Material flows of car related PGM

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Umicore Precious Metals Refining

2nd Roundtable on the Sustainable Production & use of Platinum Group Metals

Brussels, Dec. 12, 2007

The global annual mine production for PGMs fits into a 15 m² room (31m³)

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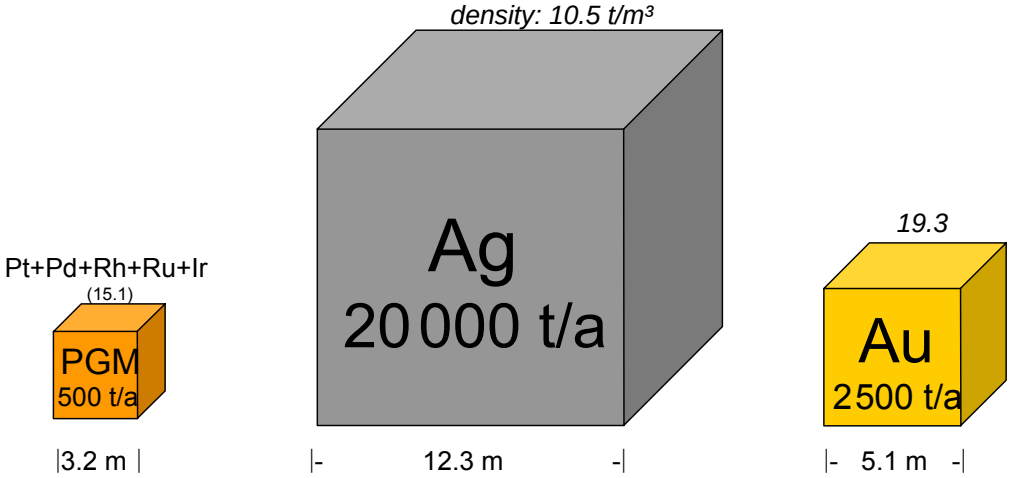
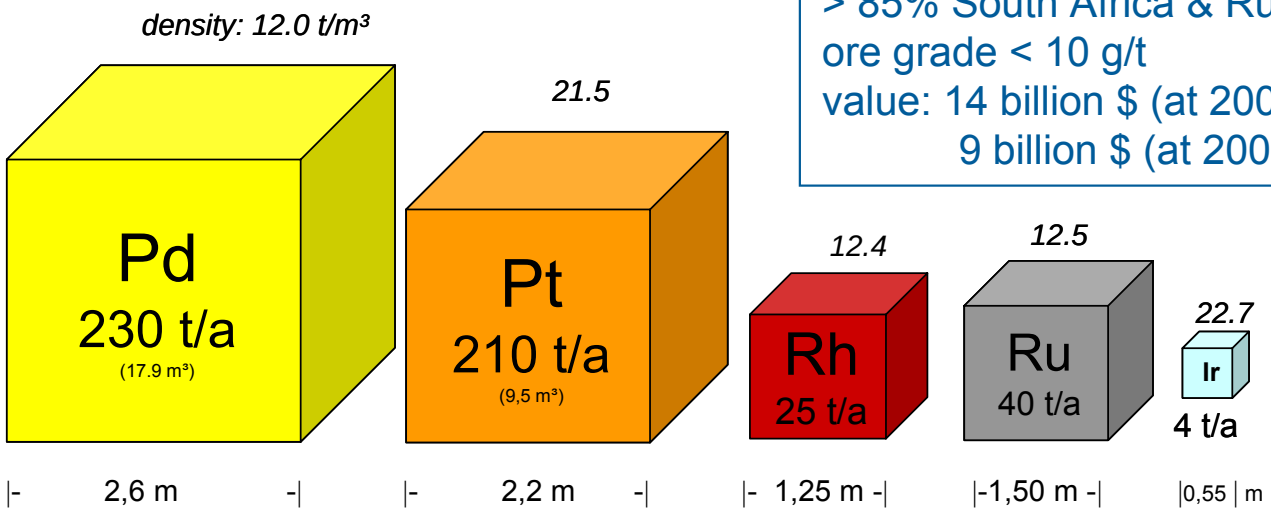


Mine production PGM:
> 85% South Africa & Russia
ore grade < 10 g/t
value: 14 billion $ (at 2006-prices)
9 billion $ (at 2005-prices)

PGM = Platinum Group Metals



85% of all PGMs ever mined were extracted after 1980!

$/g	Pd	Pt	Rh	Ru	Ir
2006	10,29	36,75	146,13	6,16	11,22
2005	6,46	28,84	66,01	2,38	5,43
2004	7,39	27,20	31,51	2,06	5,98
2003	6,43	22,22	17,04	1,13	2,98

M $	Pd	Pt	Rh	Ru	Ir	total M $
2006	2366	7717	3653	185	45	13966
2005	1486	6056	1650	71	22	9286
2004	1701	5712	788	62	24	8286
2003	1479	4665	426	34	12	6616

PGM demand 2007 worldwide – autocatalyst > 50% of net demand

Platinum	t/a	%
autocatalyst	104	48
jewellery	50	23
chemical+petroleum	20	9
investment	2	1
others	40	18
total demand*	**215**	

Palladium	t/a	%
autocatalyst	107	52
jewellery	23	11
electronics	34	17
dental	19	9
others	22	11
total demand*	**205**	

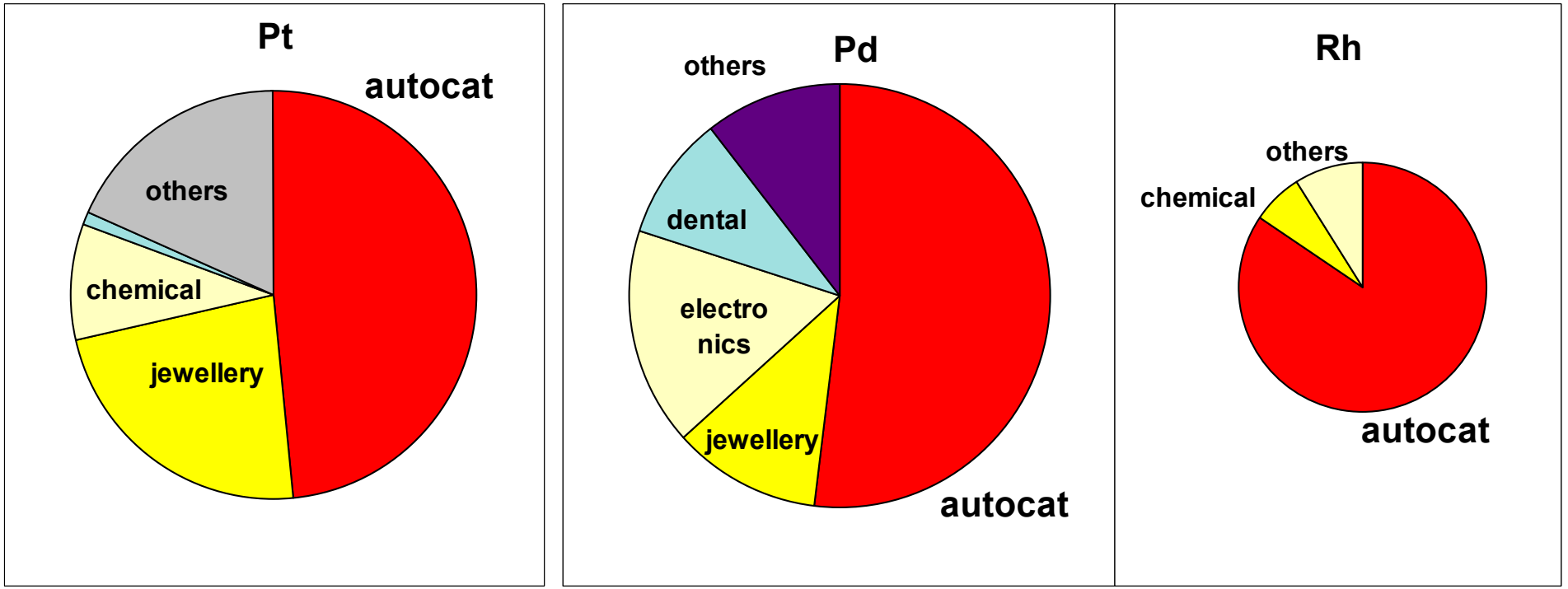
Rhodium	t/a	%
autocatalyst	21	84
chemical	2	7
others	2	9
total demand*	25	

