

Increasing complexity in autocat recycling

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Forward-looking statements

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Introducing Umicore

A global materials technology and recycling group



One of three global leaders in emission control catalysts for light-duty and heavy-duty vehicles and for all fuel types



A leading supplier of key materials for rechargeable batteries used in portable electronics and hybrid & electric cars



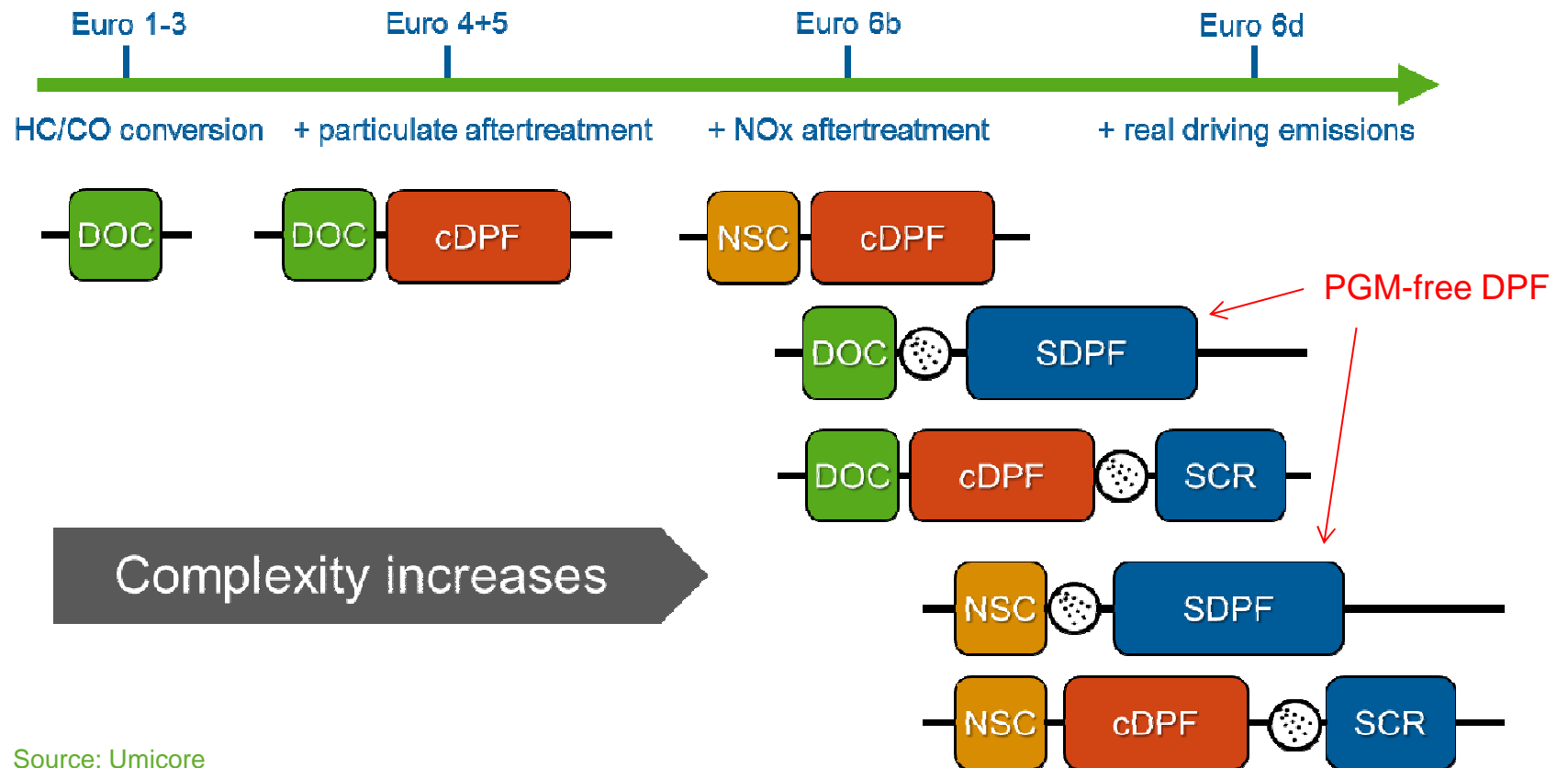
The world's leading recycler of complex waste streams containing precious and other valuable metals

