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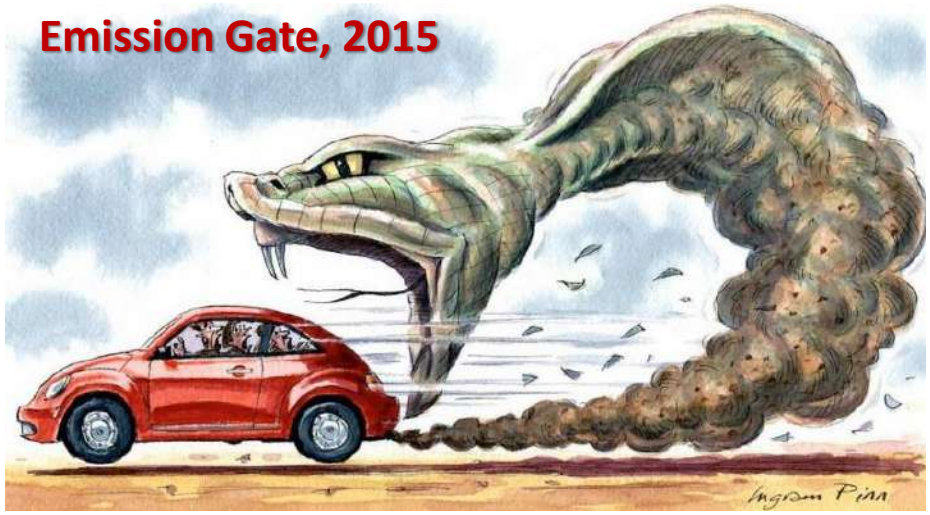
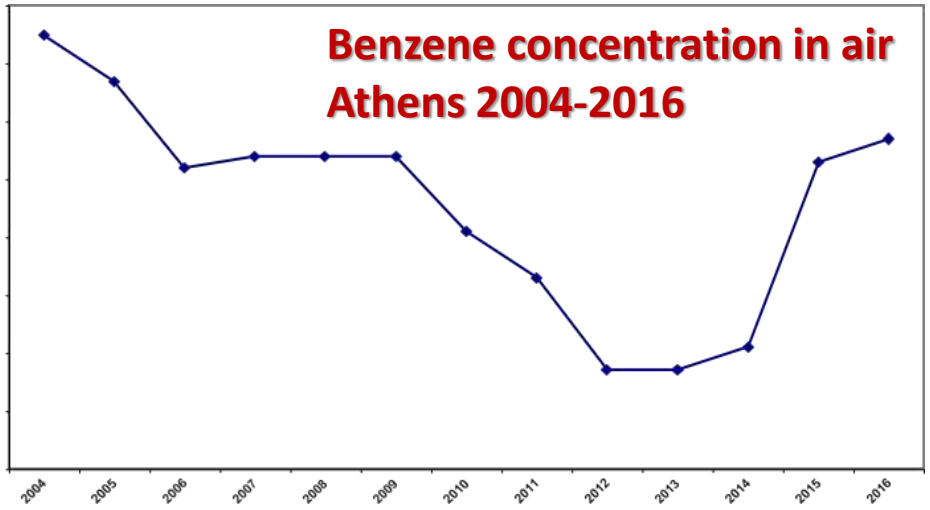
A MONOLITHOS
Disruptive Innovation