* net demand

total PGM for autocat (net) = 232 52%

= gross demand - recycling

total demand* Pt+Pt+Rh: 446



Numbers based on JM 2007

There are more precious metals in automotive applications

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	global annual gross demand in t*	Pt	Pd	Rh	Ir	Au	Ag
✔	Catalysts & DPF	131,7	136,2	26,8	(x)		
-	Sensors & spark plugs	5			X		
-	Electronics		X			X	X
	total automotive	136,7	>129	26,8	1	?	?
	total mine supply*	207,2	230	25	4	2.500	20.000
	% of mine supply	**66%**	**>56%**	**107%**	25%		

DPF= Diesel Particulate Filter

catalyst recycling in t/a*	28	29,4	6
% catalyst demand covered by recycling	**20%**	**23%**	**21%**

*2007, Based on JM & GFMS figures

⇨ **Automotive is most important segment for Platinum Group Metals (PGM).**

⇨ **Recycling only takes place for car catalysts, but hardly for sensors/spark plugs or car electronics**

Autocat is main driver for PGMs since 1990s – Europe: 27% of total demand & 33% of autocat

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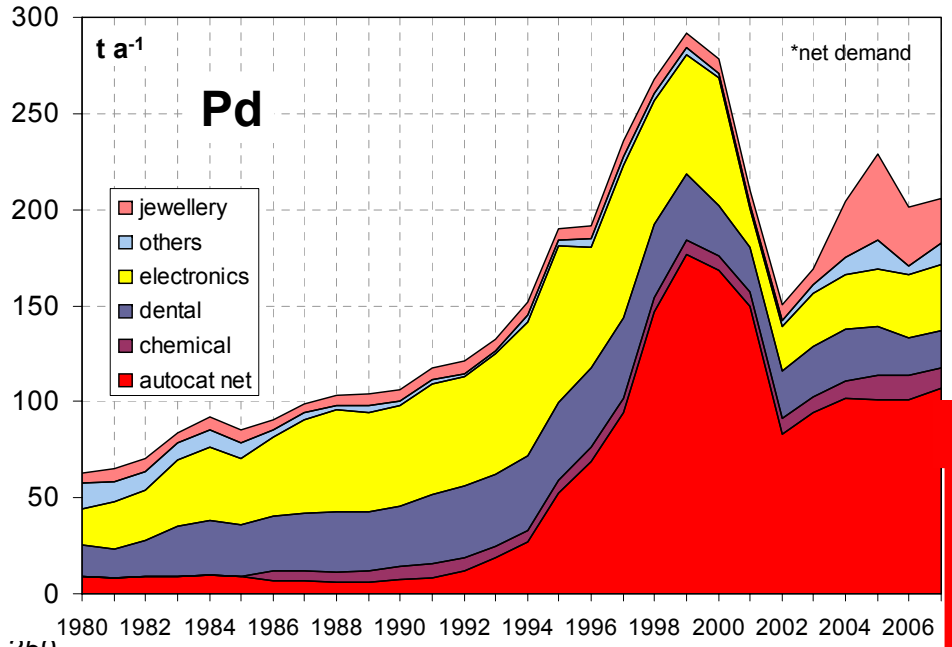
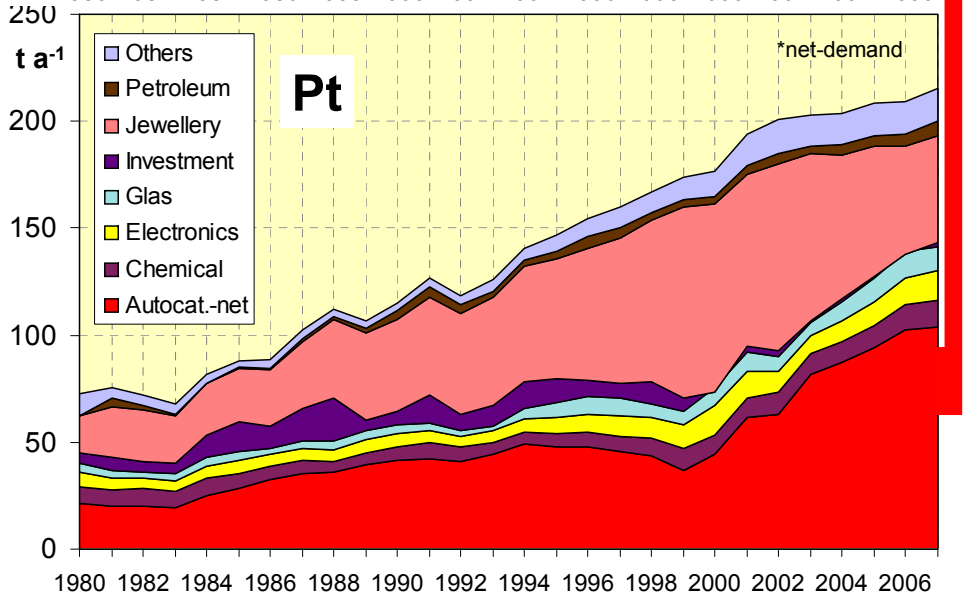
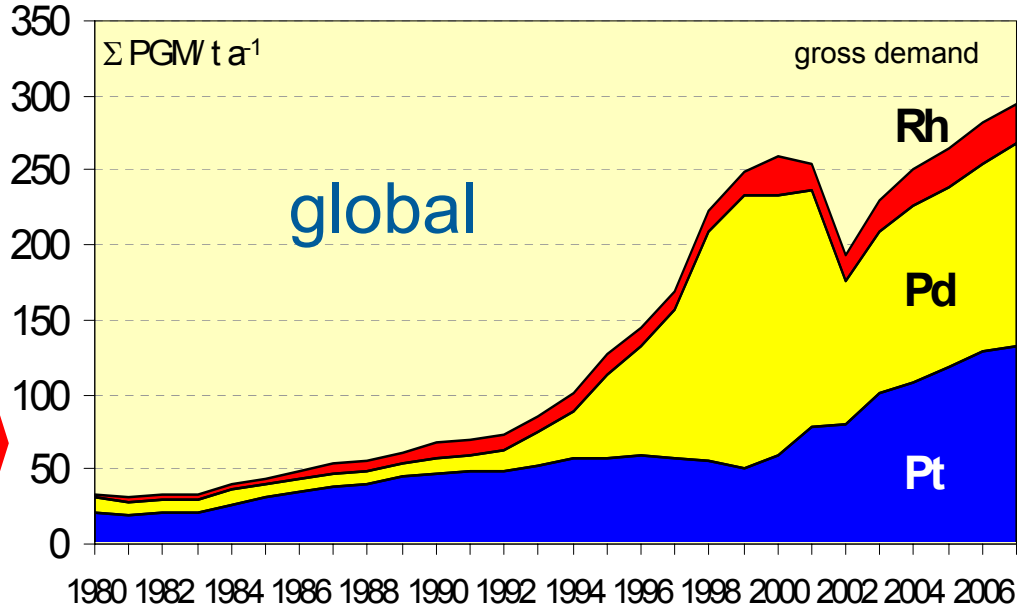
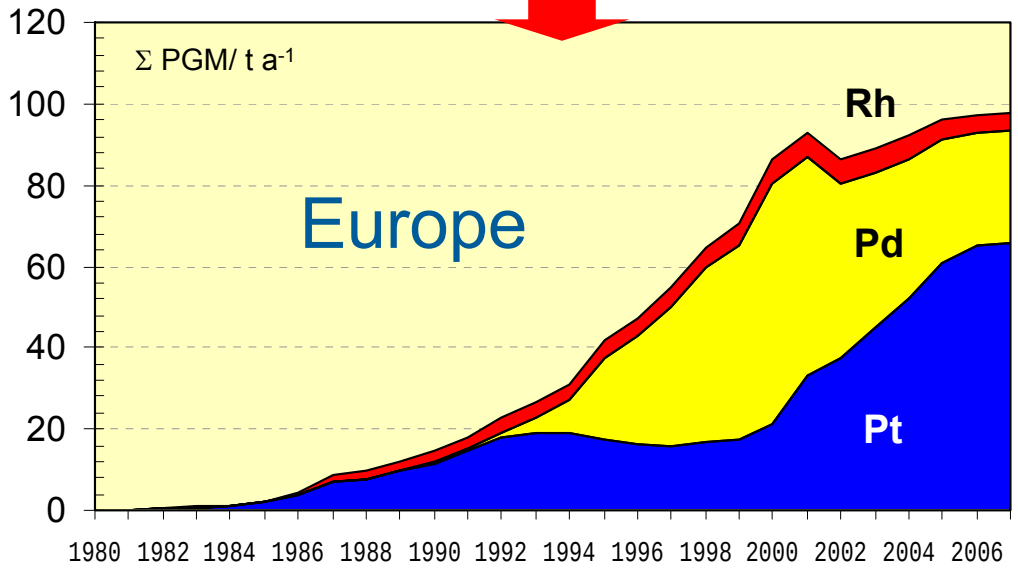
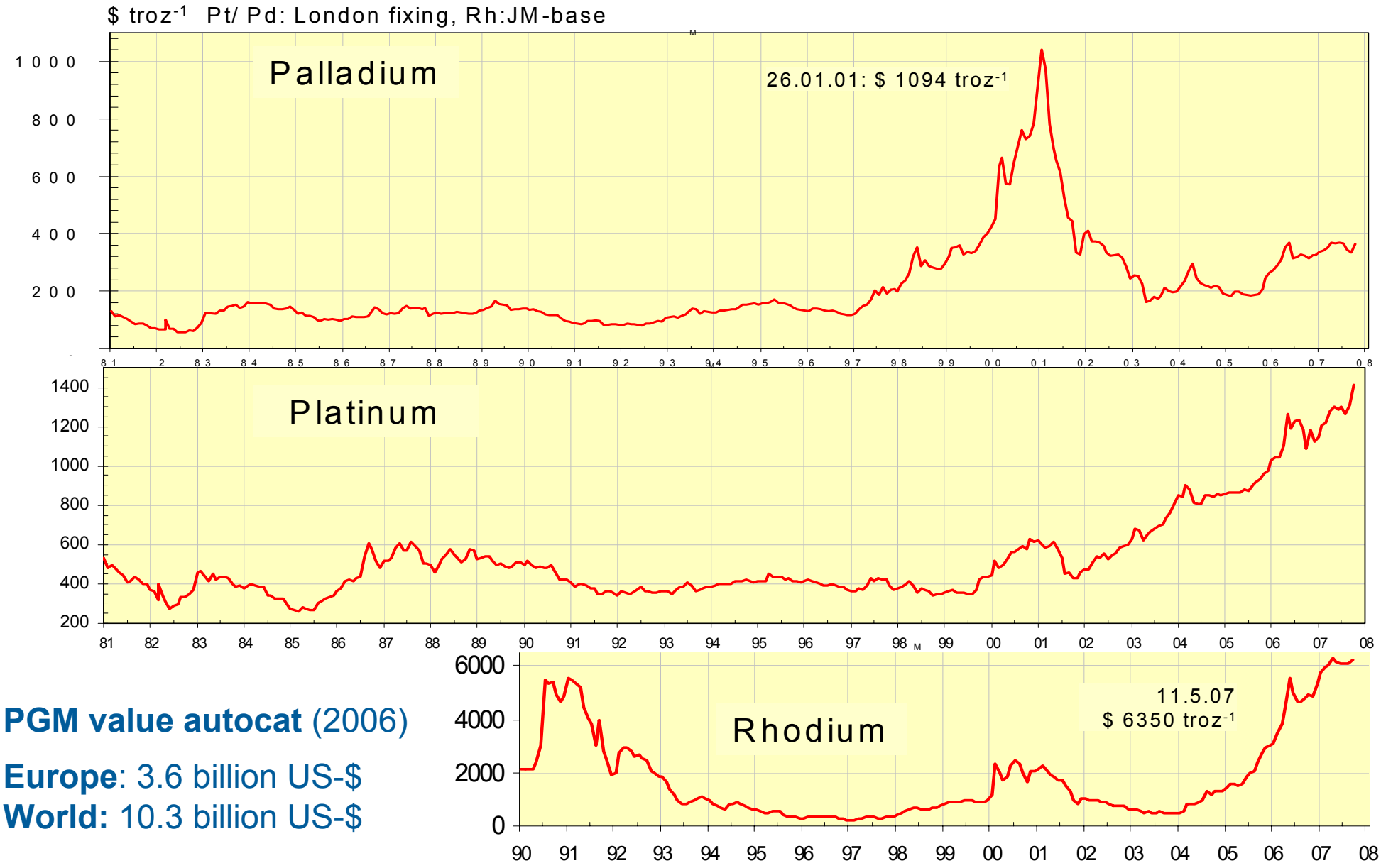








