Materials Flow of Platinum Group Metals in Germany (& beyond)

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Roundtable on sustainable use and production of PGM
The Hague, September 12, 2005

Platinum & palladium price development (annual averages) & milestones in application

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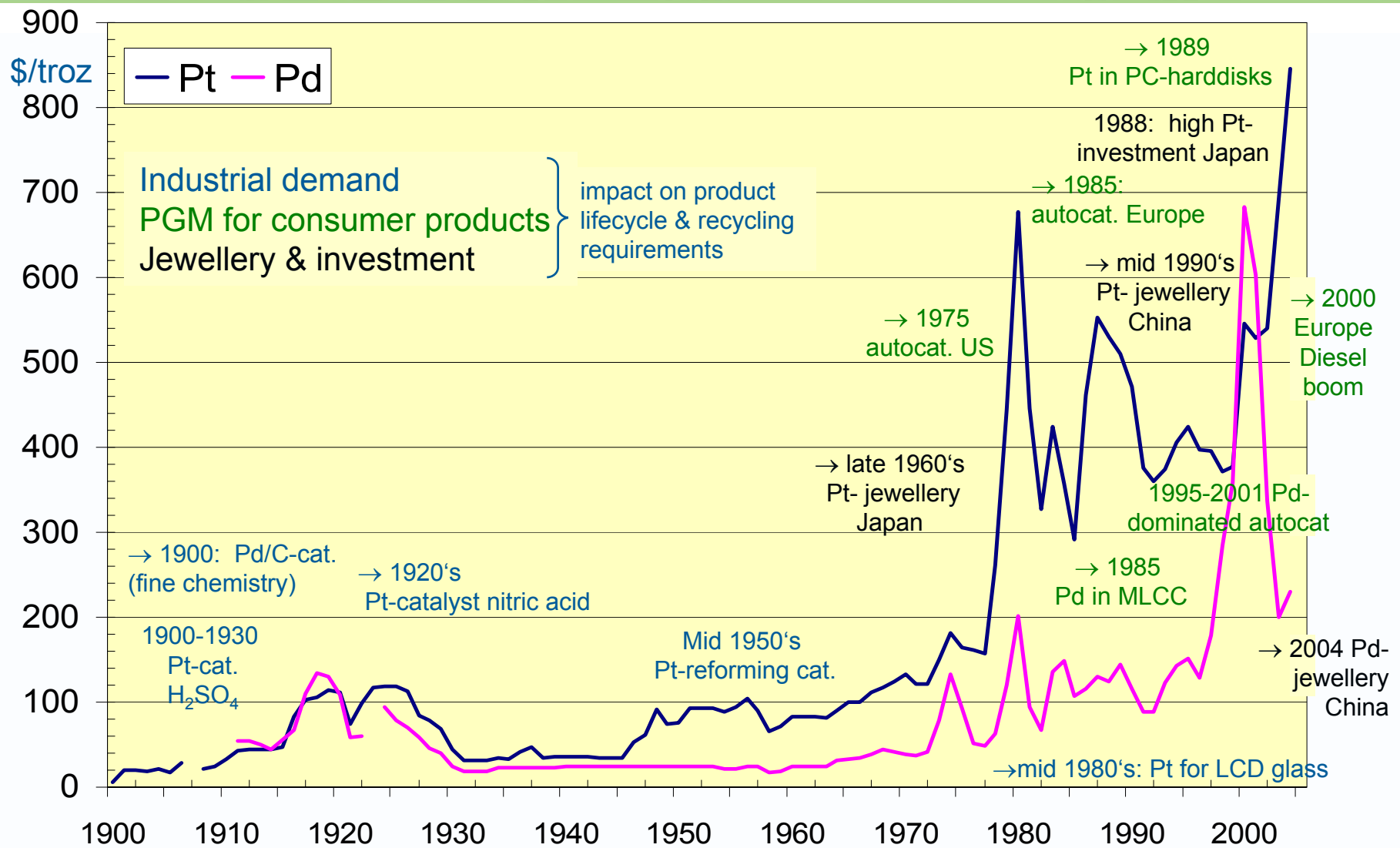

Development of platinum and palladium net demand (global)

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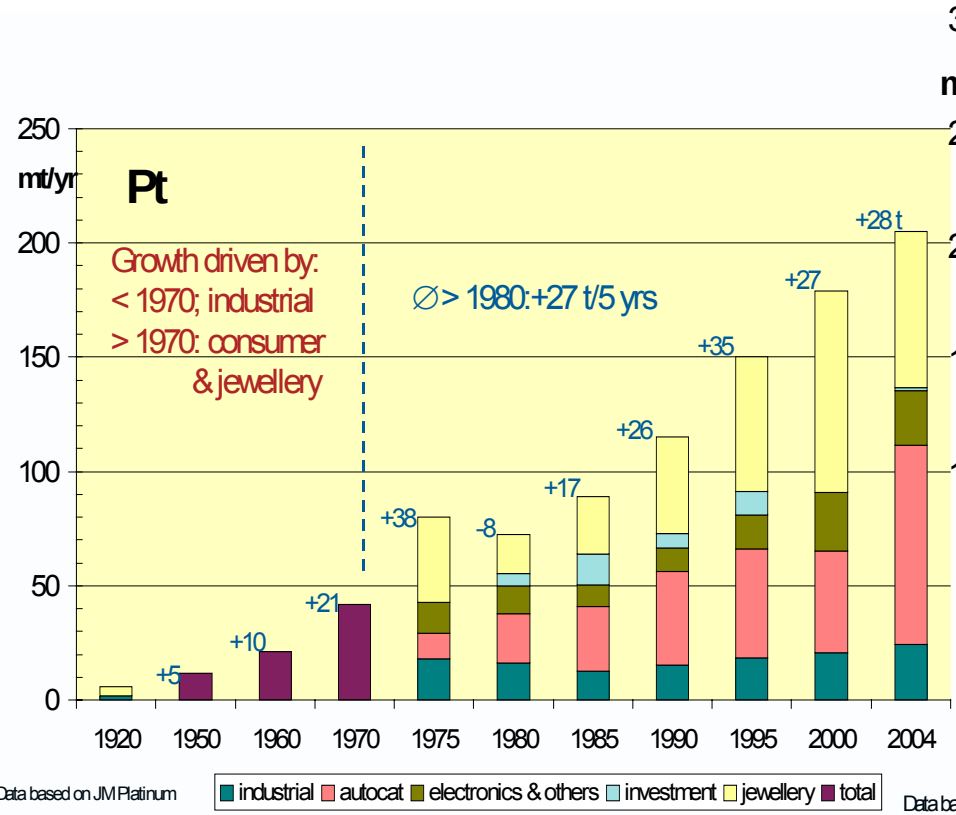
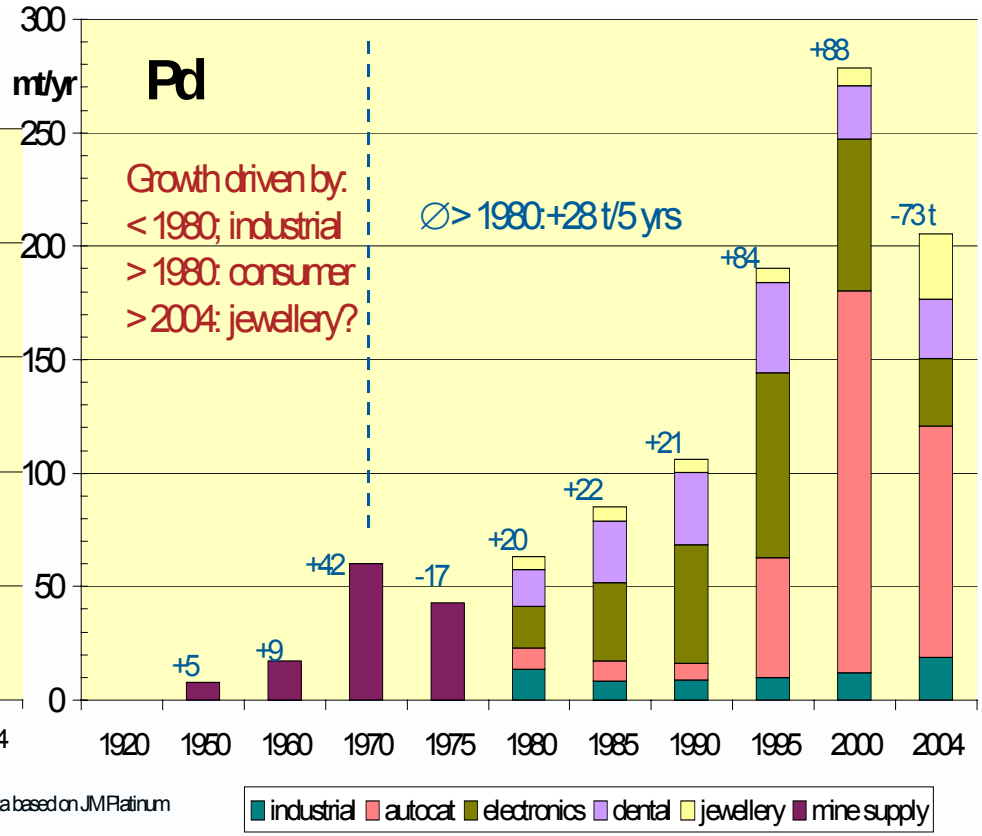
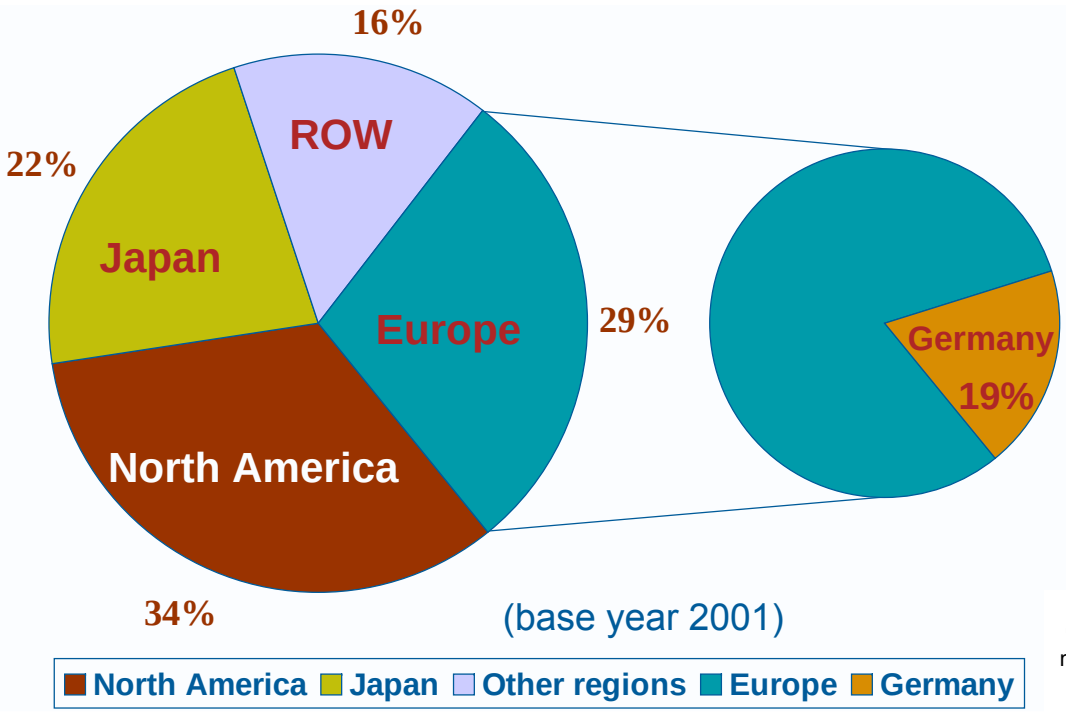