Market Gap/Market Size

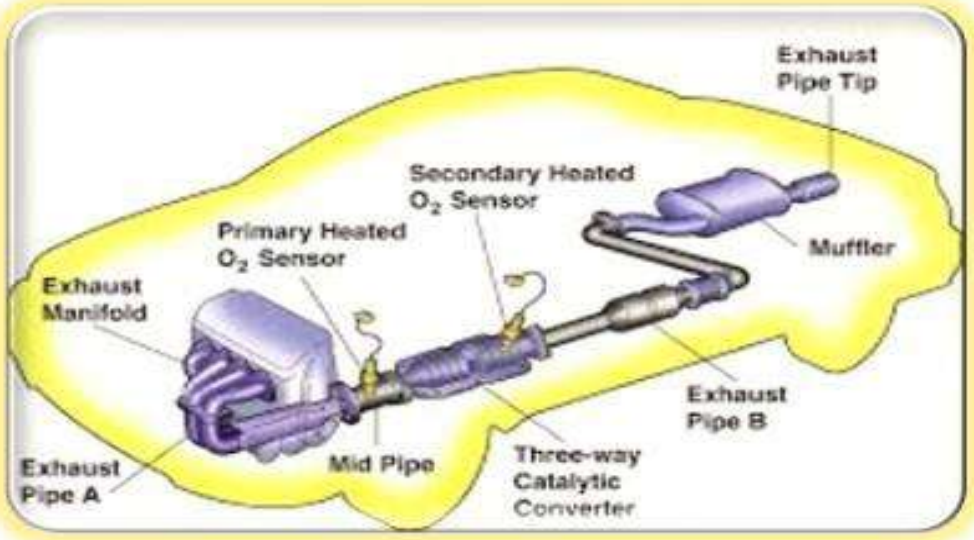




The global emission control catalysts market is expected to reach €15 Billion by 2021 growing at a compound annual growth rate (CAGR) of 10.37%, being driven primarily by growth in automotive vehicle sales and tightening regulatory trends.

Europe is the world's largest consumer of Platinum Group Metals, with an annual demand for 43 tones of platinum, worth €1.4 billion.

Catalytic Converter



LEGISLATION:

- ***1960s:*** **A typical car *(after 120.000 miles drive)* had hydrocarbon emission of 15g/mile**
- ***2012:*** **Emission Level is lower than 0.01g/mile**

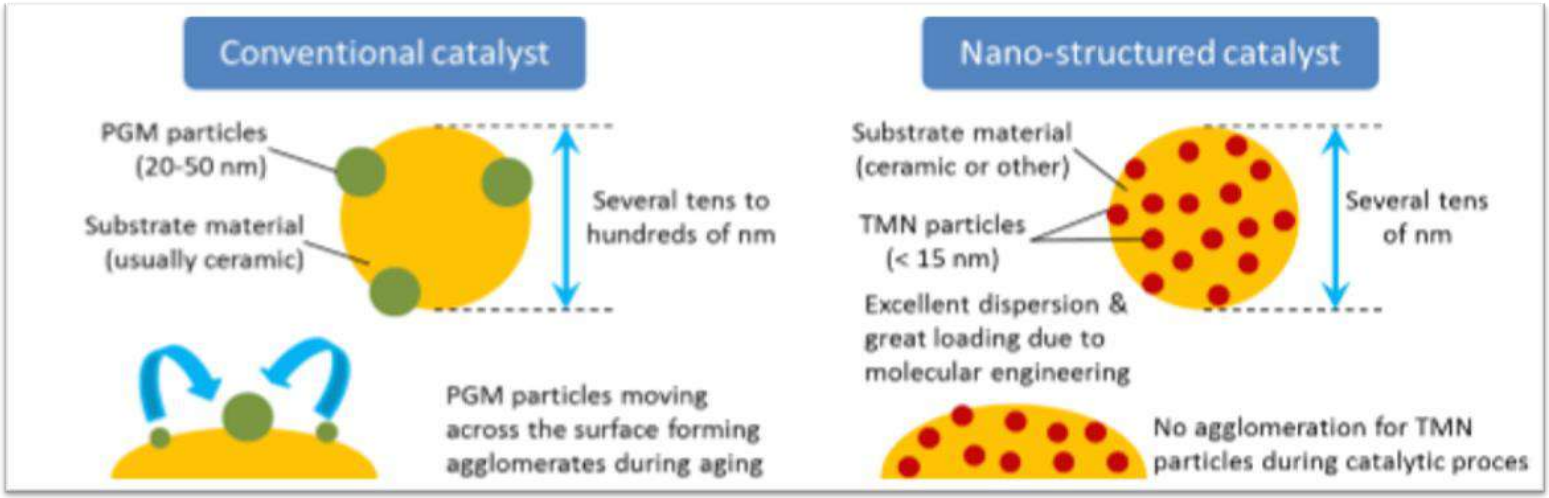
CHARACTERISTICS (PER CATALYST):