Autocat demand & technology impact PGM prices – which impact catalyst costs …



PGM value autocat (2006)

Europe: 3.6 billion US-$

World: 10.3 billion US-$

Autocatalysts – an above ground PGM-stock to be mined with a 10-15 years delay

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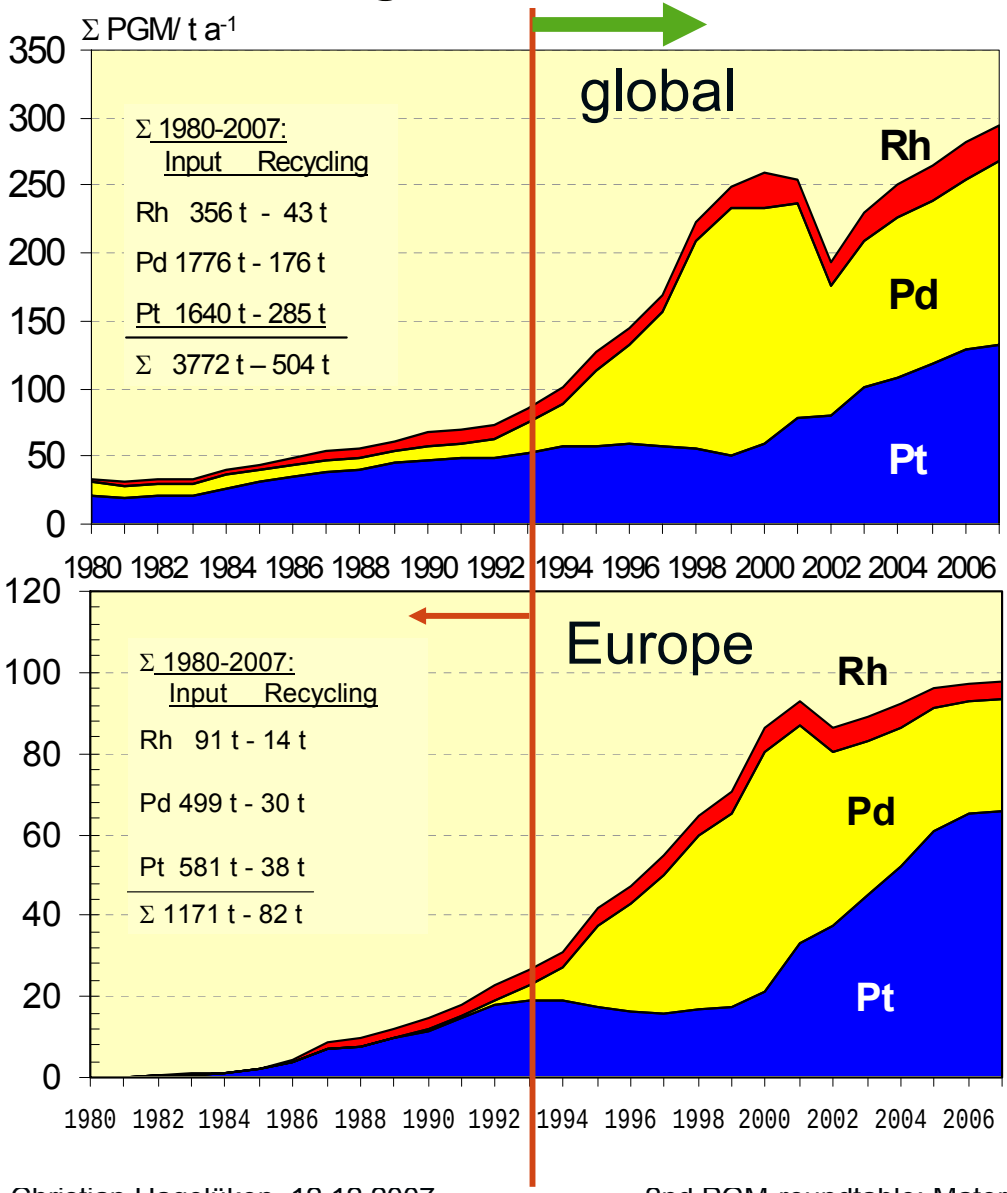
Annual PGM gross demand for autocat



