = **30%**
- 2020 LED market share = **50%**

T12-halo
 T8-halo
 T8-mix
 T8-tri
 T5-tri
 T-LED
 LEDinaire

Solvay confidential data