Significant change in application fields

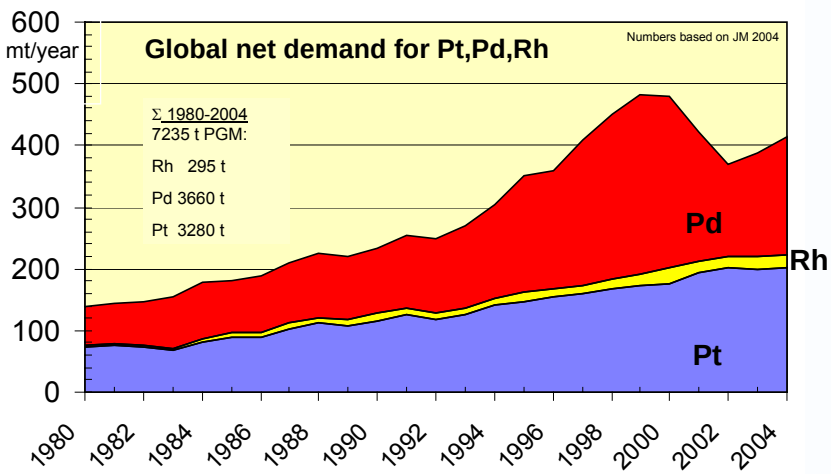
- Initially: coinage, jewellery, early industrial demand
- 1920-early 1970's: focus on industrial demand (catalysis + glass)
- since 1975: growing PGM-demand driven by consumer products (autocat, electronics), dental and jewellery
- Only moderate growth in industrial demand over the last 30 years

Global net PGM demand



Cumulative net demand 1980-2004

Consumer:	65%
Industrial:	12%
Jewellery:	20%
Investment:	3%



Cumulative PGM-mining* until 2004: 9000 t

- from this 1980-2004: (> 80 %) 7500 t
- from this 1995-2004: (≈ 50 %) 4400 t

⇒ huge „mine above ground“ to be exploited

* incl. Ru, Ir

Material Flows of PGM - System Analysis and Measures for a Sustainable Optimisation

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Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Research Project:

- Conducted by Umicore & Öko-Institute, August 2001 - Sept. 2004
- Funded by the German Federal Ministry of Education & Research
- Case study of situation in Germany (global market environment is considered) → reference for PGM industry worldwide
- 250 p. final report (German) published in 4/2005 (GDMB Medienverlag)
- GFMS: review of report, context chapter putting the results in a global perspective, executive summary.
- Joint publication of extended report in English language in 6/2005 (published by GFMS, London)

GFMS

Project target:
How to improve life cycle efficiencies for PGM's and minimise PGM-losses.
Basis: In-depth market analysis

Areas of Investigation:
All relevant application segments for PGMs

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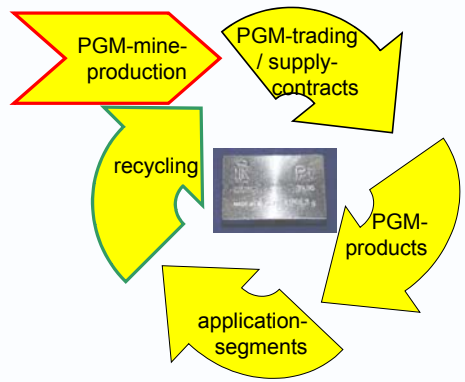
- Automotive catalysts
- chemical & oil refining catalysts
- dental
- electronics
- electroplating
- fuel cells
- glass
- jewellery
- others

Analysis & quantification of PGM flows (incl. gross demand & recycling)
Identification of deficits & assessment of recycling potentials
Proposals for improvement in selected segments
Development of scenarios for future PGM flows (- 2020)
Analysis of their economical and ecological consequences



- Bottom up data collection, top-down cross-checking
- gross & net demand, recycling volumes, losses, inventory for Pt, Pd, Rh

What questions does the report address?

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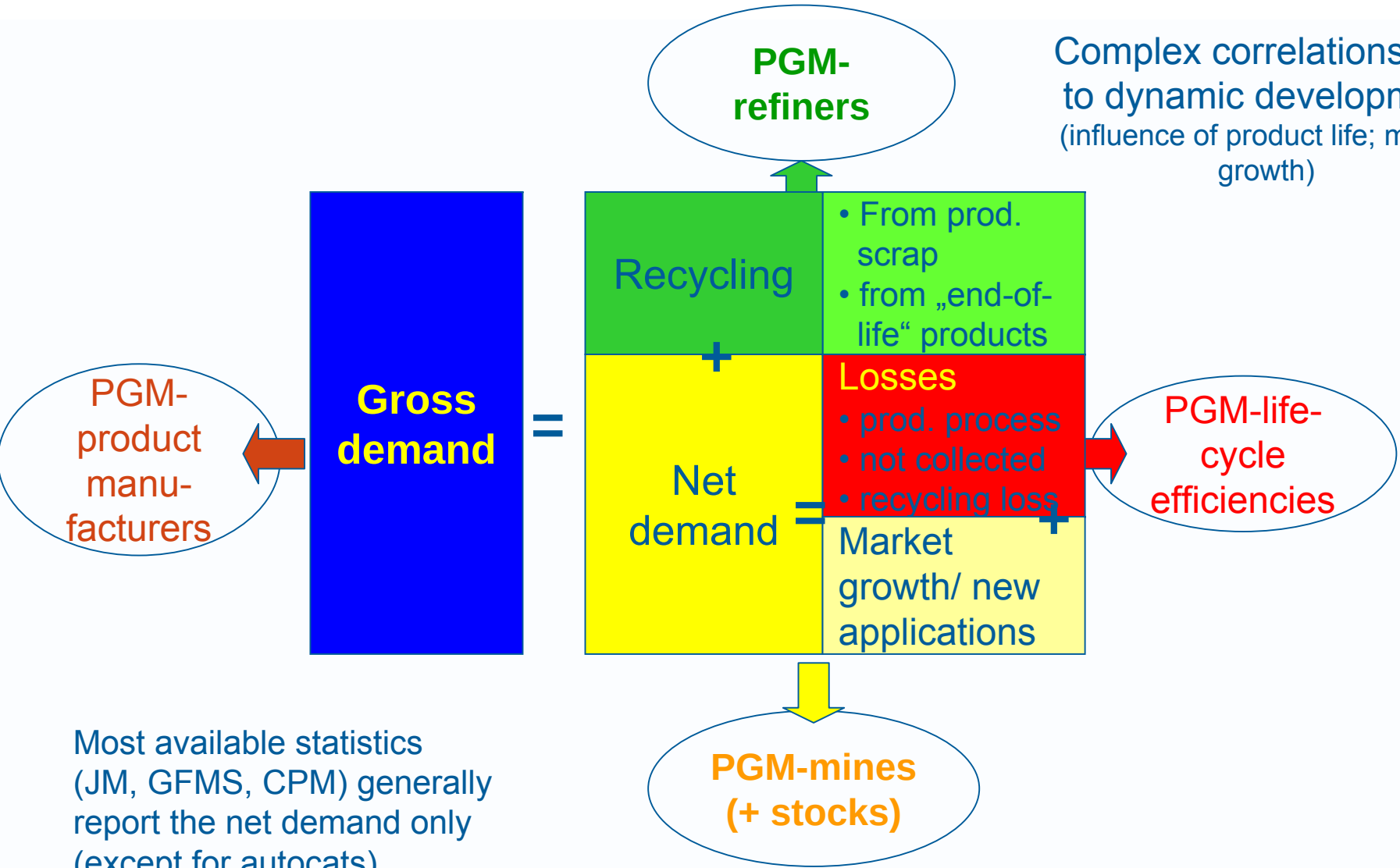
- What PGM materials are being recycled?
- What escapes recycling and why?
- Why have recycling volumes often disappointed?
- What are the lifecycles within PGM use sectors?
- Why are some sectors more efficient than others?
- What kind of recycling structures exist?
- What isn't working and can it be fixed?
- What future contribution can we expect from recycling?
- Is recycling more environmentally friendly than mining?

Methodology - PGM-demand interdependencies

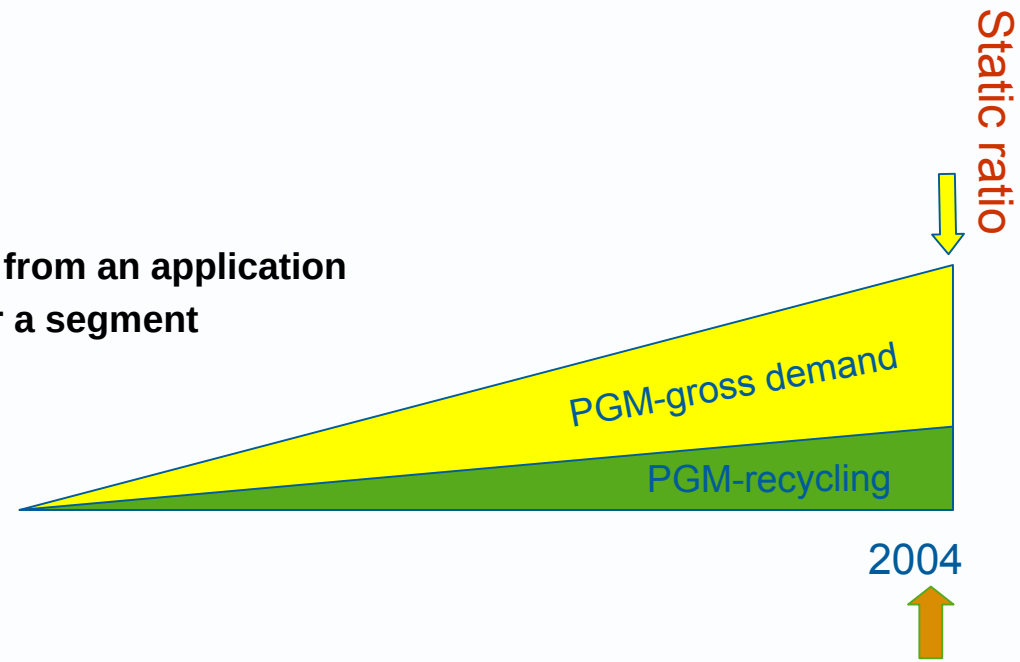


Methodology - the static recycling ratio (quota)

***Static* recycling ratio =** $\frac{\text{recycling today*}}{\text{gross demand today**}}$

* **today's PGM-recycling from an application**

** **gross PGM-demand for a segment**



Example auto catalyst: today's recycling was produced > 10 years ago

Methodology - static vs. dynamic recycling ratio

Static recycling ratio = Recycling today* / gross demand today**

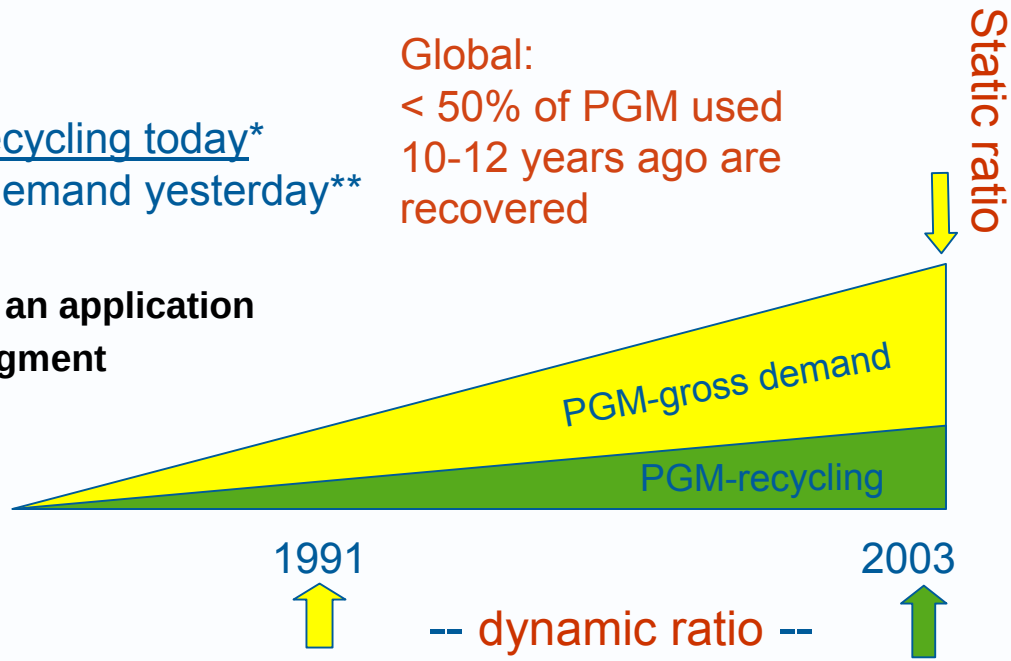
2005:
- Pt = 21%
- Pd = 18%
- Rh = 18%

Dynamic recycling ratio = Recycling today* / gross demand yesterday**

Global:
< 50% of PGM used 10-12 years ago are recovered

* **today's PGM-recycling from an application**

** **gross PGM-demand for a segment**



Only the dynamic recycling ratio determines the lifecycle efficiency!