Agenda



- **Diesel Particulate Filters (DPFs)**
- DPF market size
- DPF recycling at Umicore
- Conclusions





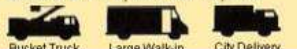

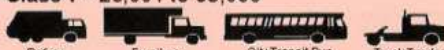

Developments in EU light duty diesel Exhaust systems are becoming more complex



Source: Umicore

Focus on Diesel Particulate Filters (DPFs)

Material characteristics depend on vehicle class

Class 1 - 6,000 & Less 
Class 2 - 6,001 to 10,000 
Class 3 - 10,001 to 14,000 
Class 4 - 14,001 to 16,000 
Class 5 - 16,001 to 19,500 
Class 6 - 19,501 to 26,000 
Class 7 - 26,001 to 33,000 
Class 8 - 33,001 & Over 

Vehicle class	Substrate	Unit weight	PGM loading
Light Duty (Class 1-2a)	<ul style="list-style-type: none"> SiC AT 	2-3 kg	>10g/ft ³
Medium Duty (Class 2b-3)	<ul style="list-style-type: none"> SiC AT 	~8 kg	~5 g/ft ³
Heavy Duty (Class 2b-8)	<ul style="list-style-type: none"> Cordierite AT SiC 	10-13 kg	~1 g/ft ³

Photo source: FHWA

Info source: Umicore estimates

SiC = Silicon Carbide, AT = Aluminium Titanate, Cordierite = Aluminium Silicate

DPFs introduce recycling challenges

Linked to substrate material and PGM-content

1. DPFs use **different substrates**
 - Traditional autocats (TWC, DOC): cordierite
 - DPFs: SiC, AT, cordierite
2. SiC-DPFs are **2-3x heavier**
3. SiC-DPFs can complicate the smelting process in recycling due to **high carbon content**
4. Not all DPFs are **PGM-coated**, examples:
 - Early DPFs in EU
 - More recently SCR-DPFs in EU and US

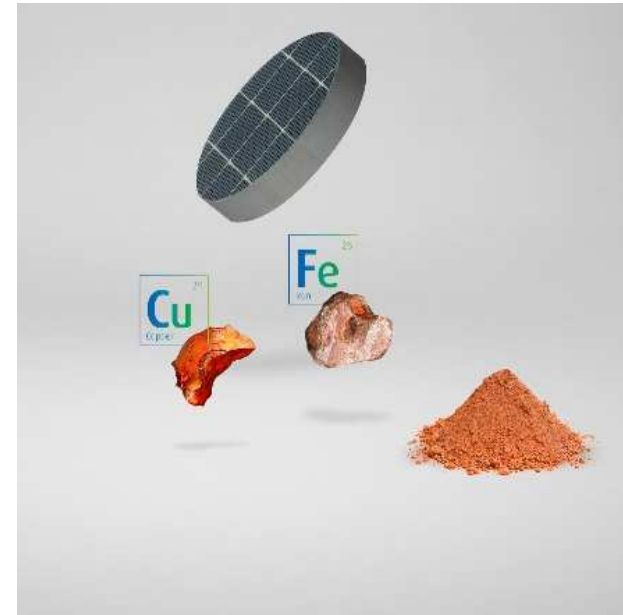


SiC (top), cordierite (others)
Photo source: Umicore

DPF technologies and PGMs

Catalyzed DPFs are PGM-containing (left)

SCR-DPFs used for NO_x control are not PGM-containing (right)