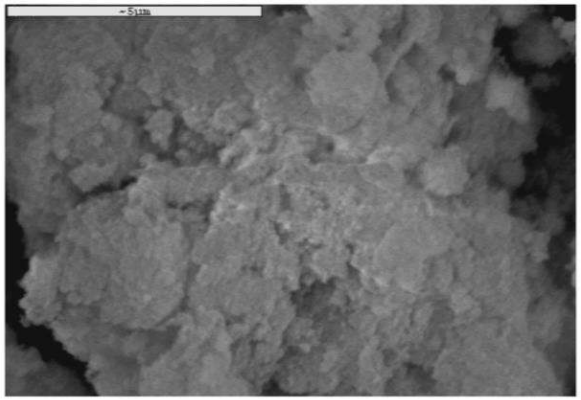
- **750 gr of honeycomb**
- **30 gr of rare earths**
- **2 gr of noble metals**

1.500 times less emissions in 50 years

Technological Background

Development of nano-structured automotive catalysts utilizing transition metal nanoparticles (mainly Cu) to substitute noble metals

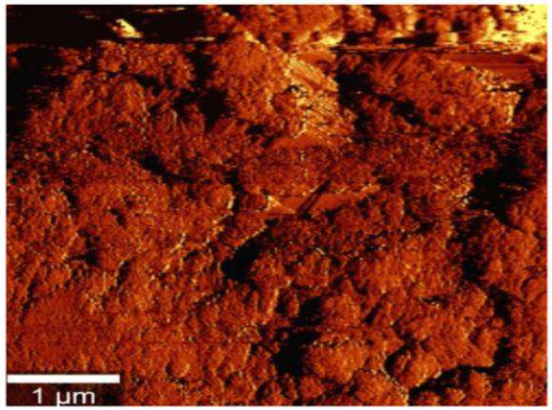




Prometheus trimetallic nano-catalyst *(single layer)*

Scanning Electron Microscope (SEM)

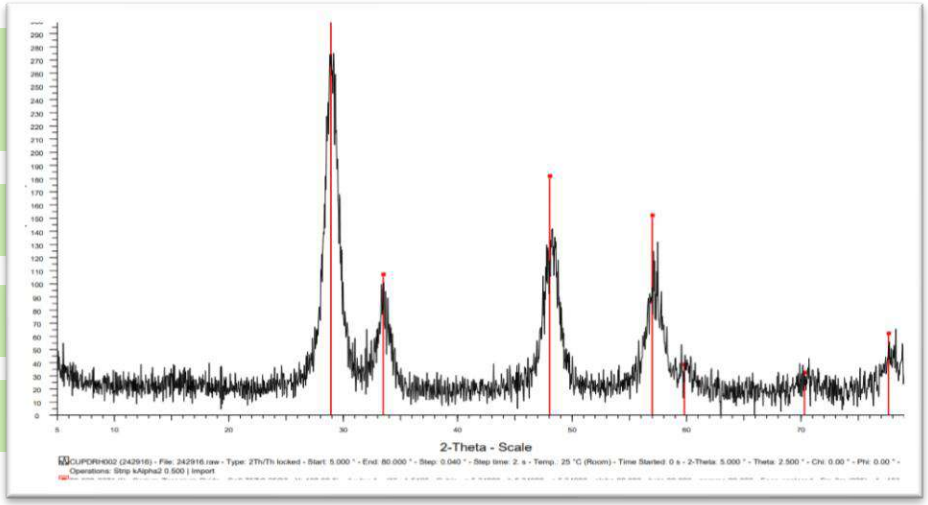
Atomic Force Microscopy (AFM)



Nano Polymetallic (Pt, Pd, Rh, Cu) Catalytic Washcoat – Production Scale: 100kg

Prometheus catalyst

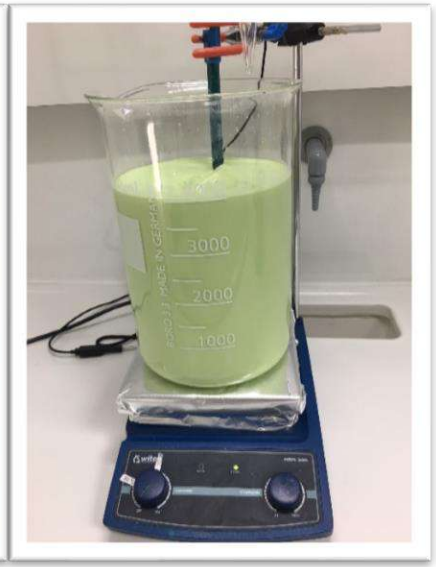
XRD Pattern of Prometheus Trimetallic Catalyst



