

# Environmental Catalysis

# Lecture outline

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☞ Introduction to “*Environmental Catalysis (EC)*”

☞ Global Environmental Catalysts Market

☞ Mobile and Stationary Emissions and Control

- **Mobile Emissions Regulations and Legislation**
- **Mobile CO, HC, NO<sub>x</sub> and PM Emissions and Control**
  - **Automotives**
  - **Ships and trains**
- **Stationary Emissions and Control**
  - **Introduction to NO<sub>x</sub> Emissions and Control**
  - **NH<sub>3</sub>-SCR deNO<sub>x</sub> Technology**

☞ Stationary and Mobile VOCs Emissions and Control

☞ Stationary and Mobile N<sub>2</sub>O Emissions and Control

☞ Recommendable future studies

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# Introduction to “*Environmental Catalysis*”

# History of environmental catalysis

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- In the beginning of the 1970s

@ B. Lindstrom and L.J. Pettersson, CATTECH, 7 (2003) 130

- *“At some point during the early 70's the world started to become aware of the impacts that industry had on the environment, partially sparked off by Rachel Carson's “Silent Spring”.”*
- *“This new trend of thought gave birth to the discipline of environmental catalysis. Environmental catalysis was the first step towards the modern chemical industry where catalysis is applied to almost every process, including the production of fine chemicals for pharmaceutical applications to the production of bulk chemicals and exhaust gas catalysts.”*

@ J.N. Armor, Appl. Catal. B, 1 (1992) 221

- *“Since the late 60's when legislation restricting auto emissions mandated a solution in the USA, catalysis has allowed automotive companies to meet the regulations.”*

# (Continued)

@ B. Lindstrom and L.J. Pettersson, CATTECH, 7 (2003) 130

- *“The first period of catalysis ..... The sixth and current period of catalysis.....”*

1. From alchemy to chemistry ( $\phi$  - 1834)
2. From empirics to science (1835 – 1887)
3. The birth of industrial catalysis (1898 – 1918)
4. The increase in global mobility by developing catalytic fuel processes (1919 – 1945)
5. From war to peace (1946 – 1970)
6. Environmental catalysis (1970 – 20??)

## • Widespread use of the term ‘environmental catalysis’

@ G. Centi and S. Perathoner, Stud. Surf. Sci. Catal., 172 (2007) 79

- *“In the 1990s to indicate catalysts and catalytic technologies for environmental protection, mainly in relation to end-of-pipe technologies” to abate  $\text{NO}_x$ , and VOCs from mobile sources and in power plants*

# Definition of environmental catalysis

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- J.N. Armor, Appl. Catal. B, 1 (1992) 221
  - “The phrase ..... is used to refer to a collection of chemical processes that employ **catalysts to control the emission of environmentally unacceptable compounds.**”
  - “The term also encompasses the application of **catalysts for the production of alternative, less polluting products, waste minimization, and new routes to valuable products without the production of pollutants.**”
- G. Centi and S. Perathoner, Stud. Surf. Sci. Catal., 172 (2007) 79
  - Environmental catalysis is “catalysts and catalytic technologies for environmental protection”.

# Major topics in environmental catalysis

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- **Mobile engine-out emissions controls**
  - CO and HC oxidation catalysis
  - DeNOx catalysis
- **Stationary sources controls**
  - DeNOx catalysis
  - DeVOCs catalysis
- **Greenhouse gases reduction**
  - Stationary and mobile deN<sub>2</sub>O catalysis
  - Catalytic conversions and transformation (CCT) of CO<sub>2</sub> into useful chemicals
- **Catalytic combustion**
- **Catalytic wet oxidation of contaminants in water**
- **Photocatalysis**
  - Waste water treatments
  - DeVOCs catalysis

# Conditional features of environmental catalysis

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@ G. Centi and S. Perathoner, Stud. Surf. Sci. Catal., 172 (2007) 79

- *It is unlike catalysis for chemical production and refineries.*
- *It is often necessary in environmental catalysis to develop a technology able to efficiently operate at the conditions defined by upstream units.*
- *It is often necessary in environmental catalysis to develop a technology that should be efficient under extreme conditions*
  - *very low or high temperatures*
  - *in the presence of non-removable poisons*
  - *with very high space velocities*
  - *with ultra-low concentrations, etc*