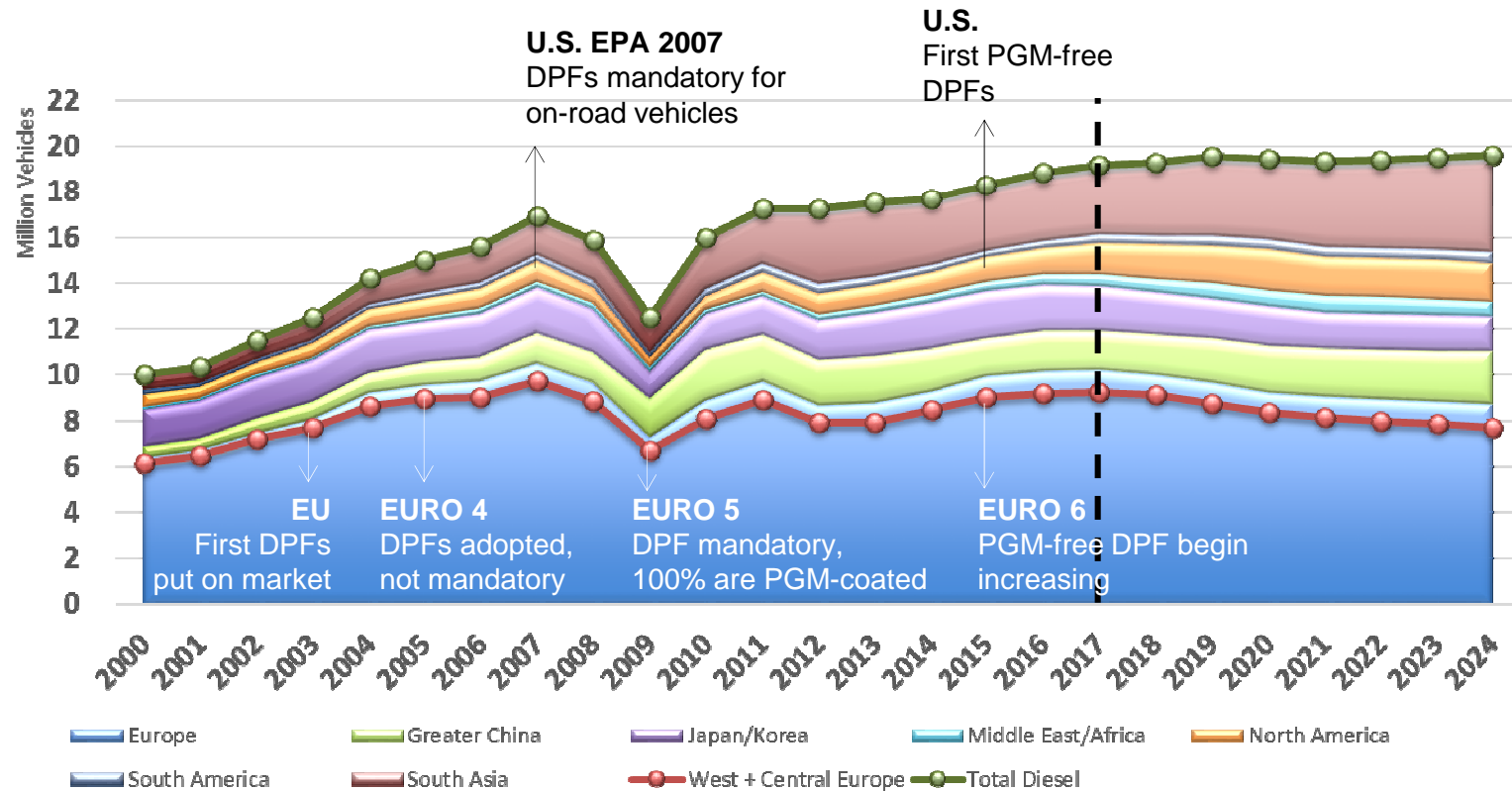
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Light duty diesel production