Surface Area (BET) >90m²/g

ICP characterization performed

XRF characterization performed



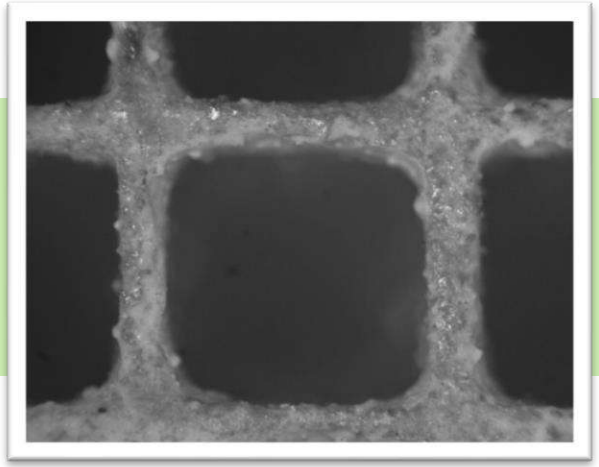
Pore size determined

Pore volume determined

Real size Prometheus monolithic catalysts

Prometheus washcoat on cordierite monoliths (400cpsi)

Axially uniform Prometheus washcoat



Cross-section optical microscopy: 50-150µm washcoat thickness (similar to commercial catalysts)

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Benchmarks - New Original Catalytic Converters

OEM-III: New Original VW Polo 1.4lt Motor: AEX Loading: 32g/ft³ PGM

OEM-IV: New Original VW Polo 1.4lt Motor: AUA Loading: 108g/ft³ PGM

OEM-V/VI: New Original Renault Megane 1.2lt Turbo Motor: H5Ft Loading: 101g/ft³ PGM

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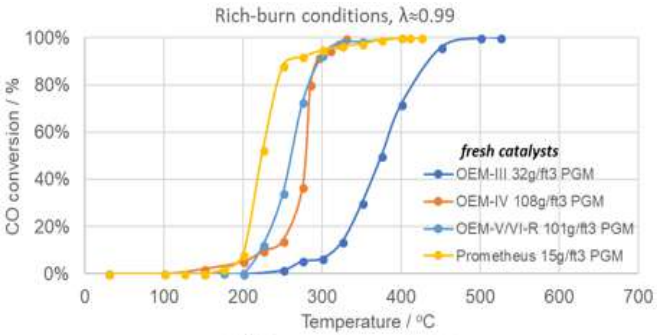
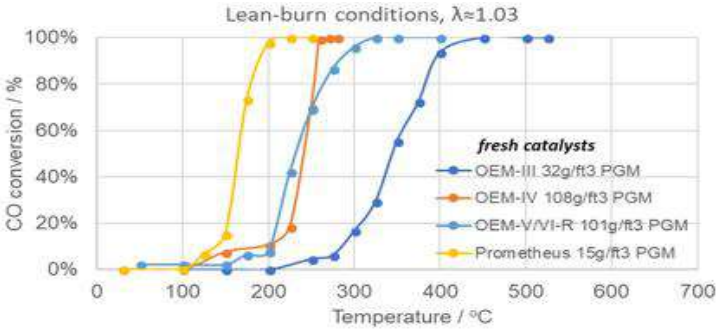
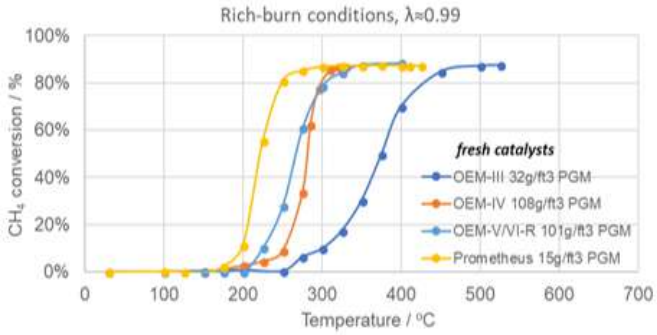
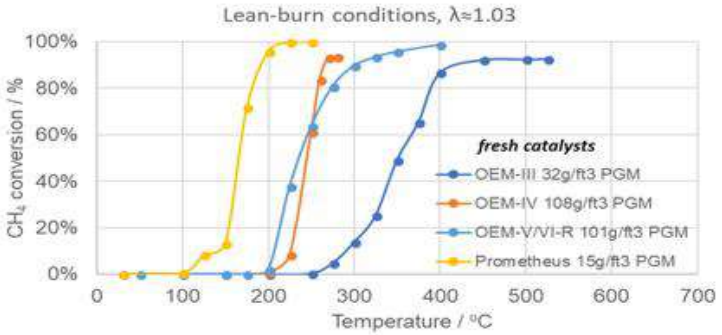
Catalytic Efficiency vs Temperature - Fresh