Main catalysts recycled today are from the early 1990's.

- How much of the later increase will become available for recycling ?
- What needs to be done to secure these resources ?

	Global / Europe	1000 M$*
cumulative demand	3770 t / 1170 t	130
recycling until 2007	500 t / 80 t	15
still „on the road"	2300 t / 900 t	80
losses	≈ 1000 t / 200 t ?	35

*global at 2006 prices

CO_2 primary equivalent:
30 Mt for still "on the road"
13 Mt for losses

2007	M$ cum	Mt CO2	Mt CO2 cum
Pd	18.275	1,3	16,7
Pt	60.270	1,8	22,9
Rh	52.022	0,8	10,9
	130.567	**3,9**	**50,4**

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

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Sources for spent catalysts

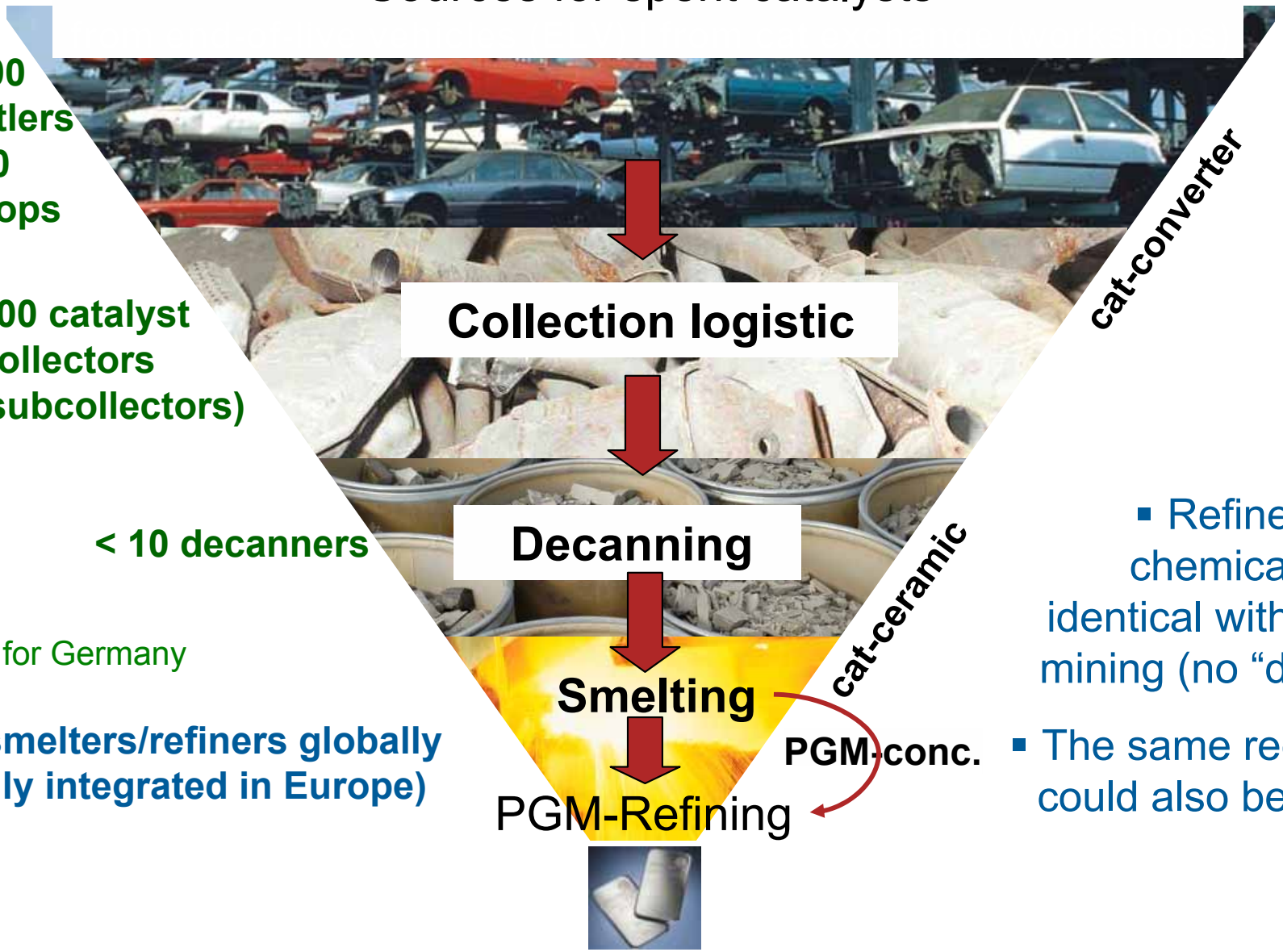
Ca. 1.000 dismantlers + 60.000 workshops

< 100 catalyst collectors (incl. subcollectors)

< 10 decanners

numbers for Germany

< 10 smelters/refiners globally (1 fully integrated in Europe)



- Refined metals are chemically/physically identical with metals from mining (no “downcycling”)
- The same recycling chain could also be used for car electronics

Example for “high-tech” metals recovery - Umicore’s Hoboken plant near Antwerp

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- Unique flowsheet, focus on secondary materials
- Recovering 17 metals:
  Au, Ag, Pd, Pt, Rh, Ir, Ru,
  Cu, Pb, Ni, Sn,
  Bi, Se, Te, Sb, As, In
- Annual PGM-output > 30 t
  ≈ 7% of world mine prod.
- Wide range of complex precious metals bearing feed materials
- Market leader (EU) for car catalysts & circuit boards
- Global customer base
- Minimizing waste
- World class environ-mental standards (BAT)

Recycling reality for autocatalysts: 50% PGM-losses globally with Europe even worse