PGM flows in Germany
(products used & processes operated in Germany)

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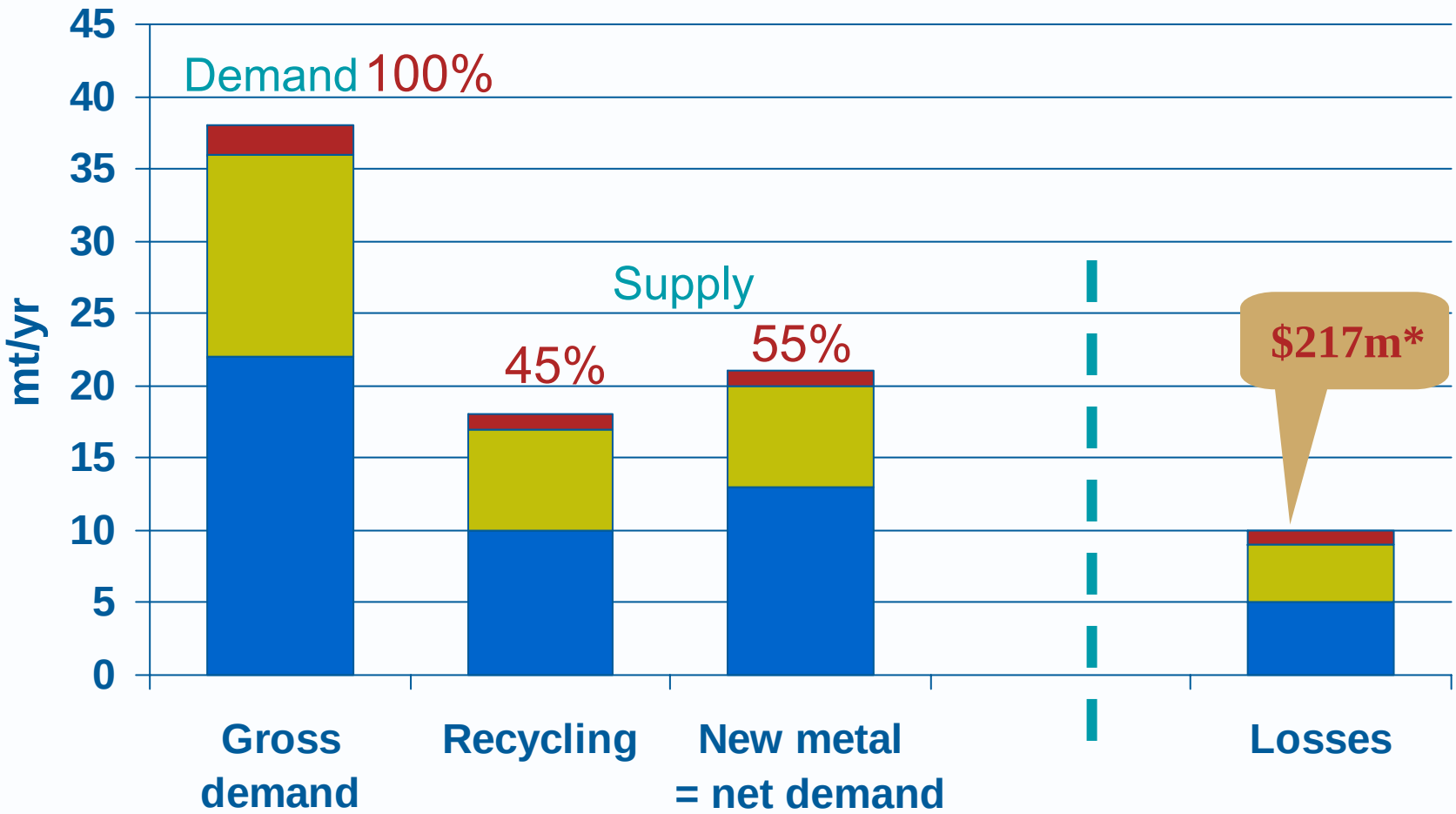
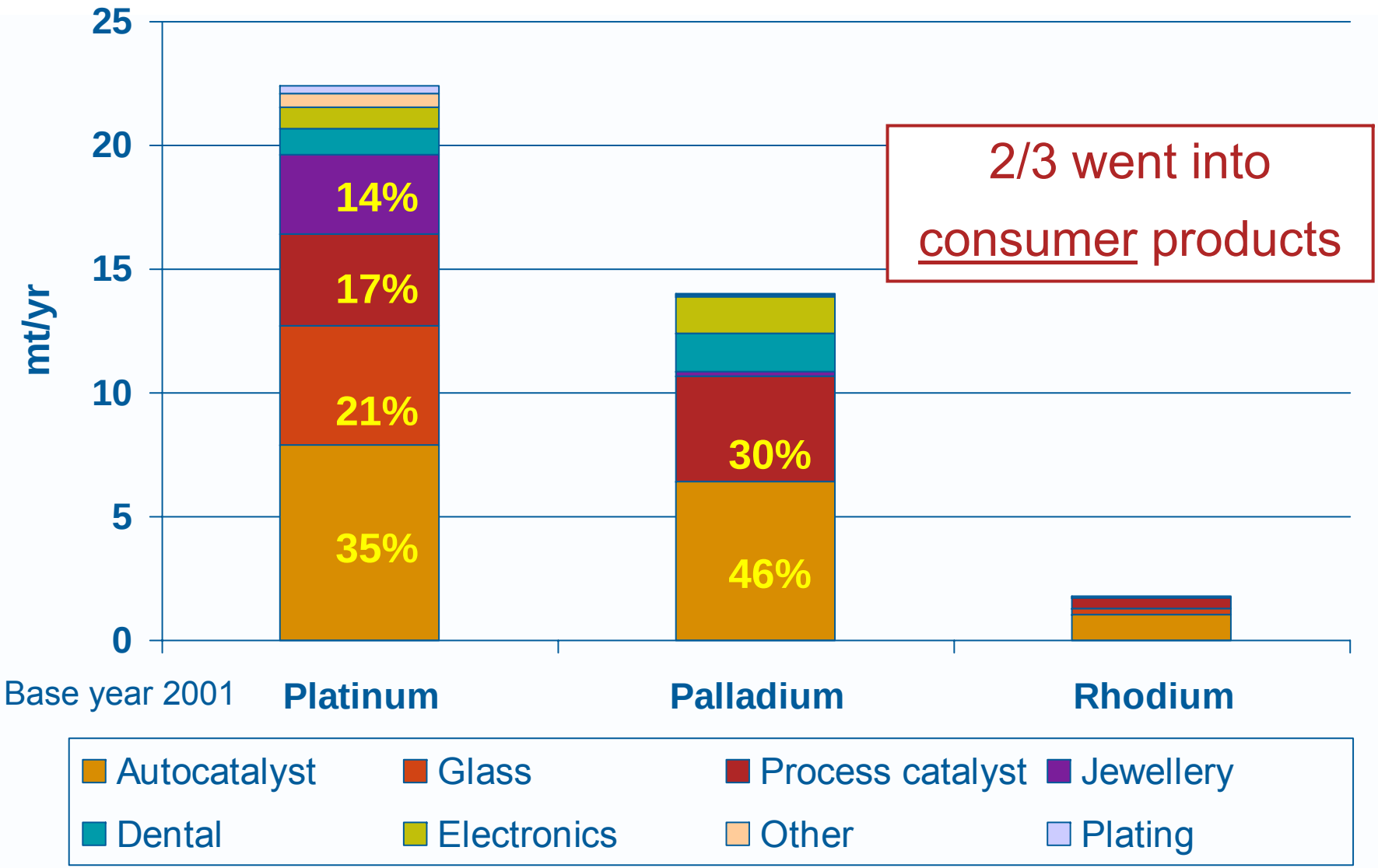


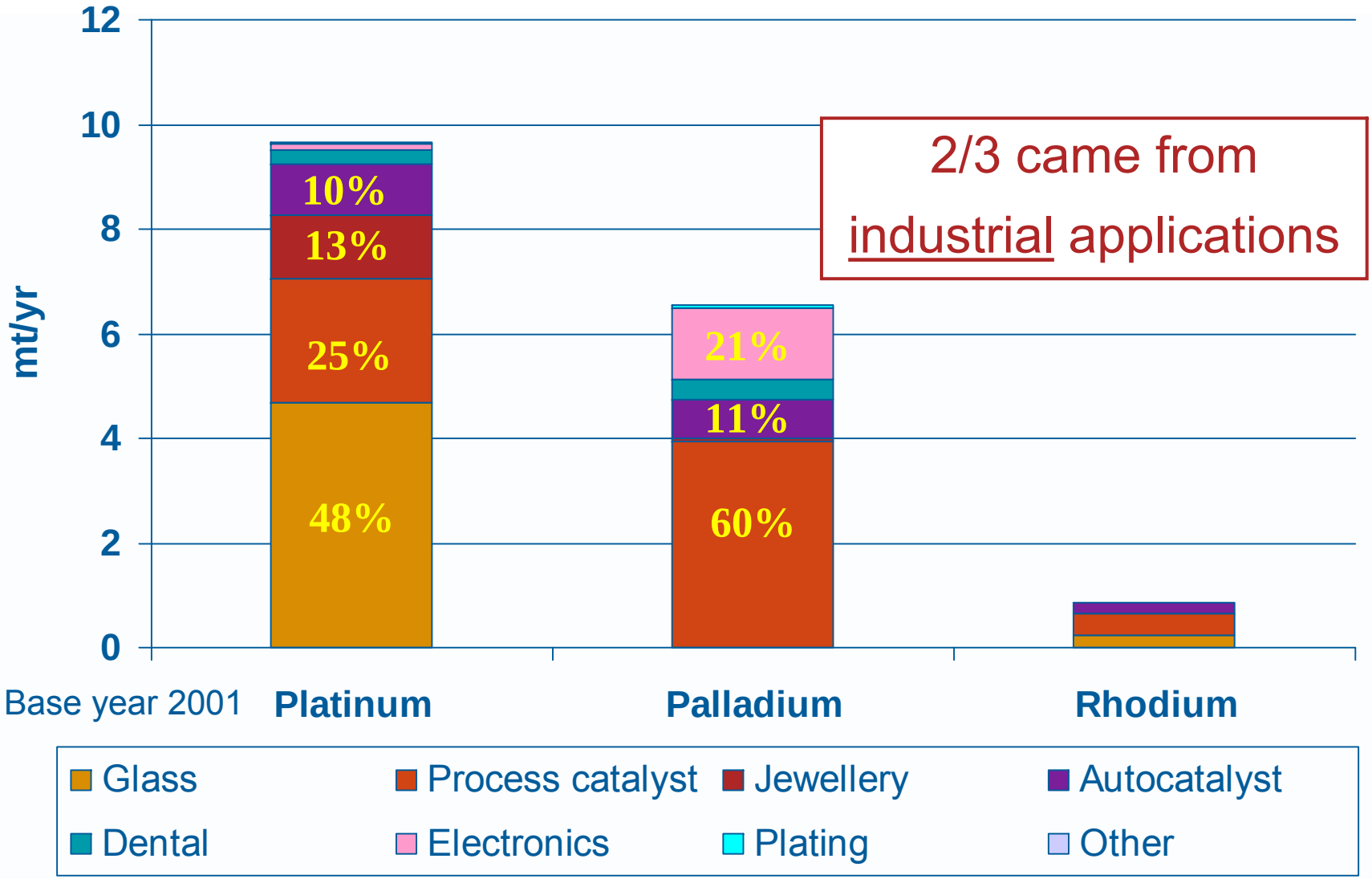
Base year 2001

* at May 2005 prices

Gross PGM demand in Germany by sector



PGM-recycling in Germany by sector



Germany's PGM inventory: 242 t
(Base year 2001)