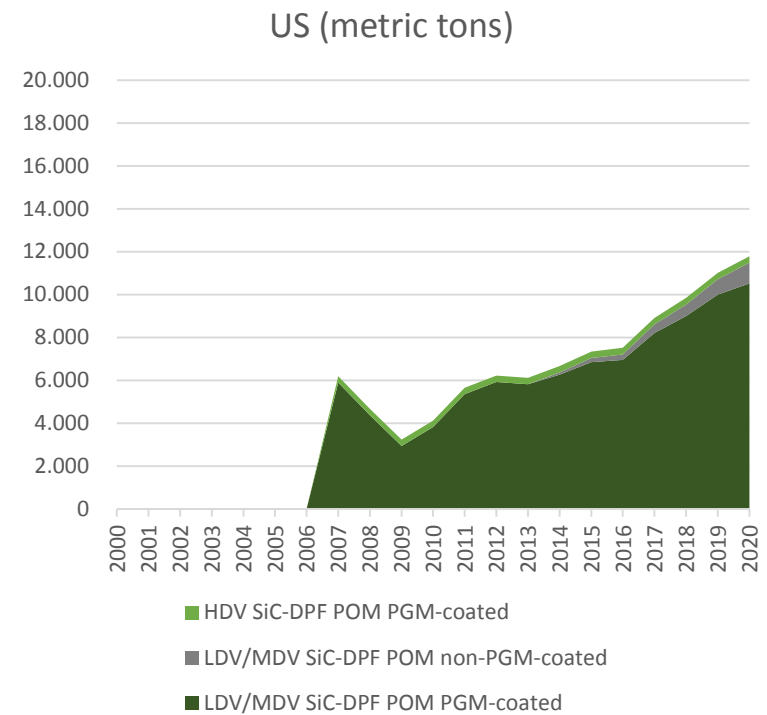
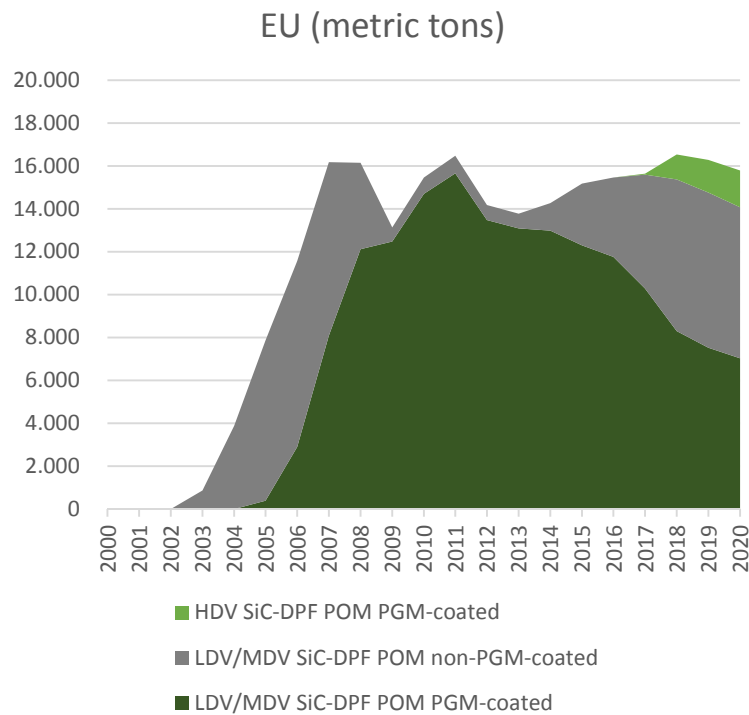
Growing DPF market driven by vehicle production and regulation