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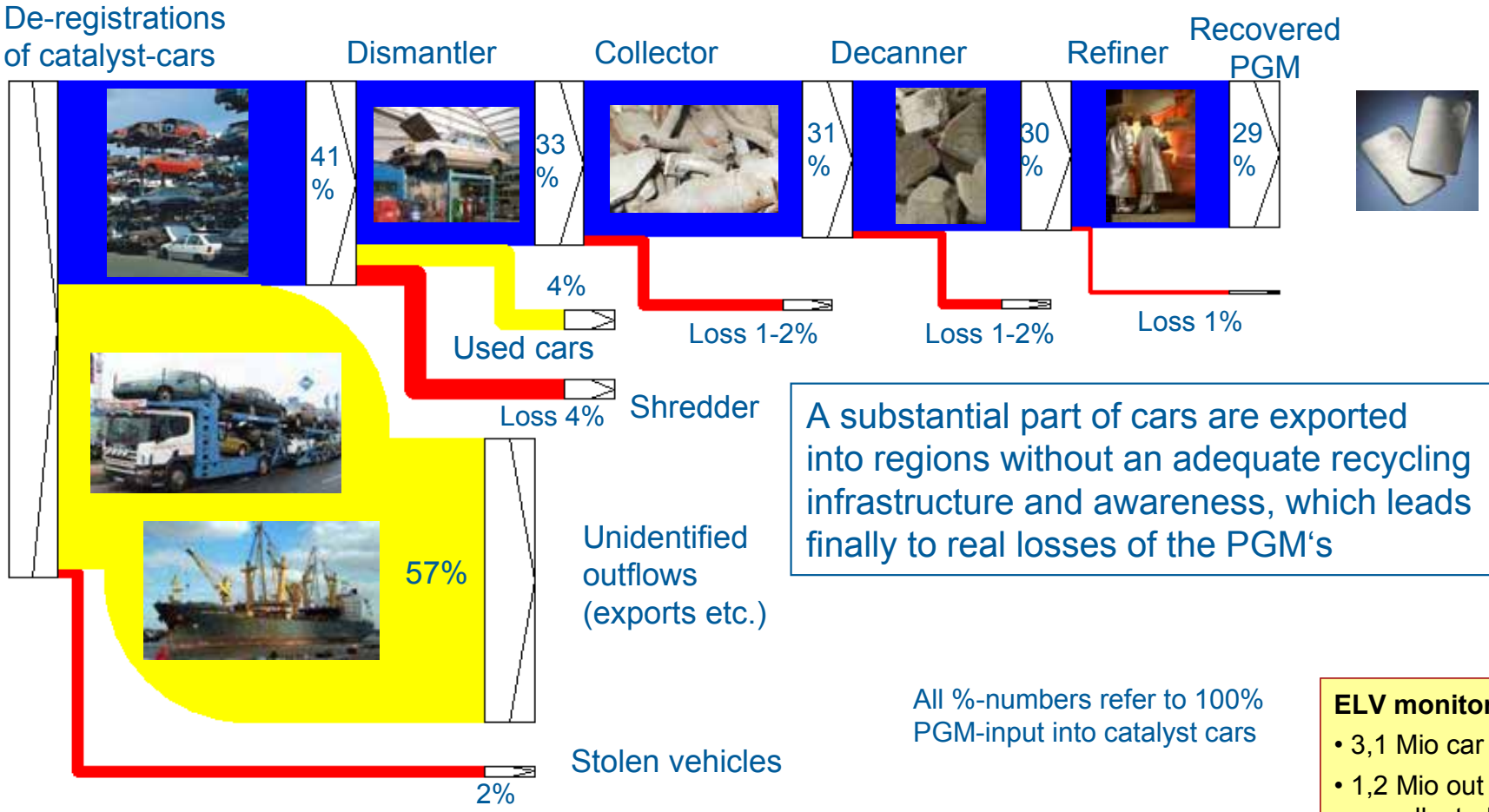
Material flows of PGM's from autocatalysts in Germany 2001



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

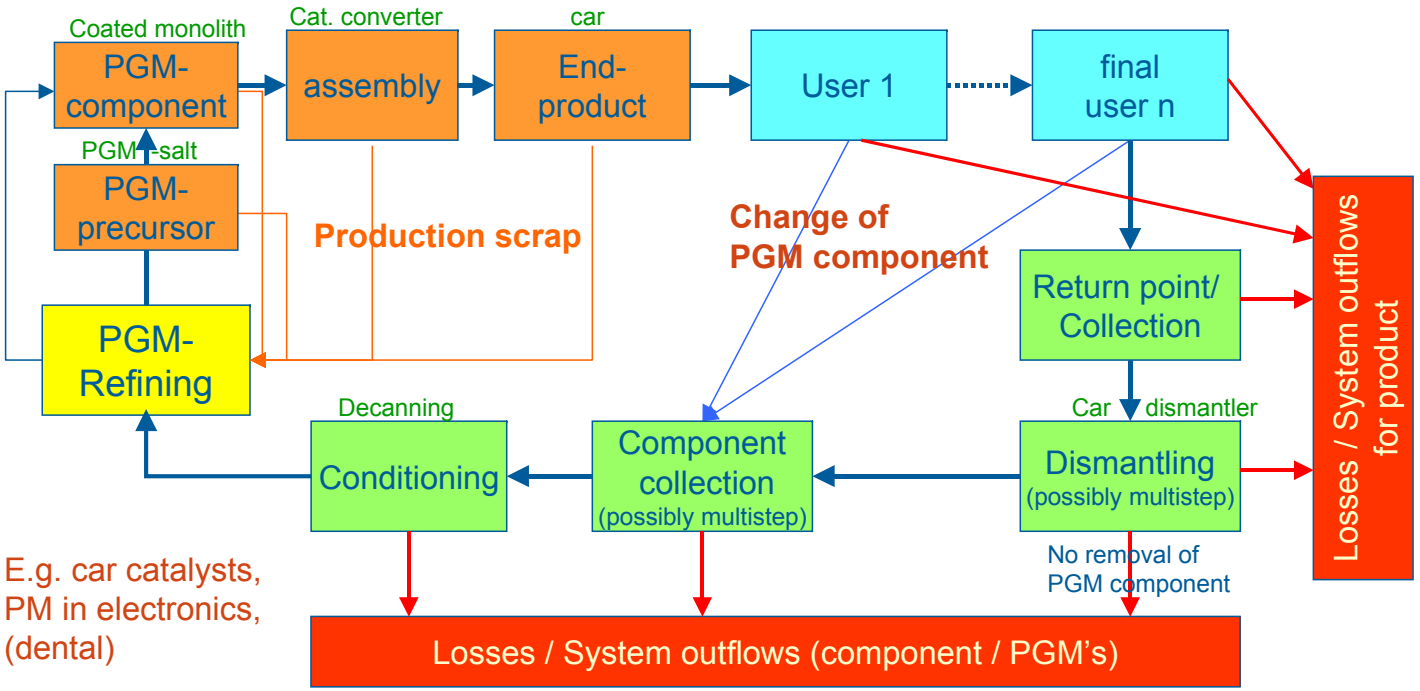
All %-numbers refer to 100% PGM-input into catalyst cars

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

ELV monitoring 2004, D

- 3,1 Mio car de-registrations
- 1,2 Mio out of these collected/first treated in D
- 540 000 only final treatment in D