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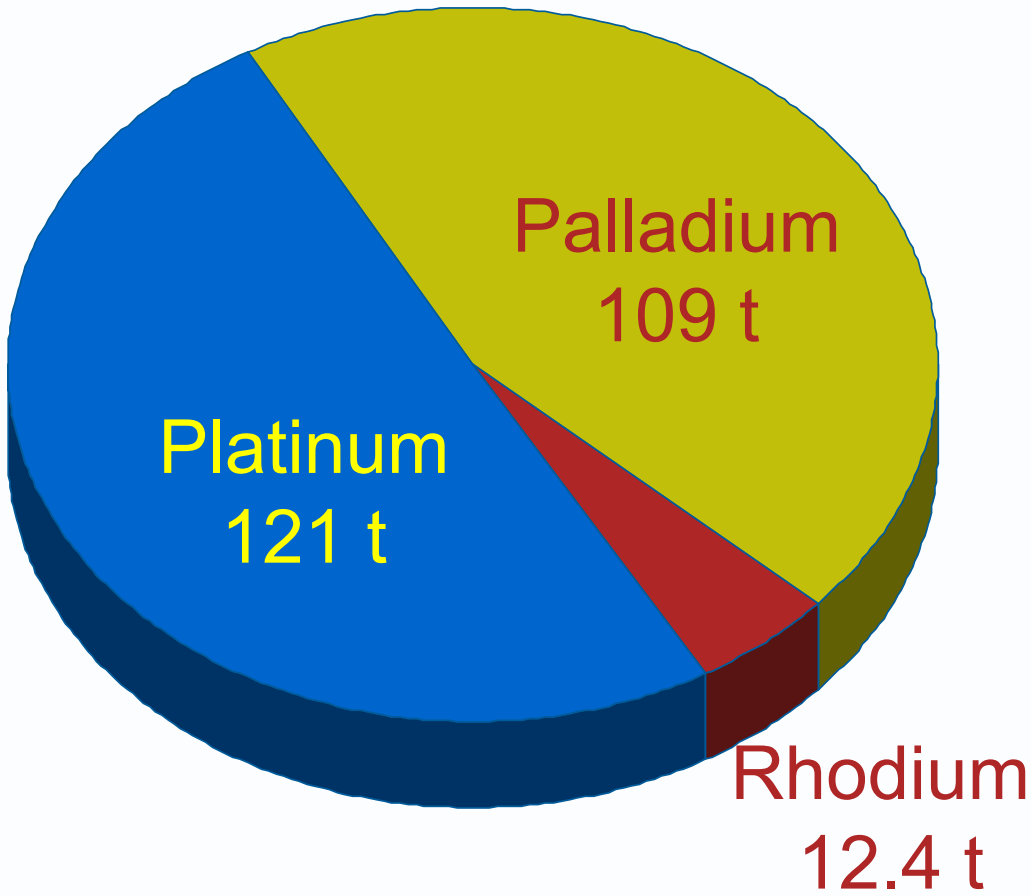
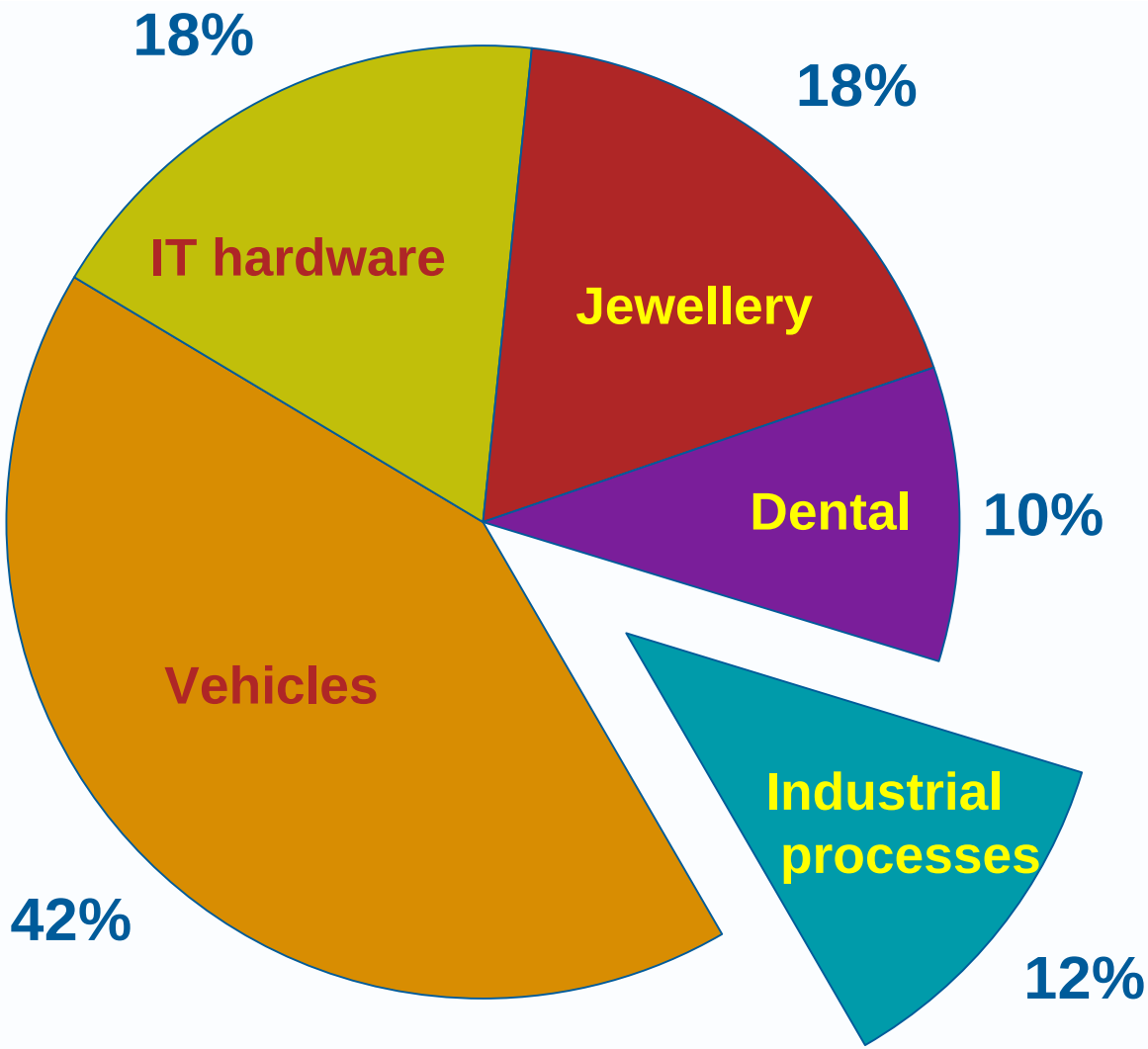
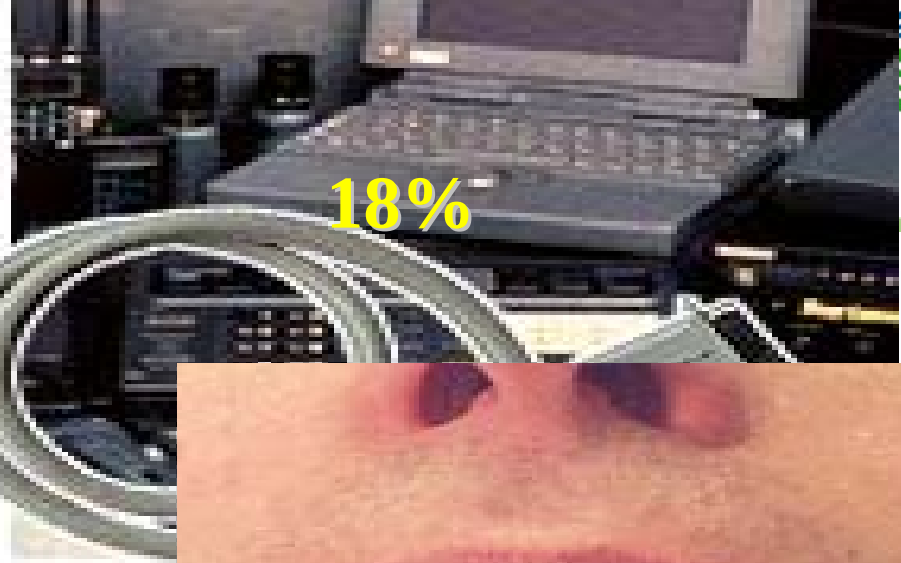


Germany's PGM inventory: Where is it?



Base year 2001


42%


18%


10%


18%
GFMS


12%

Deficit analysis:
PGM lifecycle efficiencies for main segments

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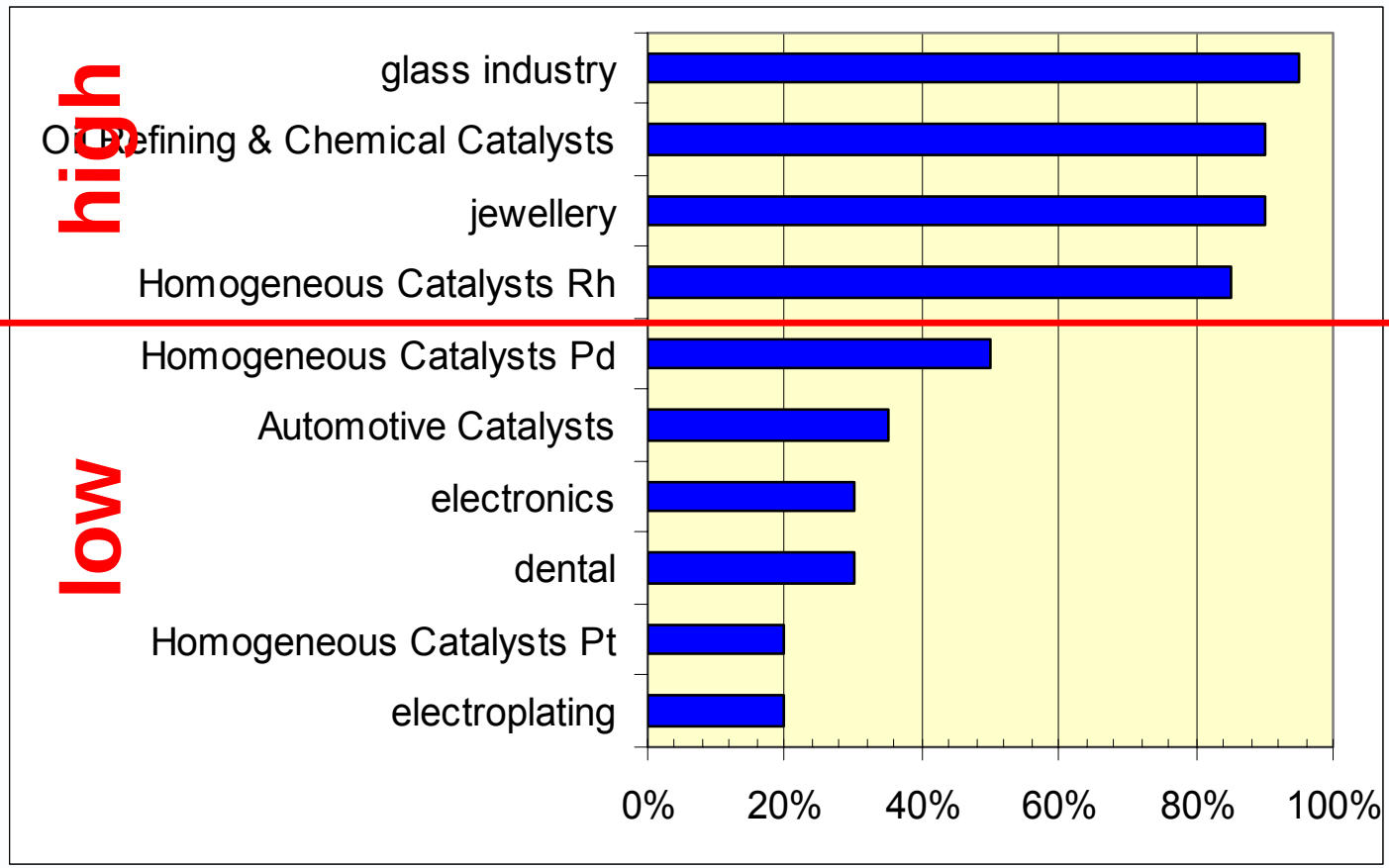
PGM-lifecycle efficiency = dynamic recycling quota



	Gross-demand t/a	Lifecyle loss t/a
glass industry	5,0	0,2
Oil Refining & Chemical Catalysts	6,4	0,5
jewellery	3,5	0,2
Homogeneous Catalysts Rh	0,4	0,06
Homogeneous Catalysts Pd	0,1	0,04
Automotive Catalysts	15,0	9,8
electronics	2,4	1,7
dental	2,5	1,8
Homogeneous Catalysts Pt	1,5	1,2
electroplating	0,4	0,1
	Σ 37,2	**15,6**

?? What makes the difference ??