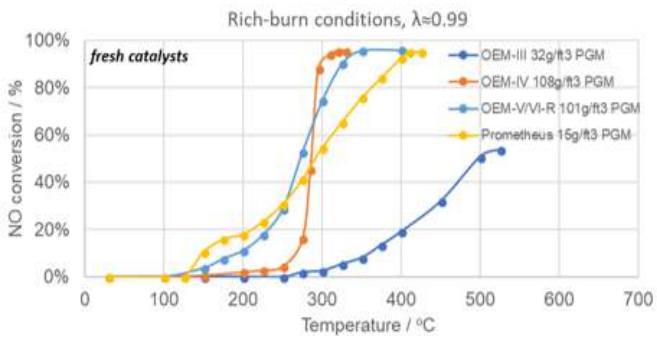
Gas component	Conditions
CO	1%
CO_2	12%
NO	800ppm
CH_4	2500ppm
H_2O	10%
Total vol. flowrate	300sccm
GHSV	50,000h^{-1}

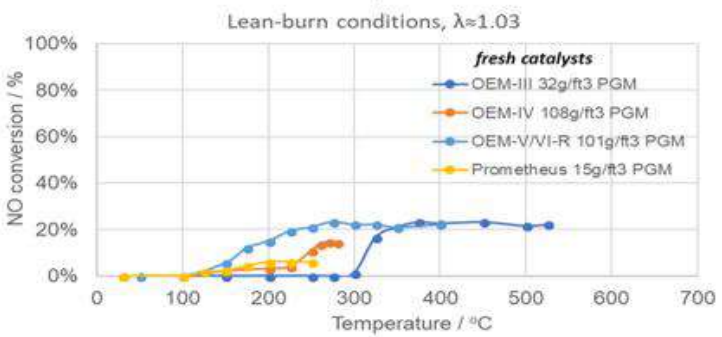












Light-Off Temperature Maximum Efficiency - Fresh

Rich Burn (λ=0.99)		CO Oxidation		CH_4 Oxidation		NO reduction	
Catalyst	Loading (g/ft^3 PGM)	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency
OEM-III	32	380	100%	375	87%	495	54%
OEM-IV	108	280	100%	280	87%	290	96%
OEM-V/VI	101	260	100%	265	88%	265	96%
Prometheus	15	220	100%	220	87%	285	96%

1. 85% less PGMs than Euro VI original cat
2. 40°C lower T_{50}
3. Same efficiency

Lean Burn (λ=1.03)		CO Oxidation		CH_4 Oxidation		NO reduction	
Catalyst	Loading (g/ft^3 PGM)	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency
OEM-III	32	340	100%	355	93%	-	22%
OEM-IV	108	240	100%	240	93%	-	15%
OEM-V/VI	101	230	100%	230	88%	-	21%
Prometheus	15	170	100%	140	100%	-	6%

1. 85% less PGMs than Euro VI original cat
2. 60°C lower T_{50}
3. Same efficiency