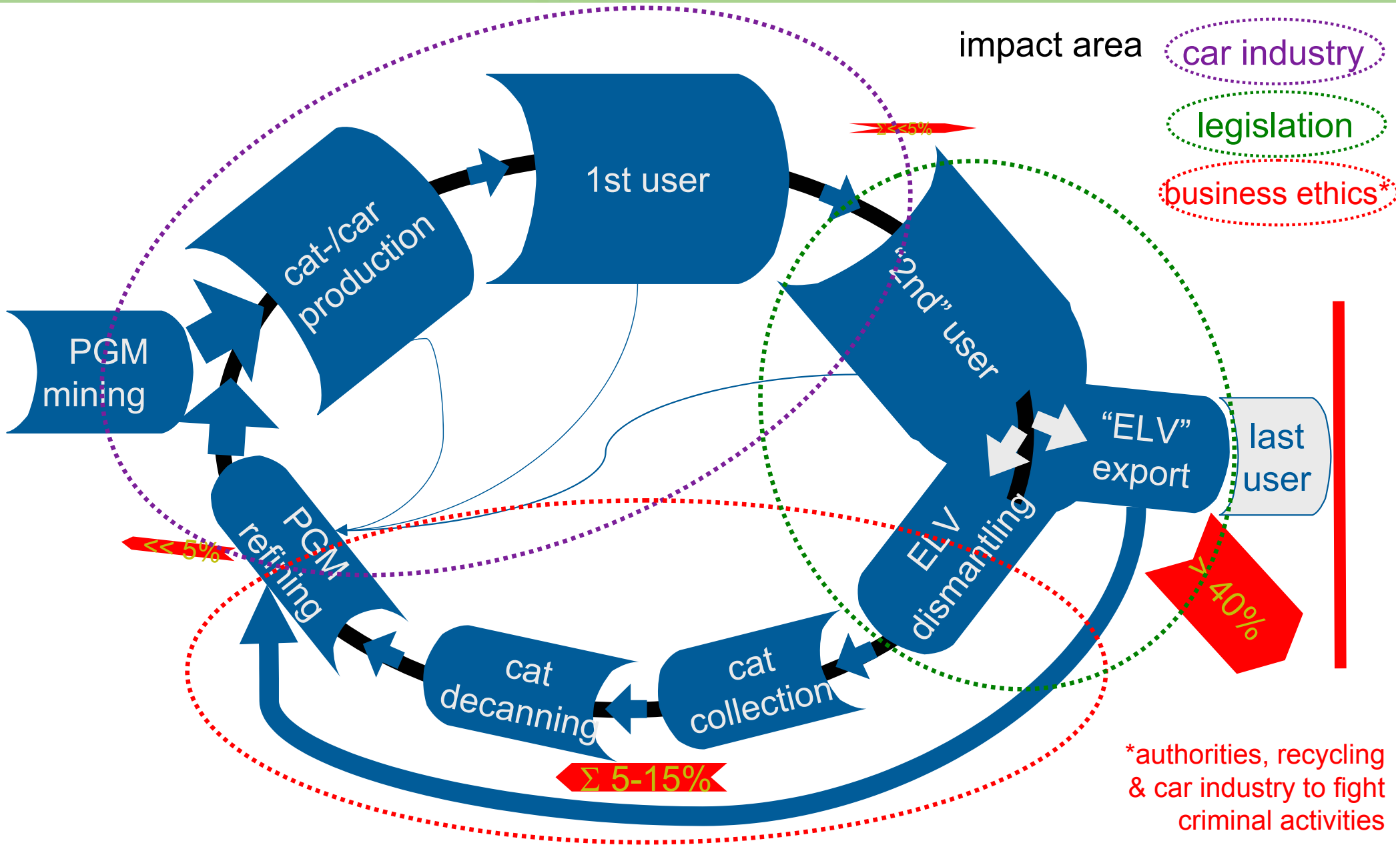
The challenge of "open cycles" - recycling from consumer durables



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

- Multiple changes of ownership, no connection between final owner and manufacturer
- High product mobility & long life time, no defined EOL, reuse in other regions than 1st use
- Intransparent material flows, "informal" participants in early "recycling" stages
- High exports of old cars, computers etc. to less developed countries with poor recycling infrastructure/awareness
- Highly complex structures with numerous opportunities for failure of metals-recovery

The European autocat lifecycle - what steps can be influenced by whom?



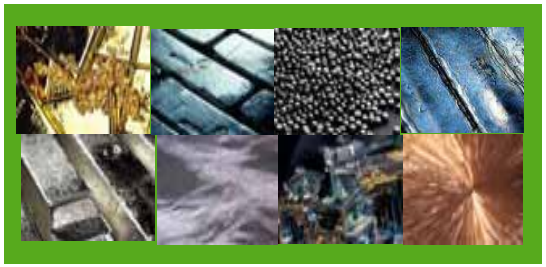
There is much more in cars than PGM

other metals contained (in kg/vehicle)*

built (Europe):	**1990**	→	**2004**
weight/vehicle	*900kg*		*1350kg*
• Cu ≈ 1.2%:	11kg	→	16kg
• Al ≈ 8%:	70kg	→	120kg
• Pb ≈ 1%:	9kg	→	13kg
• Steel ≈ 65%:	590kg	→	870kg

- + Zn, Sn, Cr, special metals
- + Ag, Au, Pd in car-electronics
- + Pt, Ir in spark plugs & sensors

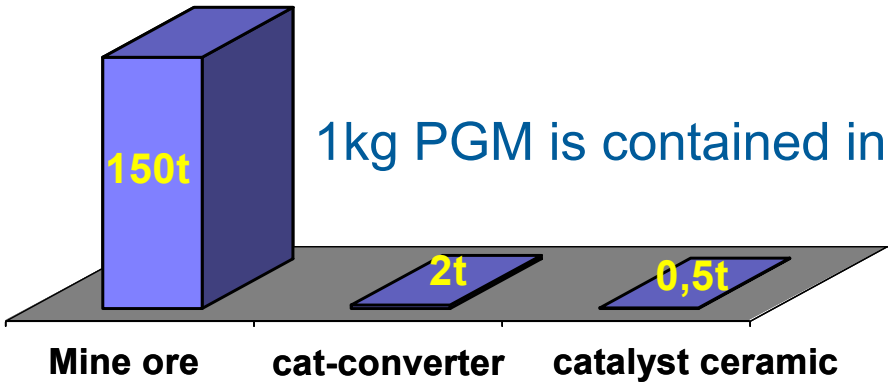
built 1990 ≈ deregistered in 2006
2004 ≈ deregistered in 2020



*source: Daniel Goldmann, VW Sicon

PGM recycling has significant benefits …

… which can be of vital interest for the car industry



- less environmental burden to „mine the catalyst“ (factor 5 in CO_2 impact)
- huge intrinsic PGM value that can be recovered (> 50 billion US-$)
- improved supply security
- Relief of supply / demand balance mitigates price increase and volatility

- Car companies can establish internal collection systems for catalysts from contract workshops → weight account model with catalyst recycler/producer, recovered PGMs can be used for fresh catalysts
- Car companies should support an effective recycling of ELV-cars & catalysts in their own interest. ELV-exports out of Europe reduce the supply base for recycling PGMs and other metals significantly. They indirectly contribute to tightness of supply and rising metal prices.
- A company which follows a sustainable business approach must not ignore the effects of current ELV-exports (image risk)

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

GFMS

Some books for more info:

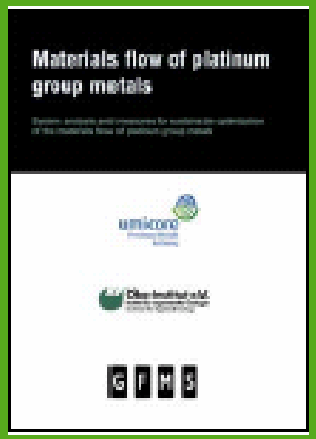
„Autoabgaskatalysatoren“ (2nd ed.)