To recap……..

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- 2/3 of gross PGM demand went into consumer products
- PGM inventory comprised 88% consumer products
  - Who said these were industrial metals?!
- And yet, end-of-life consumer products generated only 1/3 of all PGMs recycled
- Why?
  - Short lifecycles in industrial applications e.g. glass
  - Recycling structures are fundamentally different:

→ Industrial applications = “closed loop” systems

→ Consumer products = “open loop” systems

“Closed loop” recycling / direct cycles for PMs in industrial processes

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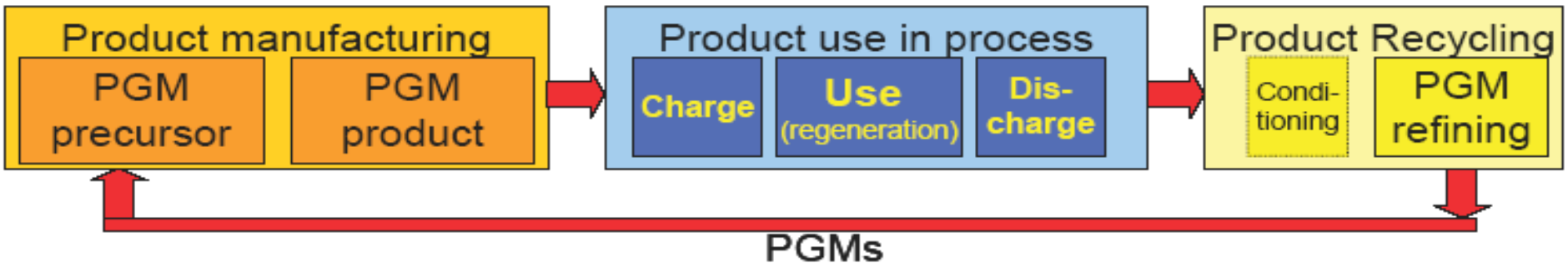
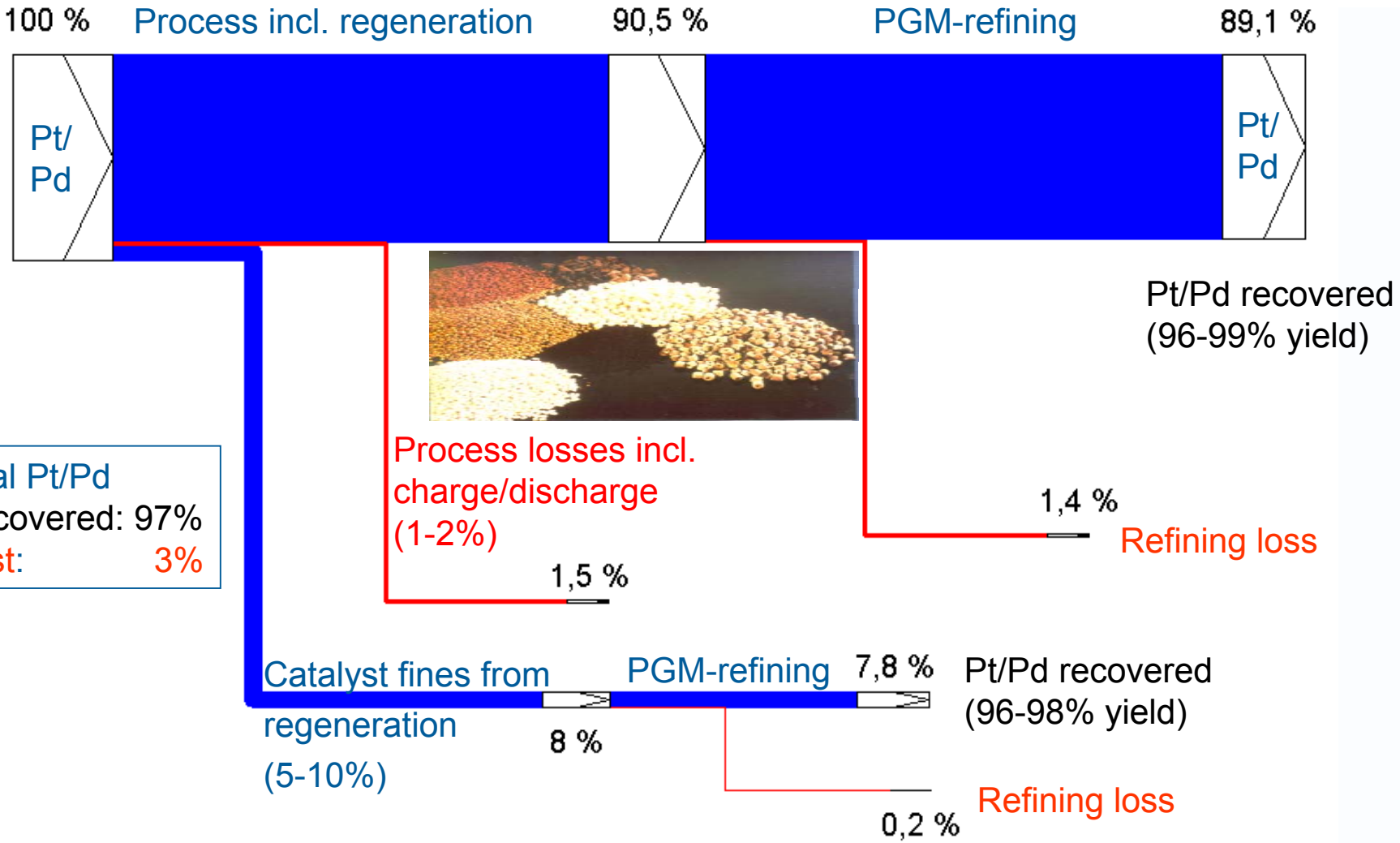


- Final products typically contain no PGM
- PGMs survive; recovery is an economic imperative
- Physical location of PGMs is confined to users plant
- Provider, user & refiner of PGM product work closely together:
  → Technical performance of PGM product is critical
- User typically retains ownership of the PGMs
- Spent products recycled by provider or specialised refiners into new
- Professional handling, rather transparent material flows

→ Inherently efficient; >90% measured efficiency

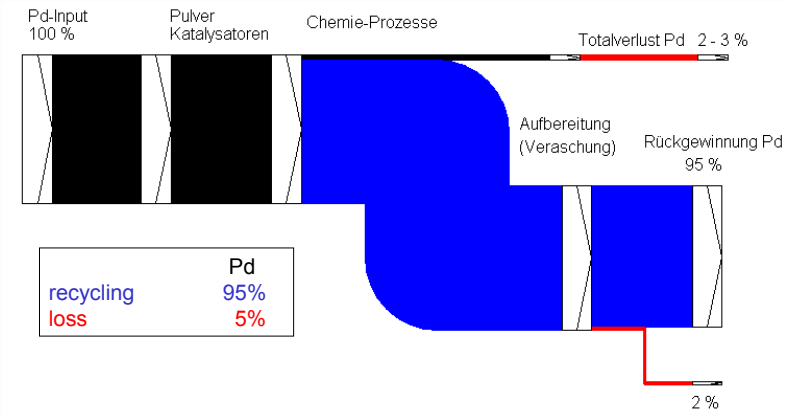
Example: PGM-flows of Pt/Pd catalysts used in the oil refining industry



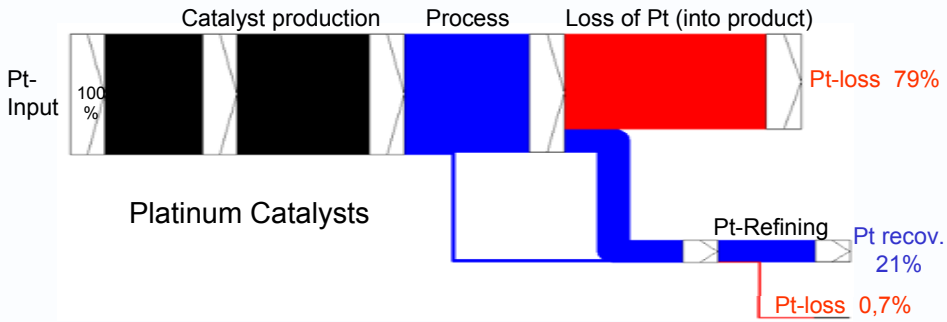
all %-numbers at single flows refer to 100% initial material; refining yields on input into PGM refinery

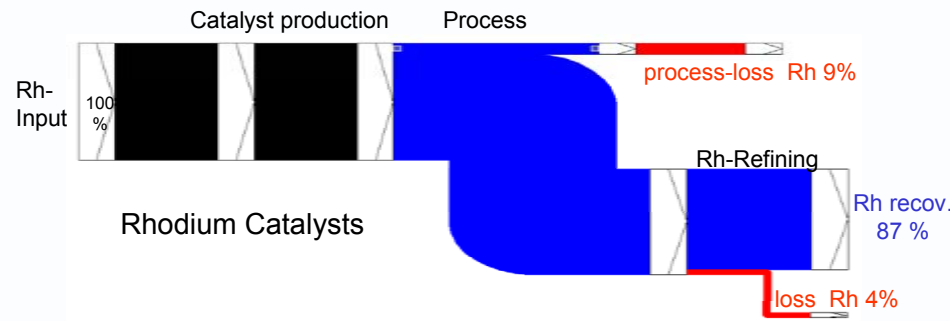
PGM-flows of other industrial catalysts

Pd carbon based

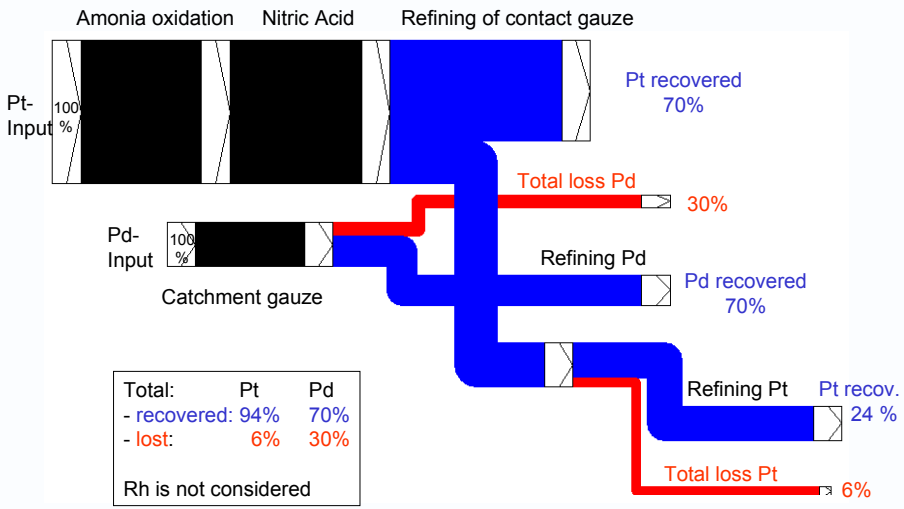


Pt and Rh in homogeneous catalysis

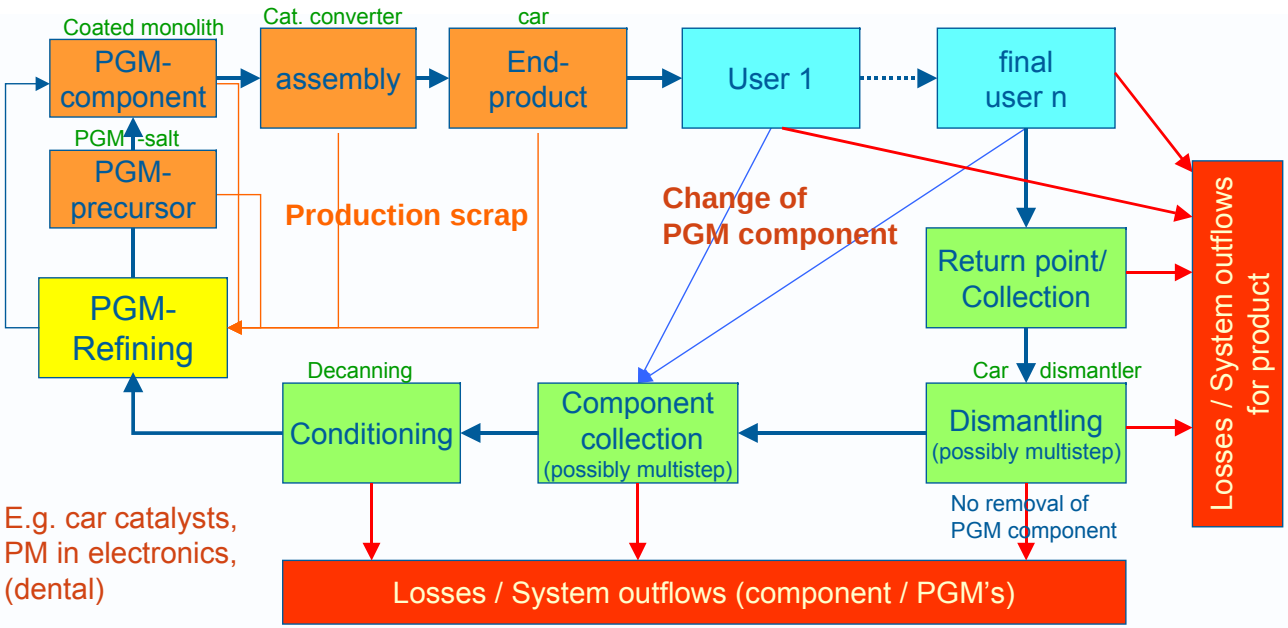




Pt/Pd catalyst-gauzes in nitric acid production



“Open loop” recycling / indirect cycles for consumer durable products … a complex affair