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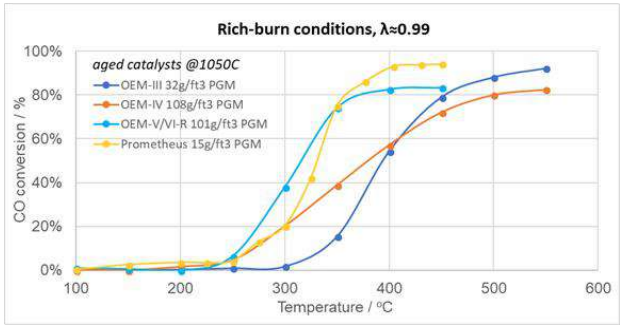
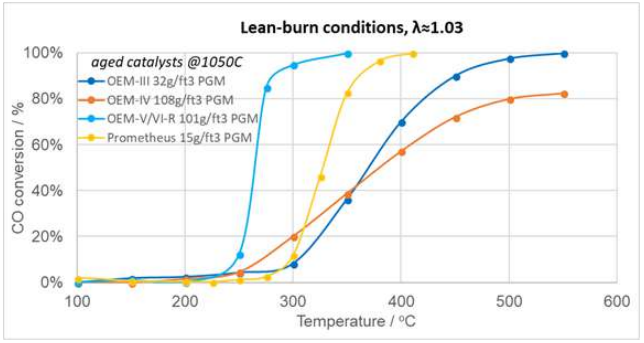
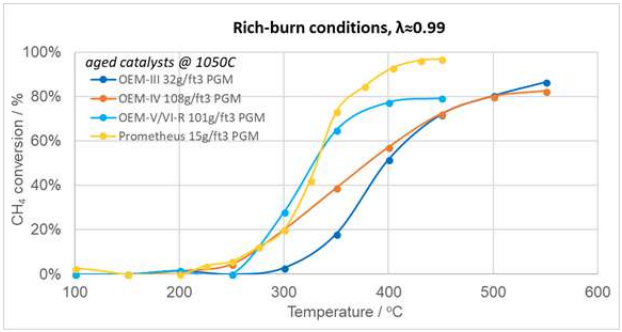
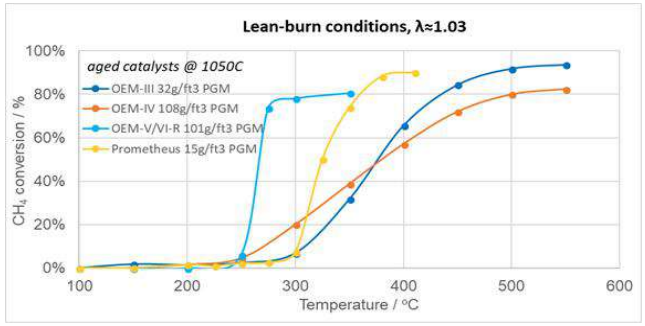
Catalytic Efficiency vs Temperature – Aged at 1050°C for 4h (10% water)

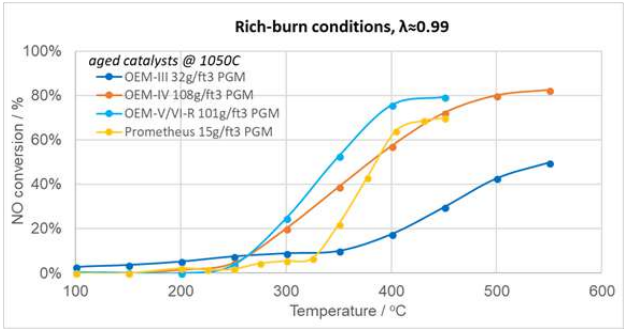
Gas component	Conditions
CO	1%
CO_2	12%
NO	800ppm
CH_4	2500ppm
H_2O	10%
Total vol. flowrate	300sccm
GHSV	50,000h^{-1}

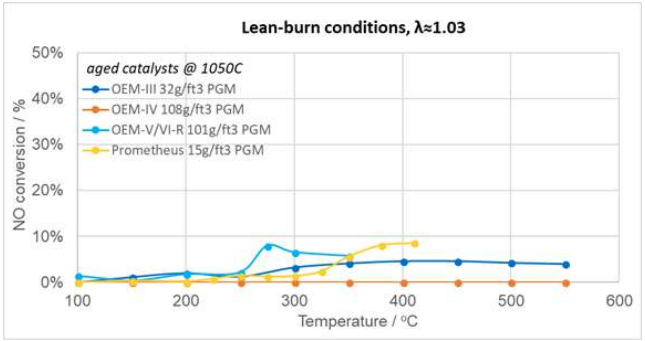












Light-Off Temperature Maximum Efficiency - Aged at 1050°C for 4h (10% water)