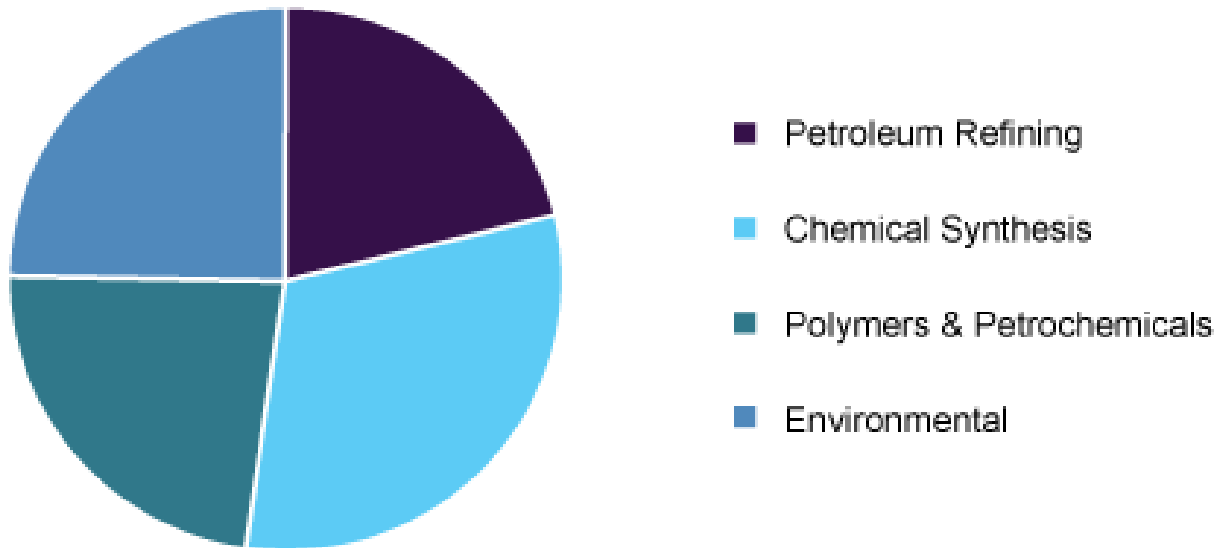
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# Global Market in “*Environmental Catalysts*”

# Global environmental catalysts market

Grand View Research, “Catalyst Market Size, Share & Trends Analysis Report By Raw Material (Chemical Compounds, Zeolites, Metals), By Product (Heterogeneous, Homogeneous), By Application, By Region, And Segment Forecasts, 2020 – 2027”

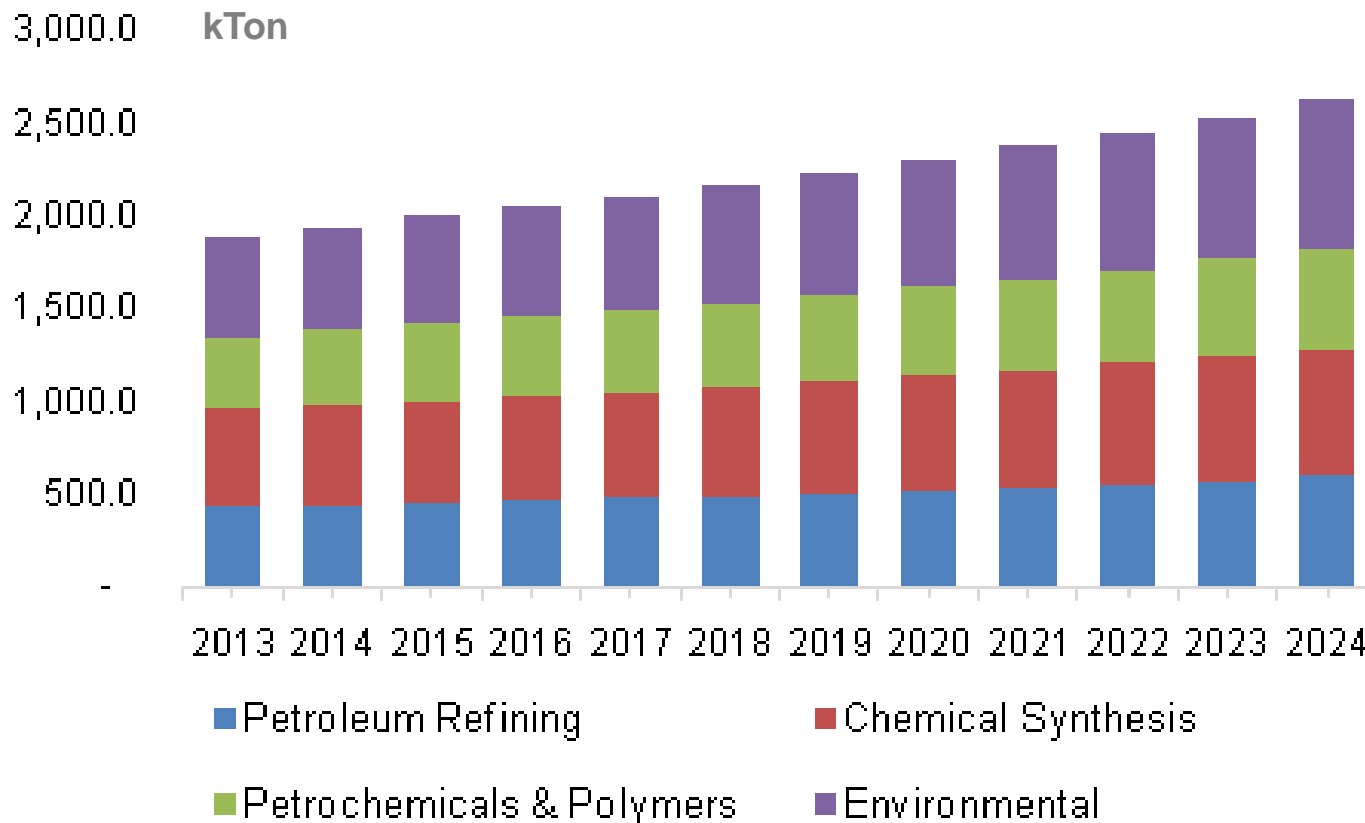
Global catalyst market value share, by application, 2019 (%)