- Multiple changes of ownership, no connection remains between final owner and product manufacturer
- Involvement of “the general public”
- Often longer product lifecycle (e.g. car catalysts)

- Intransparent material flows, “informal” participants in early stages of recycling chain
- Often limited awareness of PM-values & inadequate removal of PM-bearing parts
- Electronics: high dilution of PMs in end product hinder economic viability of recycling
- High exports of cars, computers etc. to less developed countries with poor recycling infrastructure/awareness
- Highly complex structures with numerous opportunities for failure of PM-recovery

→ Inherently inefficient, PGM recycling rate usually < 50% for entire lifecycle

→ This is not unique for Germany !

Recycling chain for autocatalysts - PGM-refining takes place at the very end

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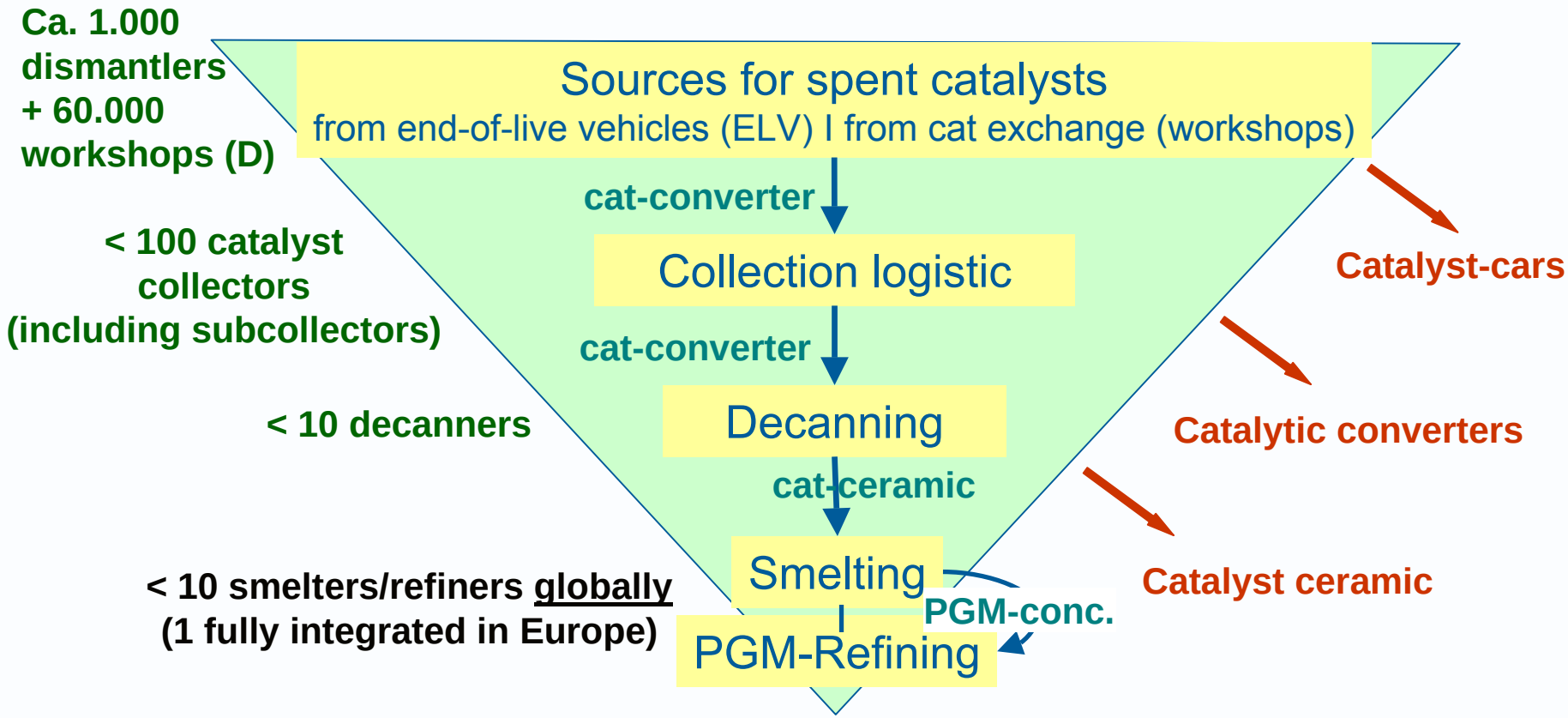


Again, this type of structure is not unique to Germany

Auto catalyst - methodology

Statistical data by year, emission level and engine size

Transfer into an „Excel“-model

Project findings, actual market data and forecast

Car inventory

New registrations

De-registrations

Calculation model

De-registered catalyst cars → PGM potential from catalyst recycling

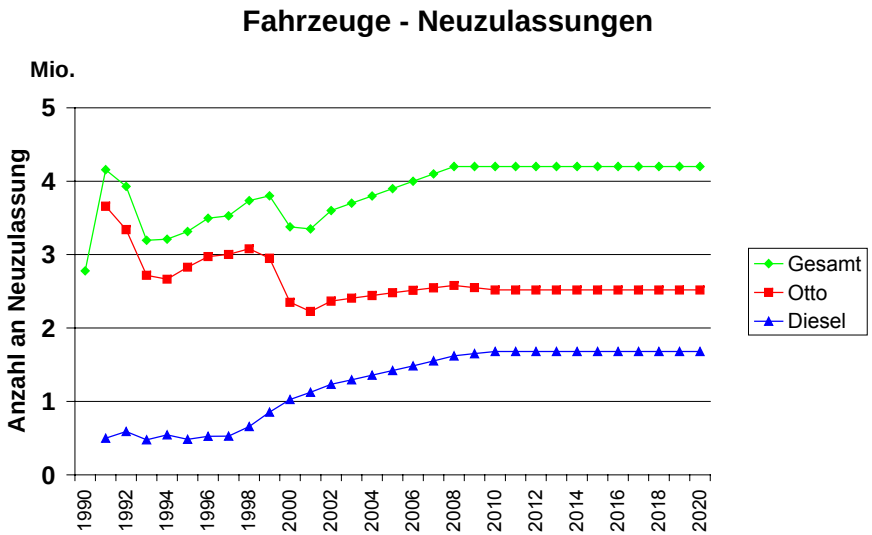
PGM-loading by emission level and engine size

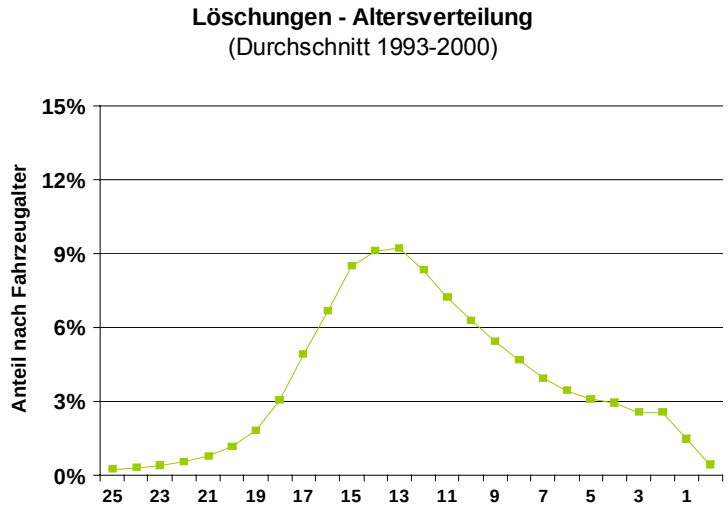
Field study

Losses

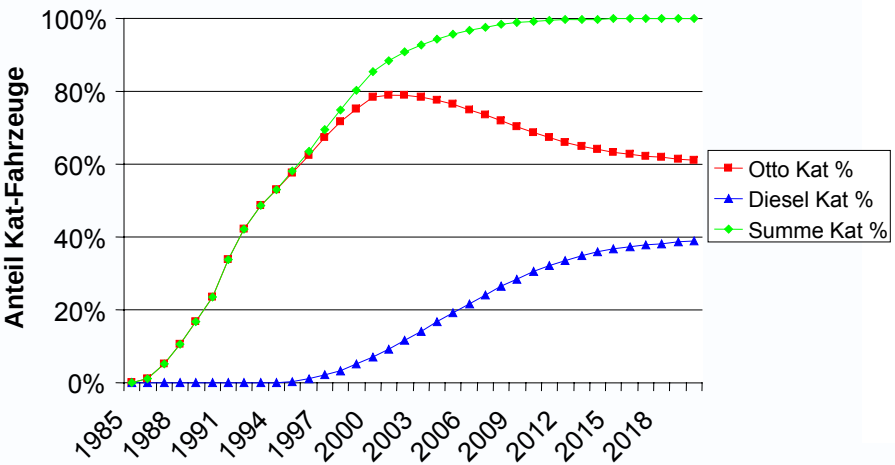
PGM recovered from catalysts in Germany

Analysis of car-statistics (D)

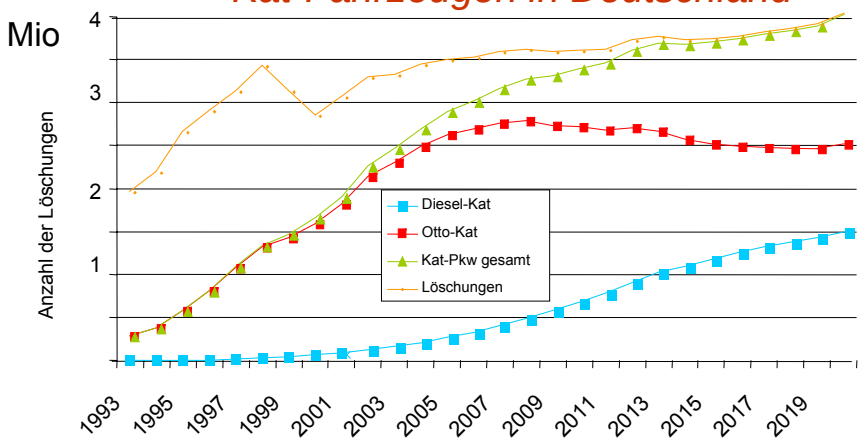




Kat-Fahrzeuge im Bestand
ab 1985 bis 2020



Prognose: Löschungen von Kat-Fahrzeugen in Deutschland



(TREMOD – own evaluation, 2002)