Rich Burn (λ=0.99)		CO Oxidation		CH_4 Oxidation		NO reduction	
Aged Catalyst @ 1050C	Loading (g/ft³ PGM)	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency
OEM-III	32	400	94%	400	87%	550	50%
OEM-IV	108	390	82%	390	79%	-	42%
OEM-V/VI	101	315	83%	325	78%	340	80%
Prometheus	15	330	94%	325	97%	390	70%

1. 85% less PGMs than Euro VI original cat
2. Similar T_{50}
3. Better (10-20%) max efficiency

Lean Burn (λ=1.03)		CO Oxidation		CH_4 Oxidation		NO reduction	
Aged Catalyst @ 1050C	Loading (g/ft³ PGM)	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency
OEM-III	32	370	100%	370	94%	-	5%
OEM-IV	108	345	100%	350	94%	-	0%
OEM-V/VI	101	260	100%	260	81%	-	8%
Prometheus	15	330	100%	325	90%	-	9%

1. 85% less PGMs than Euro VI original cat
2. 330°C T_{50}
3. Same efficiency

Cu Melting Point: 1085°C
Type approval certification test at 850°C

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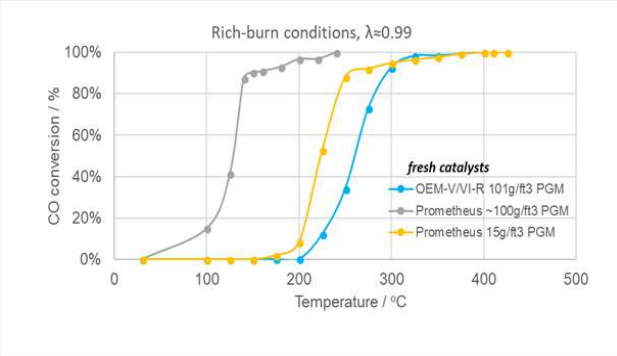
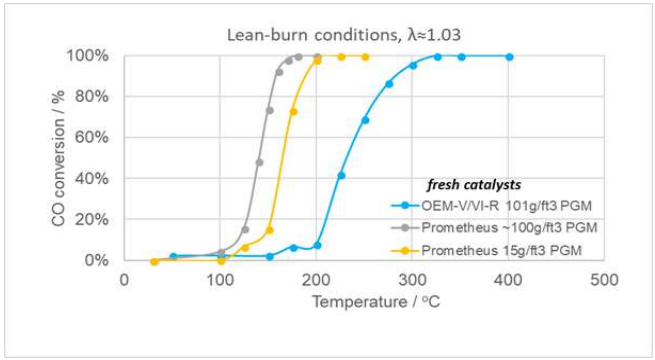
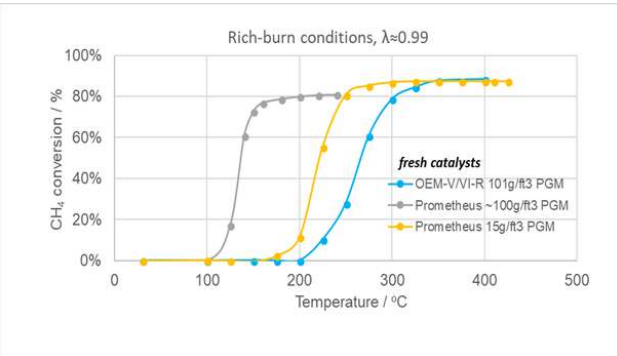
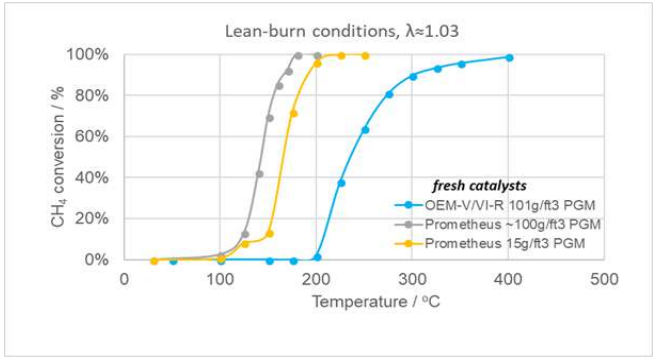
Catalytic Efficiency vs Temperature - Similar PGM Loading