- Expert Verlag, Kontakt & Studium
- ISBN 3-8169-2488-3
- 400 S, 56 €

“Stoffströme der Platingruppenmetalle”

- GDMB Medienverlag, Clausthal Zellerfeld 2005
- ISBN 3-935797-20-6
- 234 S., über 70 Abbildungen und Tabellen, 45 €

“ Materials Flow of PGMs in Germany”



- English edition with intoduction by GFMS
- GFMS-Verlag, London 2005
- ISBN 0-9543293-7-6
- 300 S., 100 €

Thank you for your attention

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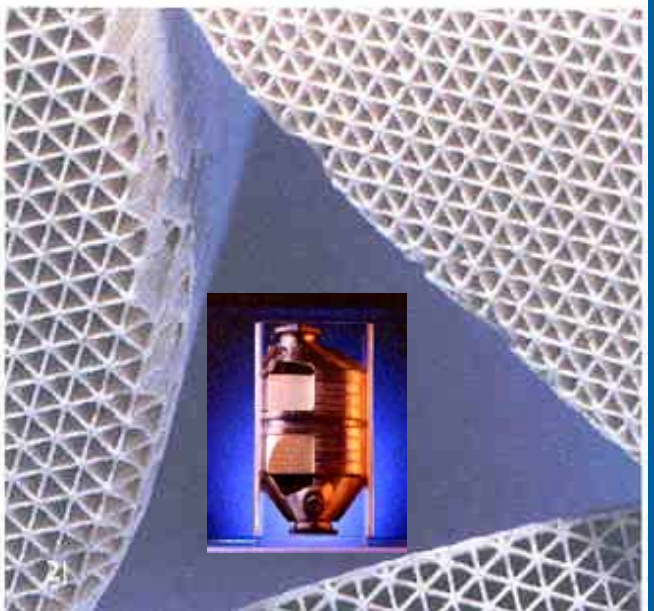
Questions ?



Annex

Historic milestones in Pt & Pd applications and corresponding price development

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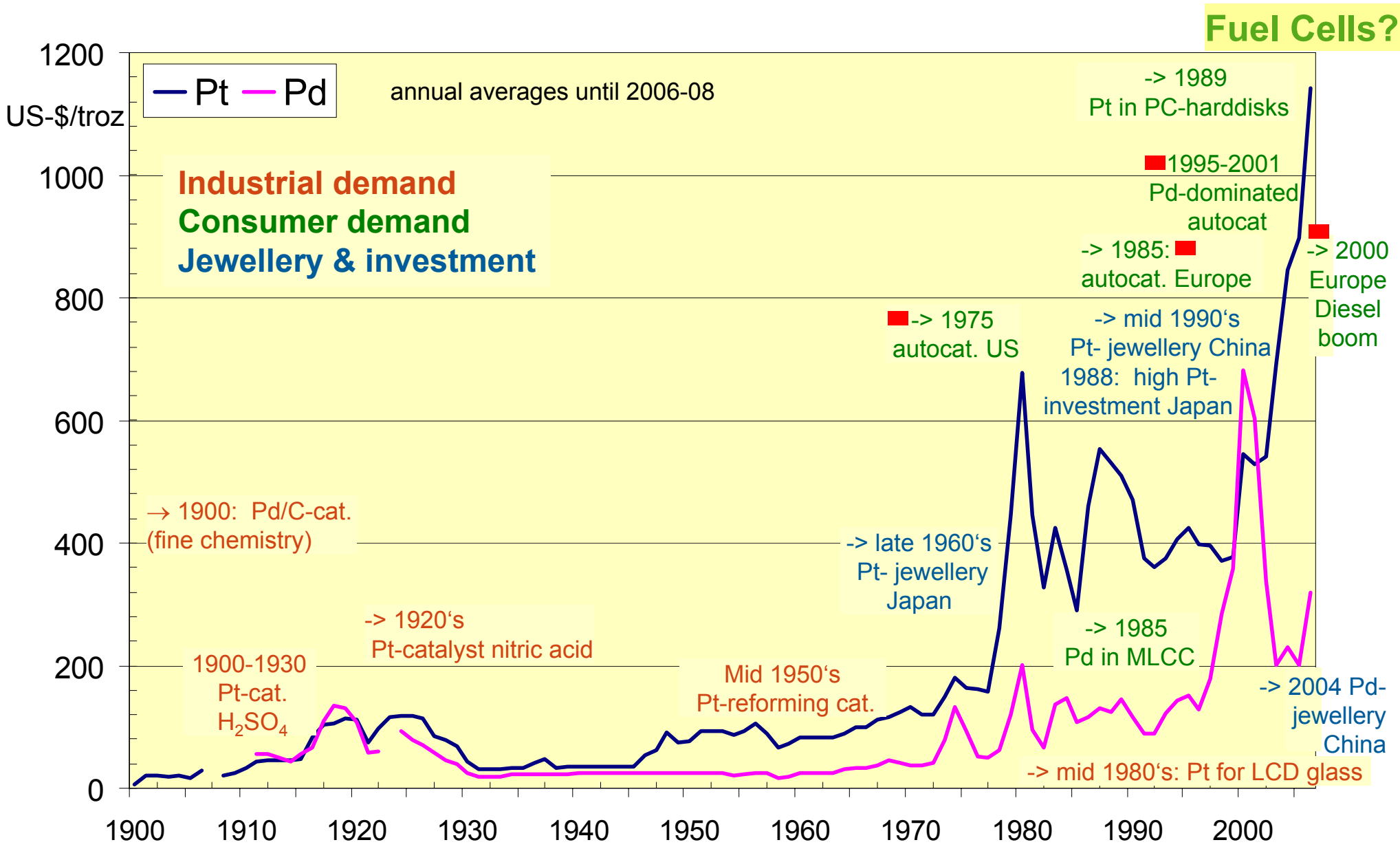

The upstream recycling chain - a market partially beyond industrial control

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Sometimes „normal“ practices in autocat recycling:

- Fake converters sold into telquel market (with unloaded bricks, cement filling, iron, …)
- Leaching of PGMs from converters/ceramics with subsequent sale of leached ceramic to market at “normal” cat-prices
- Selling of used converters as spare parts
- Backdooring of low value converters against too high telquel prices to less educated market participants
- Tax-free cash purchase
- Money laundering (one of the reasons for overpricing ?)
- Hidden deals/bribing of contract partners
- Assay skimmings: manipulation of weights, moisture content, biased samples, false report of analytical results, ….
- Theft:...of new catalysts from cars on a parking lot or a manufacturer’s plant, EOL-converters from collectors/decanners, ... Concealment of stolen catalysts - it seems not to be difficult to feedback these materials into the recycling chain.
- Interpol listed criminals temporarily dominating local markets and always finding a „refining“ outlet

Why could assay skimming be attractive?

10 t/a spent autocatalyst at (0.12% Pt, 0.08% Pd, 0.03% Rh→Σ 0.23%)

➔12 kg Pt + 8 kg Pd + 3 kg Rh = 1.2 Mio $* intrinsic value

A **manipulation** of **3%** (0.223% vs 0.23% PGM) means a fraud of **36 k$!**.
This already reaches the magnitude of refining charges of ≈ 40 k$.

⇒A company could almost offer treatment free of charge and take the profit on assay skimming.

often it’s even more than 3% ...

*at Pt=1400 $, Pd = 350 $; Rh = 6000 $/troz

These malicious practices create a heavily distorted playing field for those who strictly follow ethical business standards.