PGM-losses within the autocat recycling chain

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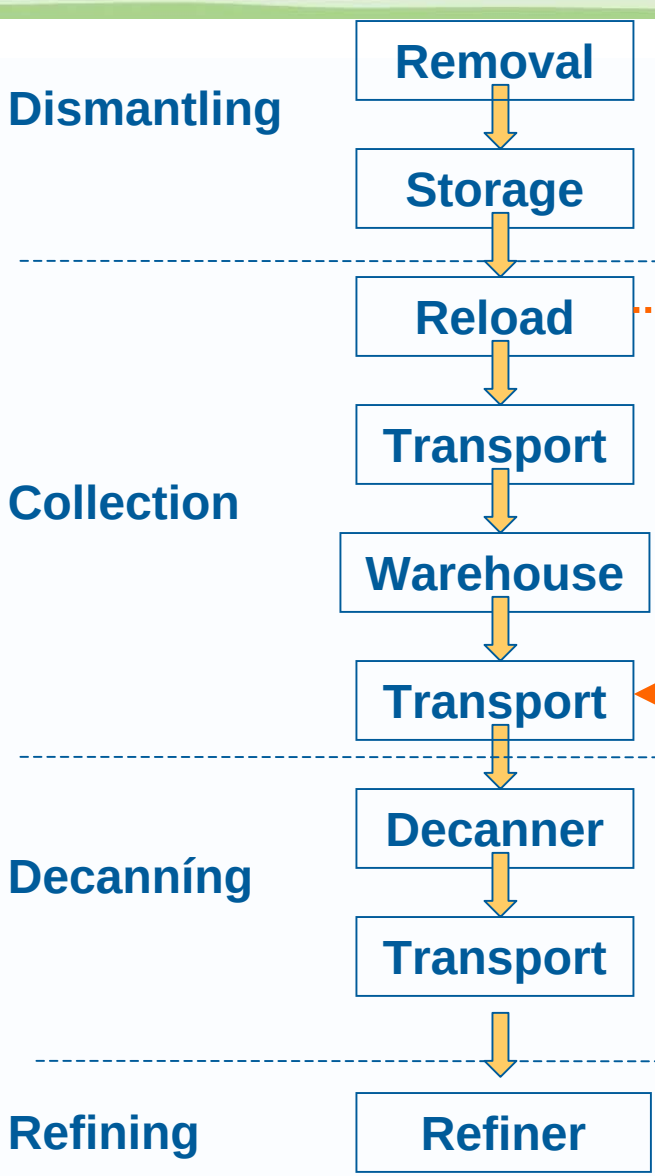

- Catalyst is not removed from the car
- wrong sorting of removed catalyst (as ferrous scrap)

⇒ not in compliance with ELV-directive

- Inappropriate or rough handling of catalyst
  - → pieces of broken monolith or dust are lost
  - → PGM-content of dust is factor 2-3 higher
- Theft of catalysts

⇒ PGM-Losses approx. 5%

⇒ The shorter and more professional the recycling, chain the smaller are the losses

- PGMs are lost with dust (especially if no or inefficient dust extraction systems are used)
- PGMs with dust stick to the steel casing (dry process) and are lost with the ferrous scrap fraction

⇒ PGM-losses up to 5%; depending on process

- PGM-losses into slags and effluents

⇒ losses Pt/Pd:2-6%; Rh:15-20%; depends on process

Flow of autocatalysts from ELV in D 2001/02

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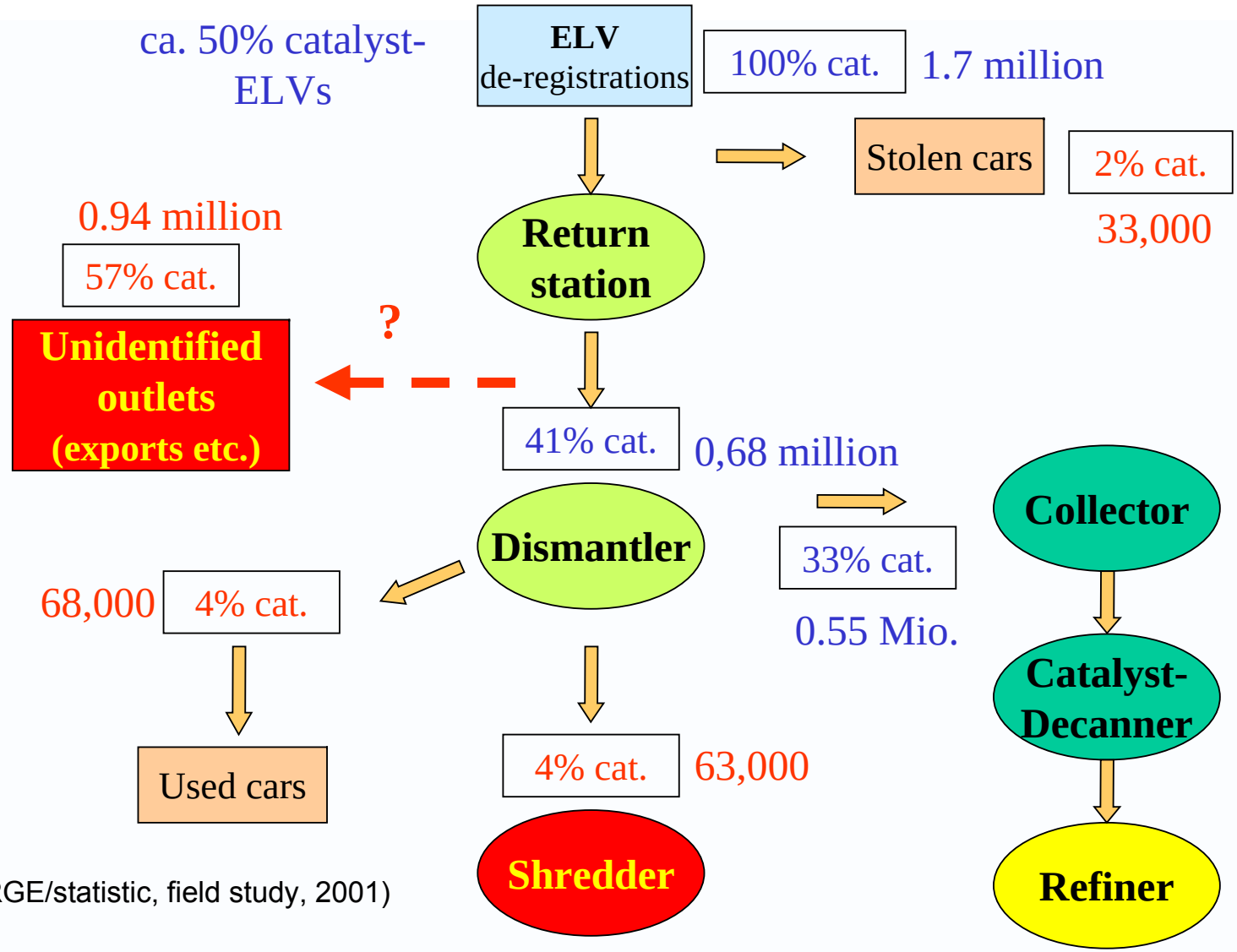

(ARGE/statistic, field study, 2001)

Lifecycle efficiency is still bad, high PGM-losses occur - 50% globally with Europe even higher

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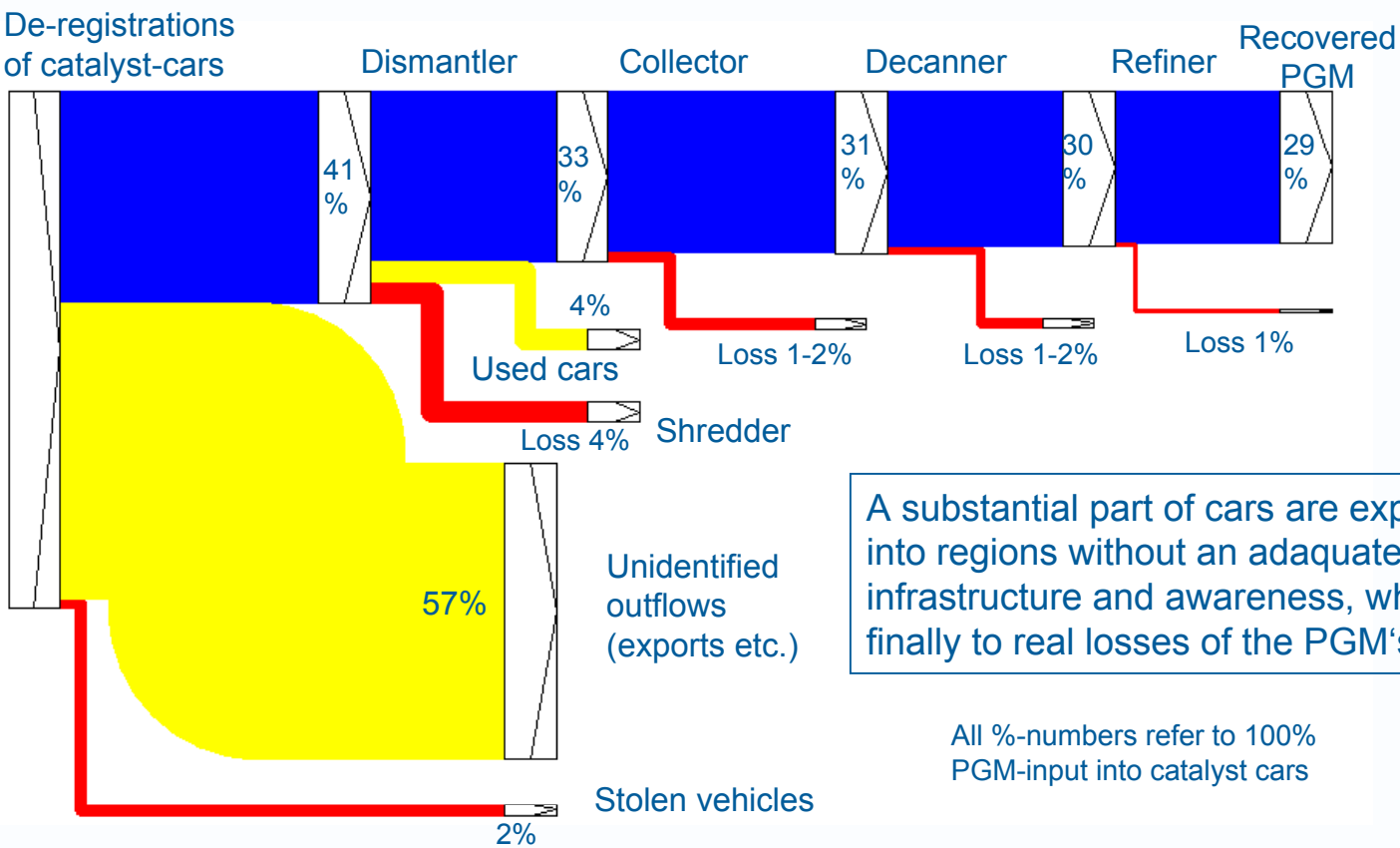
Material flows of PGM‘s from autocatalysts in Germany