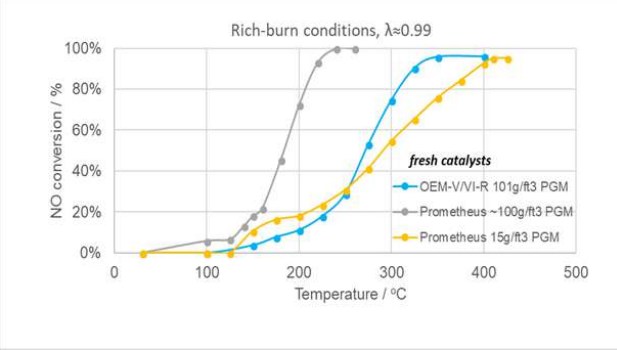
Gas component	Conditions
CO	1%
CO_2	12%
NO	800ppm
CH_4	2500ppm
H_2O	10%
Total vol. flowrate	300sccm
GHSV	50,000h^{-1}

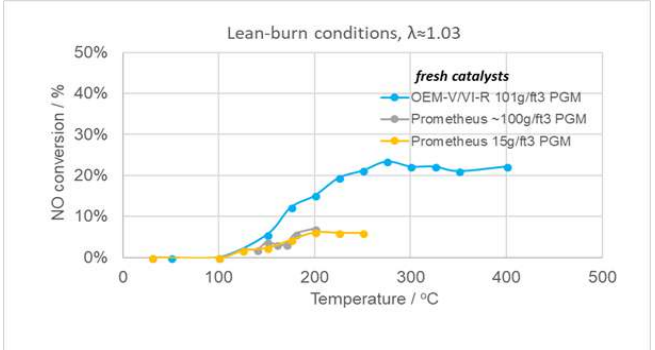












Light-Off Temperature Maximum Efficiency - Similar PGM Loading

Rich Burn (λ=0.99)		CO Oxidation		CH_4 Oxidation		NO reduction	
Catalyst	Loading (g/ft^3 PGM)	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency
OEM-V/VI	101	260	100%	265	88%	265	96%
Prometheus	~100	130	100%	135	82%	185	100%
Prometheus	15	220	100%	220	87%	285	96%

1. ~130°C lower T_{50}
2. Low T operation

Lean Burn (λ=1.03)		CO Oxidation		CH_4 Oxidation		NO reduction	
Catalyst	Loading (g/ft^3 PGM)	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency	T_{50}	Max. Efficiency
OEM-V/VI	101	230	100%	230	88%	-	21%
Prometheus	~100	140	100%	145	100%	-	7%
Prometheus	15	170	100%	140	100%	-	6%

1. ~100°C lower T_{50}
2. 100% efficiency in hydrocarbons oxidation

Addressing Euro 7 and cold start effect (hybrid cars)

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Cost reduction due to PGM lower concentration of Prometheus Catalyst – PSA case

1. PSA sold 3.632million units on 2017
2. Presume that 50% were petrol
3. Presume 1.5lt catalyst per car
4. PGM cost reduction due to implementation of Prometheus per car: 134.96Euros
5. Total cost reduction per year (only for PSA) 245.1million Euros

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Business Model

	Sales 2017	Sales 2021	Sales 2025
	Before PROMETHEUS	1st year of PROMETHEUS	5th year of PROMETHEUS
Aftermarket	1,252,000 €	2,597,000 €	5,194,000 €
OES	-	-	3,000,000 €
OEM	-	-	27,000,000 €

OES: Original Equipment Standard (Aftersales)
OEM: Original Equipment Manufacturing (Installation when the car is new)

Development Level
Scale Up
IP Rights/Homologation

1. European Patent has been granted on November 2019 (EP3569309)
2. Scale up to 100Kg of nano-powder per batch (150lt Reactor)
3. Full scale catalyst manufactured and tested
4. Homologation Procedure according R103 under way as a replacement part
5. Objective: 1st commercial Prometheus Catalyst in market before 1st half of 2020

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Next development steps

1. Apply Prometheus to Hybrid Plug-In Vehicles
2. Apply Prometheus to Diesel Engines (DOC, SCR)
3. Apply Prometheus to Heavy Duty Applications (Trucks, Municipal Vehicles)
4. Apply Prometheus to Marine Applications
5. Apply Prometheus to Stationary Applications
6. Apply Prometheus to CO_2 Utilization

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