Source: IHS (April 2017), Umicore

SiC-substrate autocats put on market

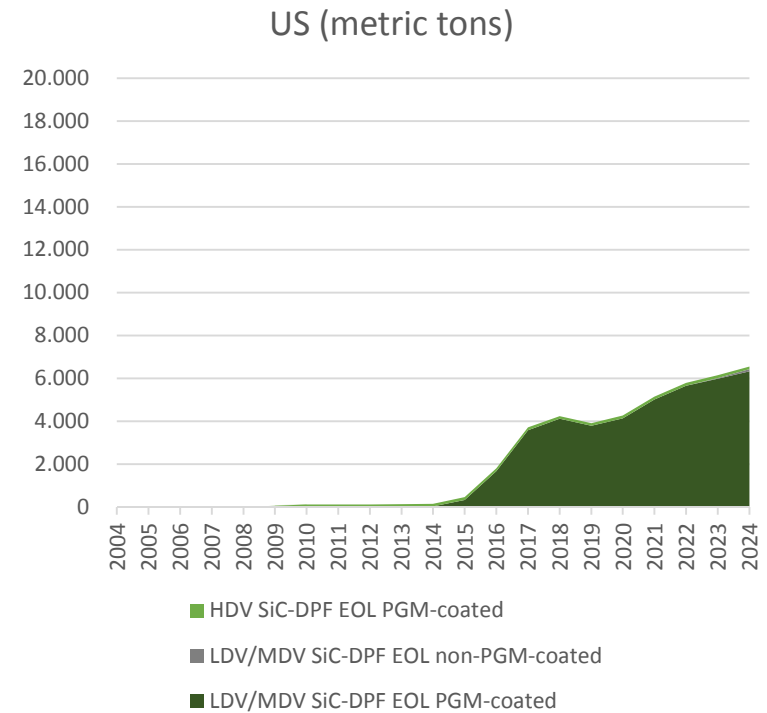
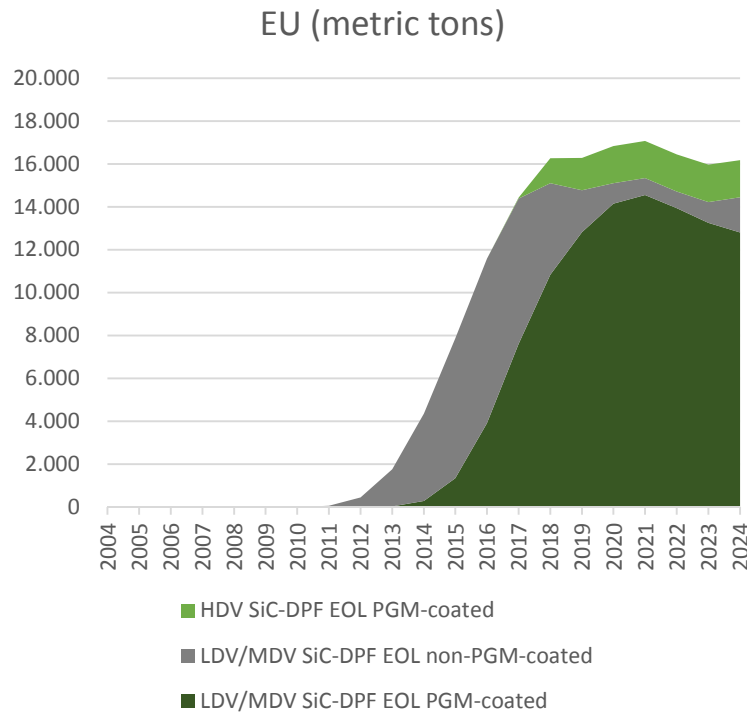
Metric tons SiC-DPF in EU and US (until 2020)



Source: Umicore estimates

SiC-substrate autocats at end-of-life

Metric tons SiC-DPF in EU and US (until 2024)



Source: Umicore estimates

Market sizing observations

End-of-life DPFs are growing rapidly, but be aware...