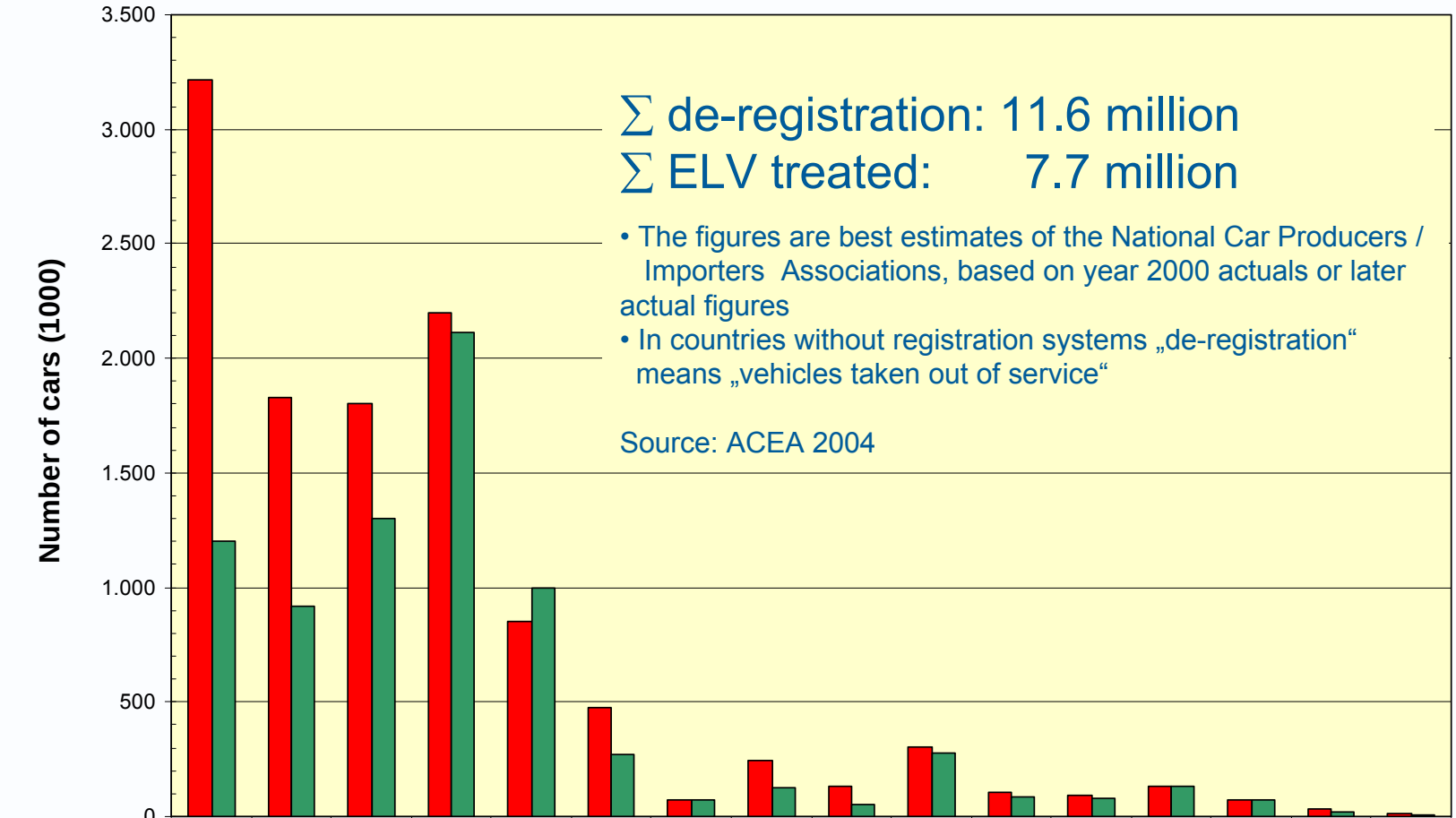


A substantial part of cars are exported into regions without an adaquate recycling infrastructure and awareness, which leads finally to real losses of the PGM‘s

All %-numbers refer to 100% PGM-input into catalyst cars

- yellow: outflow from system boundary (e.g. export of ELV); recycling abroad or re-import of catalyst is theoretically possible

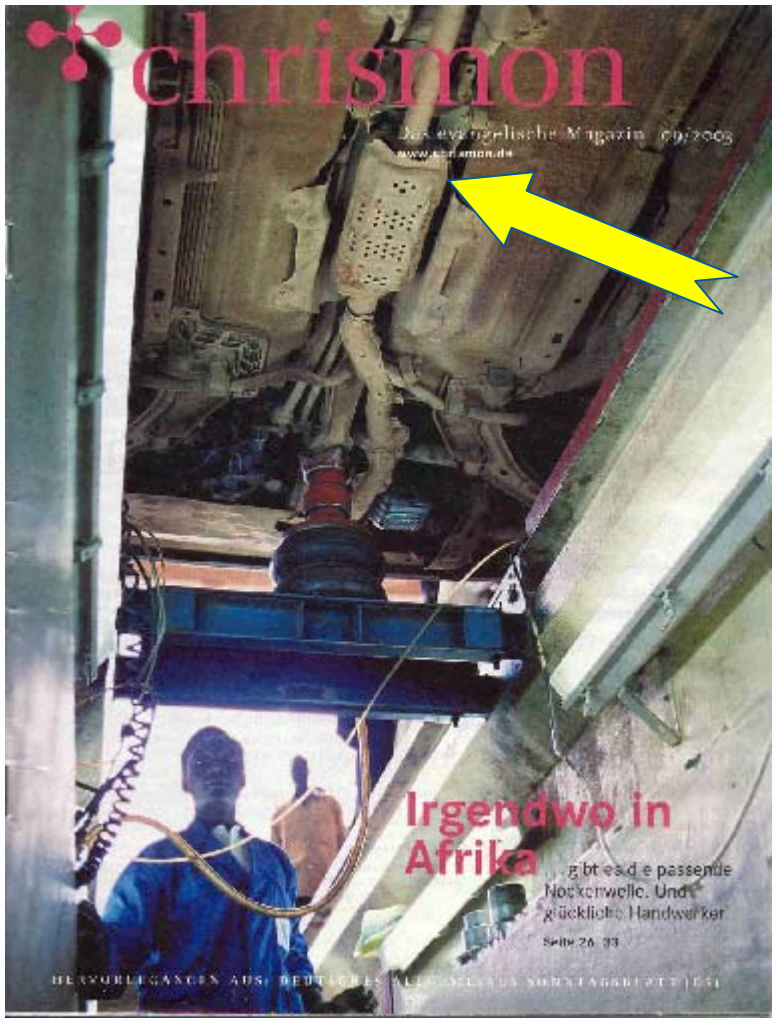
Europe: Gap between de-registrations & ELV treatment: ∑ 4 million cars/a (11,6 / 7,7 million)



	D	I	F	GB	E	NL	B	A	P	S	SF	N	IRL	DK	GR	L
de-registrations	3.216	1.830	1.800	2.200	850	473	70	247	130	305	105	90	130	73	30	10
ELV treated	1.200	915	1.300	2.110	1.000	272	70	124	52	280	89	81	130	73	20	9

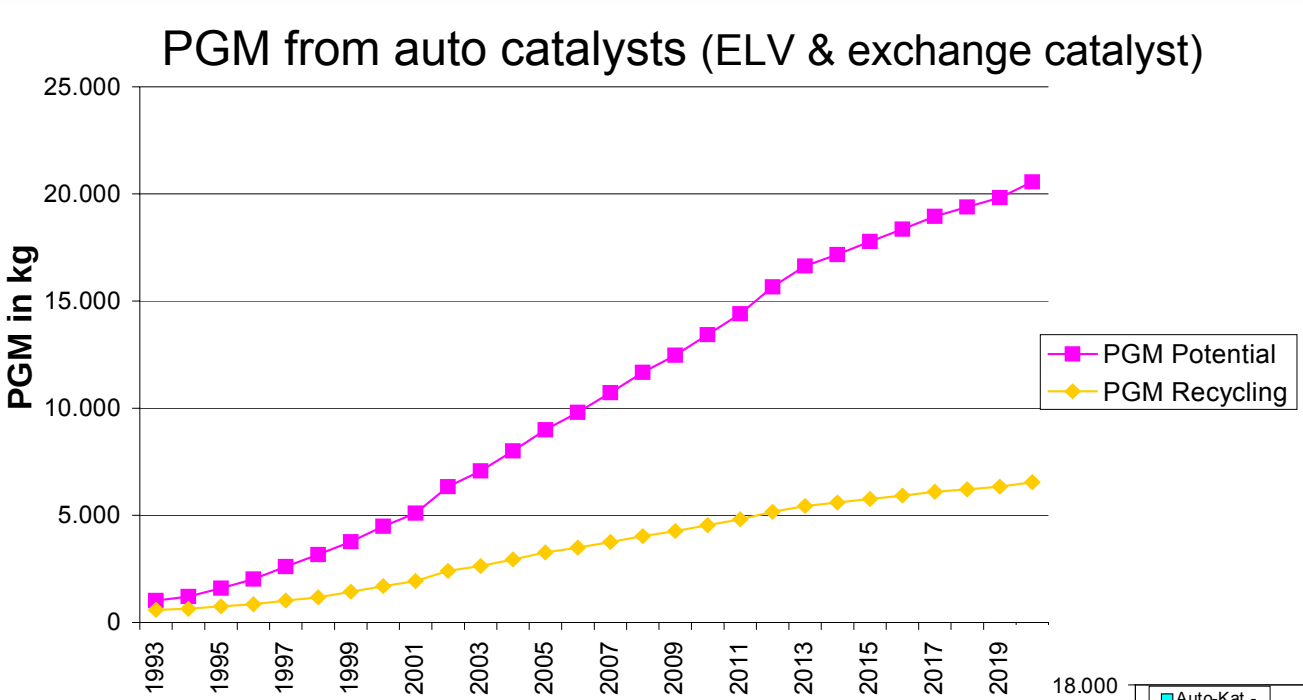
Source: ACEA Country Report July 2004

Low probability for future PGM-recycling from many export cars

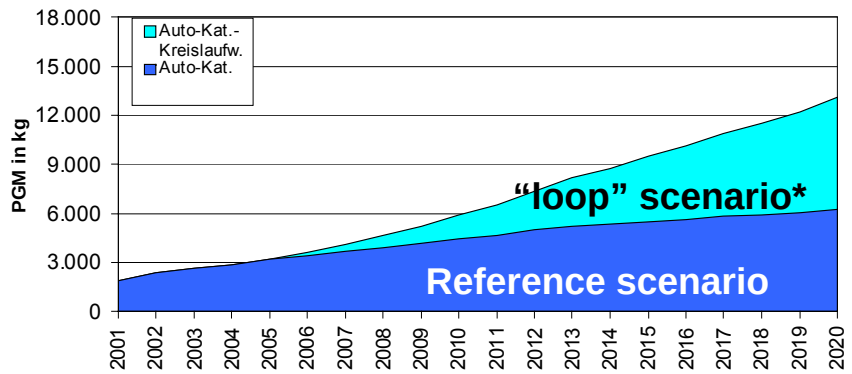


- exports mainly to Eastern Europe (& beyond) & Africa
- in most of these countries no emission legislation /-control in place
- insufficient car maintenance, bad road conditions
- high probability for destruction of catalyst → emission of ceramic/PGMs (misfire, bumps on converter ...)
- Usually high vehicle lifetime, catalyst has rather no significance (as long as car is still driving)
- insufficient recycling infrastructur, missing awareness for catalyst recycling
- difficult logistical frame conditions

PGM-recycling potential from automotive catalysts in D until 2020 **(„reference scenario“)**



A linear increase of the dynamic recycling rate to 70% (“loop scenario”) would double the PGM recycling volumes



Open loop recycling - the consequences

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PGM recycling from consumer products falls a long way short of its potential

- used autocatalysts & end-of-life electronics only < 40 %
- dental even worse

} Can this be improved ?

Recycling legislation should aid improvement

- EU laws on end-of-life vehicles and electronic waste recycling
- responsibility for recycling transfers to original producers

But…other supportive action is required:

- improved awareness of PGM value is required
- financial & environmental benefits of PGM recycling need to be understood
- more transparency is required and some rationalisation is necessary.
- dismantling and pre-processimg procedures need optimising.
- action by regulators & industry to better control & regulate “informal sector” and to eliminate unethical/ criminal business practices
- reduce export losses through stricter controls/regulations & pro-active measures

Consequences for the recycling of used autocatalysts

PGM recycling will grow organically

- Historical growth in autocatalyst application
- Rising proportions of catalyst equipped ELVs

However, losses will also grow organically

3 t in 2001, could top 10 t by 2020

"Closing the loop" could double PGM recovery by 2020

→ requires fundamental changes in the recycling practice (streamlining, industrial structures, transparency & control)

... and deliver environmental benefits

Environmental benefits

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- Germany consumed 21 tonnes of new PGM in 2001
- Mine production of 21 tonnes of PGM generates:

mine waste/tailings	4,000,000 tonnes	
Carbon dioxide*	300,000 tonnes	} (equivalents)
Sulphur dioxide	20,000 tonnes	

→ **Equivalent to production of 168,000 tonnes of steel*

- Increased recycling reduces dependence on mining
- Emissions value of "closing the loops" in Germany:

Carbon dioxide	90,000 tonnes	} (equivalents)
Sulphur dioxide	7,000 tonnes	

mine waste/tailings up to 4,000,000 tonnes

PGM-recycling will become of growing importance for future PGM-supply

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- Almost 50% of global PGM gross-demand today is covered by recycling.
- Large future potential for recycling: ≈ 50 % (4400 t) of all-time cumulative PGM-demand took place in the last 10 years.
- Specific logistical & technical requirements evolved for different recycling materials. Further investments and process development needed at PGM-refiners to comply with new refining challenges (fuel cells; new petro-cats).
- Significant changes occured in the PGM-recycling industries especially over the last 3 decades.
- Mastering the PGM-lifecycles from consumer products is the key challenge to be solved:
  - → Increase transparency and efficiency of PGM flows (incl. exports)
  - → Rationalise recycling chain, improve cooperation of industrial stakeholders
  - → Control / eliminate the informal sectors, more focus on business ethics
- "Real" smelting & refining companies play crucial role in future PGM-supply.

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