		Pt	Pd	Rh	Summe
	g/kg	1,2	0,80	0,30	2,30
	$/kg	64,0	9,0	57,9	**120,89**
PGM-prices	$/troz	1400	350	6000	
31,1035	$/g	45,011	11,253	192,9	
lot size	10				1.208,867
assay bias	1%	12,089			2,28
	2%	24,177			2,25
	3%	36,266			2,23
	4%	48,355			2,21
	5%	60,443			2,19

Low probability for future PGM-recycling from many export cars

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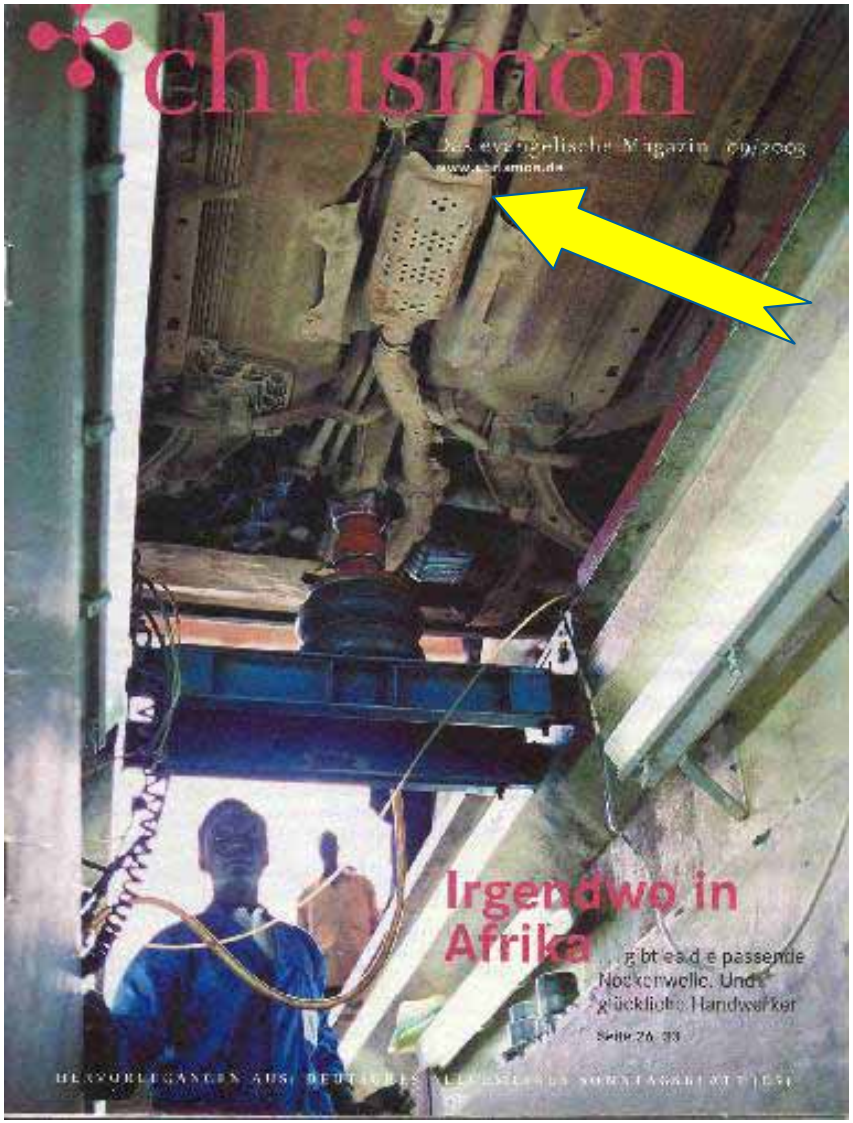
Europe: ca. 1/3 of ELVs are exported

(ACEA 2004)



- 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 availability – sufficient reserves* at even higher resources**

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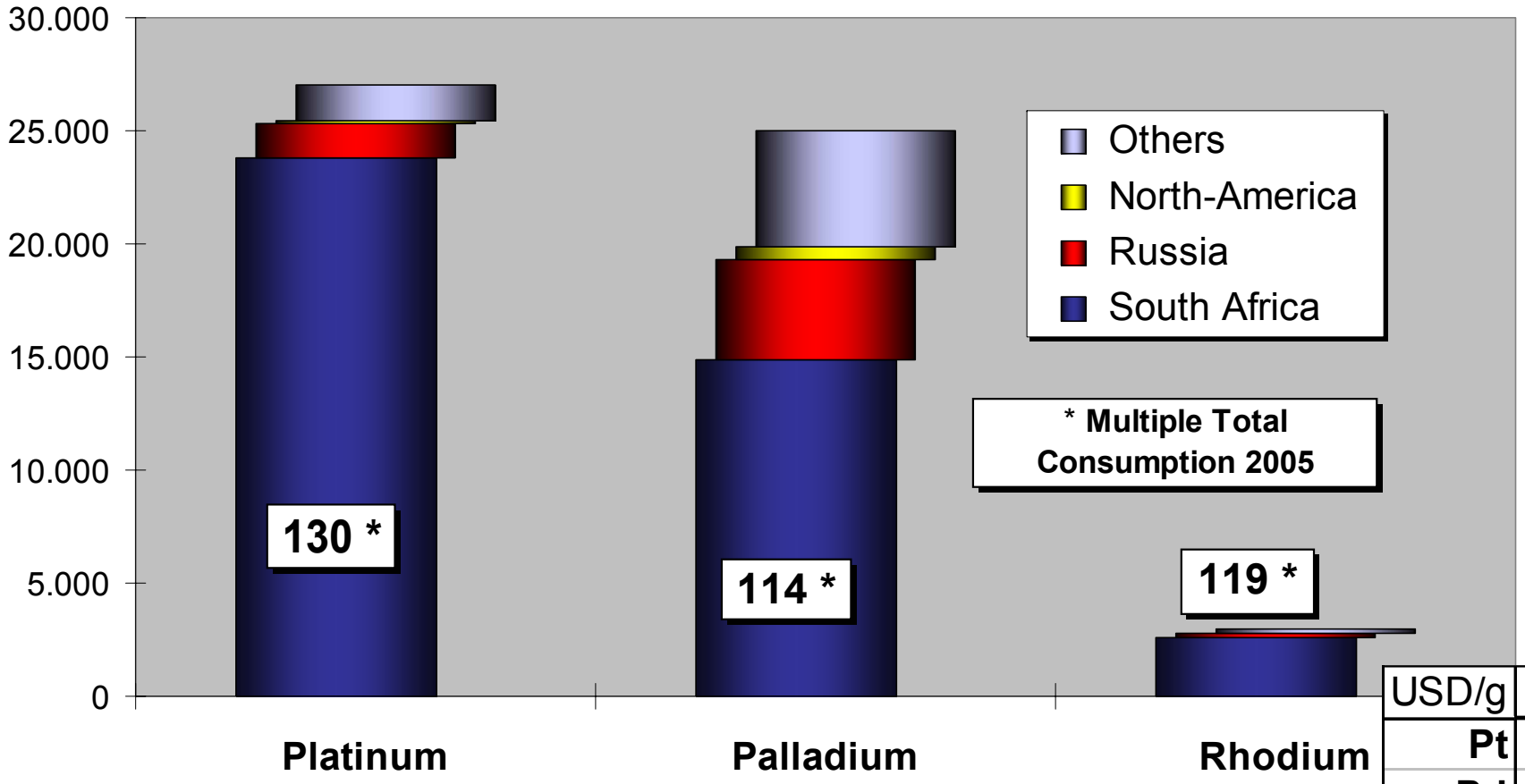
Known PGM-Reserves, being minable economically in theory at 1997 price levels



USD/g	1997	2007*
Pt	12,73	40,41
Pd	5,72	11,41
Rh	9,58	195,12
	* Jan-Sept.	

* Could be economically extracted at a given price level

**known or assumed PGM content in ore deposits

Different dimensions of resource scarcity

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- Absolute resource scarcity: depletion of geological resources that can be extracted even at higher prices
- Relative resource scarcity: supply can (temporarily) not follow an increasing demand
  - Time lag & investment risk for new mines and smelters
  - Political unrest, war, natural disasters, …
- Structural resource scarcity: constraints from "coupled production" of „minor metals" (Rh, Ru, Ir, … In, Bi, Se, Te …) with „major metals" (Pt, Ni, Cu, Zn, Pb, …)

- Continuous degradation of the natural resource base
  - Declining ore grades
  - More difficult mining conditions (mine depth, geographical location, political frame conditions, …)
  - Number of deposits/mines & their global distribution

⇒ **increasing costs, energy demand, environmental burden, …**

⇒ **impact on biosphere (rain forest, Antarctic, ocean mining, …)**

⇒ **regional dependences – „battle for resources"** ?

The Umicore recycling loop for automotive companies