- We are in a period of **steep growth for SiC-DPF recycling** with increasing tonnages reaching end-of-life (though not all are available for recycling)
- The share of PGM-coated DPF in the recycling supply is still growing, but will peak in the EU soon after 2020 and then we should see **declining PGM-content** of the EU DPF recycling supply
- SiC-DPF in the US is mostly driven by **medium duty**, hence end-of-life tonnages and PGM-contents are lower compared to the EU

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Umicore's refining offer for DPF catalysts

Our process flexibility allows for significant SiC intake

- Umicore Precious Metals Refining has been refining spent automotive catalysts for decades
- Our high flexibility in processing complex materials is now increasingly applied to SiC-DPFs
- Umicore's suppliers benefit from:
 - High tolerance for carbon content
 - Acceptance of mixed autocat lots (no pre-separation required)
 - No change in recovery rates, sampling & assaying and environmental performance

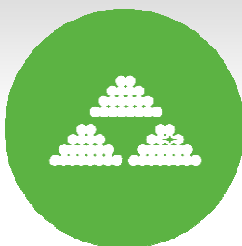


Refining @ UPMR

Our process in a nutshell

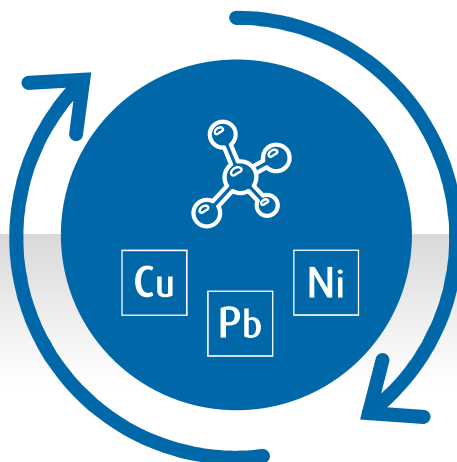


Recyclables



Industrial
by-products

Collector metals



17 different
metals



Refining @ UPMR

Recyclables



Au, Ag,
Pd, Cu...

Electronic Scrap

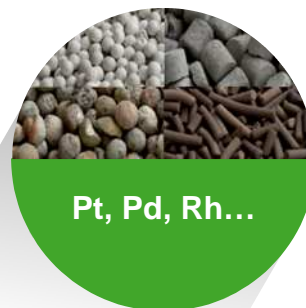
e.g.
mobile phones
printed circuit
boards



Pt, Pd, Rh...

**Spent Automotive
Catalysts**

e.g.
end-of-life
car catalysts



Pt, Pd, Rh...

**Spent Industrial
Catalysts**

e.g.
industrial catalysts
from oil refining &
petrochemical
industry



Ag, In, Se...

**Other precious metal
bearing materials**

e.g.
fuel cells
photographic
residues

Refining @ UPMR

Sampling & assaying



Sampling



- Extracting a small representative quantity from tonnes of a material
- Dedicated processes for all raw materials, using material-specific procedures
- Secured area
- About 200 people
- +/- 8,000 lots/year

Assaying



- High accuracy determination of metal content down to parts per million
- Recognized leadership in the precious metals industry
- State-of-the-art analytical equipment
- + 100 people
- 70,000 samples/year

Refining @ UPMR

We support throughout the process

- **Logistical** and **tax** assistance
- Clear **individual metal accounts** reflecting all results of the metal transactions
- **Physical return** or **repurchase** of refined metals
- **Risk management** through forward pricing, limit orders and other solutions
- **Special services** such as regular metal statement, metal account transfers, ...



Umicore key strengths

For autocat recycling and more...

Flexibility



Material compositions & complexity –

our flexible process allows us to treat the widest range of materials in the industry and respond to market conditions

Sampling &
assaying



Accuracy & transparency –

our robust process for determining customer return is trusted throughout the industry and is used to optimise processing

High metal
recovery



Efficiency & impurity management –

our unique and complex flowsheet enables a highly efficient recovery of PGMs from both primary and secondary sources

Innovation



Technology & environment –

our focus on continuous optimisation and new process innovation opens doors to the recycling markets of tomorrow

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Conclusions

Increasing complexity requires specialized refiners

- The market for SiC-DPF recycling is expected to **grow sharply** in the next 3-4 years, particularly in the EU
- DPFs will “contaminate” the autocat recycling stream for years to come, bringing **new materials** like SiC and **PGM-free** catalysts into recycling processes
- Umicore is well-equipped to handle the added complexity that DPF brings to autocat recycling and will continue to offer its competitive refining terms
- No pre-separation required



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Thank you