Source: [www.grandviewresearch.com](http://www.grandviewresearch.com)

# North America catalyst market volume

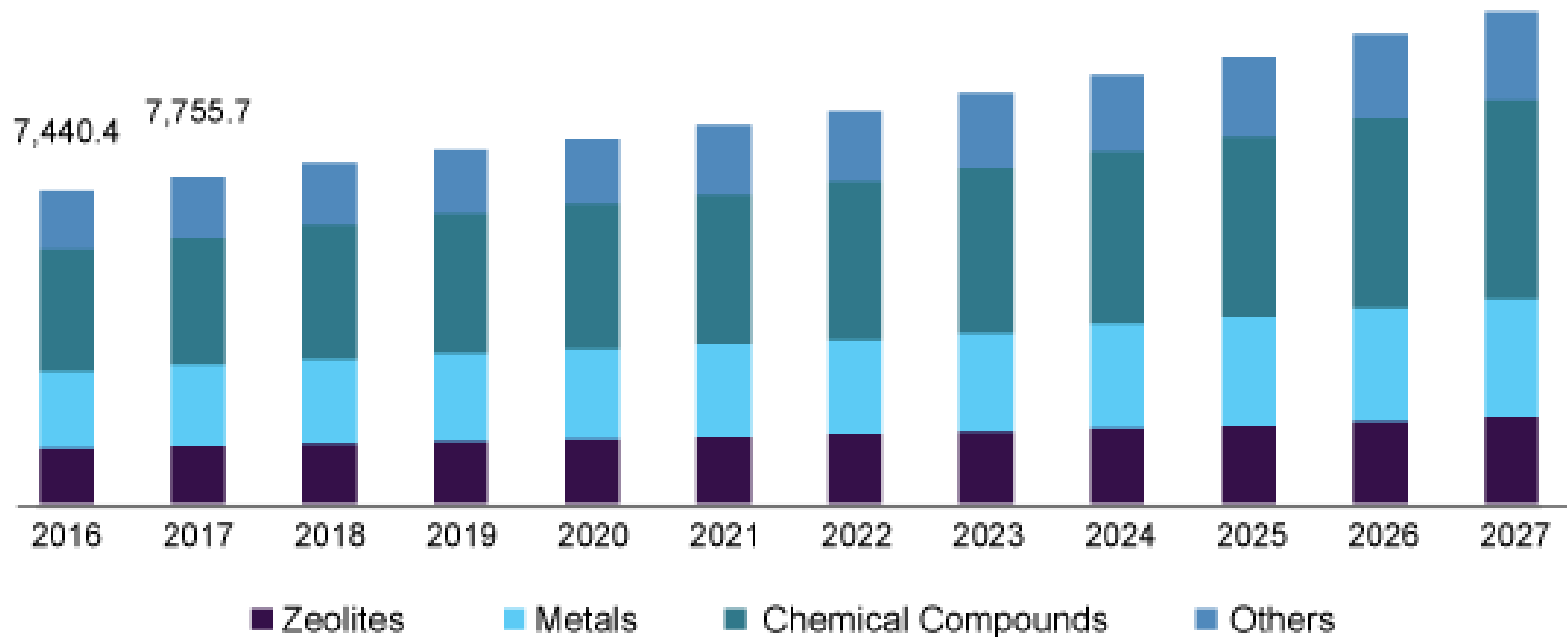
Grand View Research, “Catalyst Market Size, Share & Trends Analysis Report By Raw Material (Chemical Compounds, Zeolites, Metals), By Product (Heterogeneous, Homogeneous), By Application, By Region, And Segment Forecasts, 2020 – 2027”



# Global catalysts market

Grand View Research, “Catalyst Market Size, Share & Trends Analysis Report By Raw Material (Chemical Compounds, Zeolites, Metals), By Product (Heterogeneous, Homogeneous), By Application, By Region, And Segment Forecasts, 2020 – 2027”

U.S. catalyst market size, by raw material, 2016 - 2027 (USD Billion)



Source: [www.grandviewresearch.com](http://www.grandviewresearch.com)

# Global environmental catalysts market segmentation

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## On the basis of the application that these catalysts are used for

- VOC oxidation catalysts
- CO oxidation catalysts
- Selective catalytic reduction catalysts
- Others

## On the basis of end-users

### - Mobile sources emission control

Heavy duty vehicles

Light duty vehicles

Motorcycles

Construction equipment

### - Stationary sources emission control

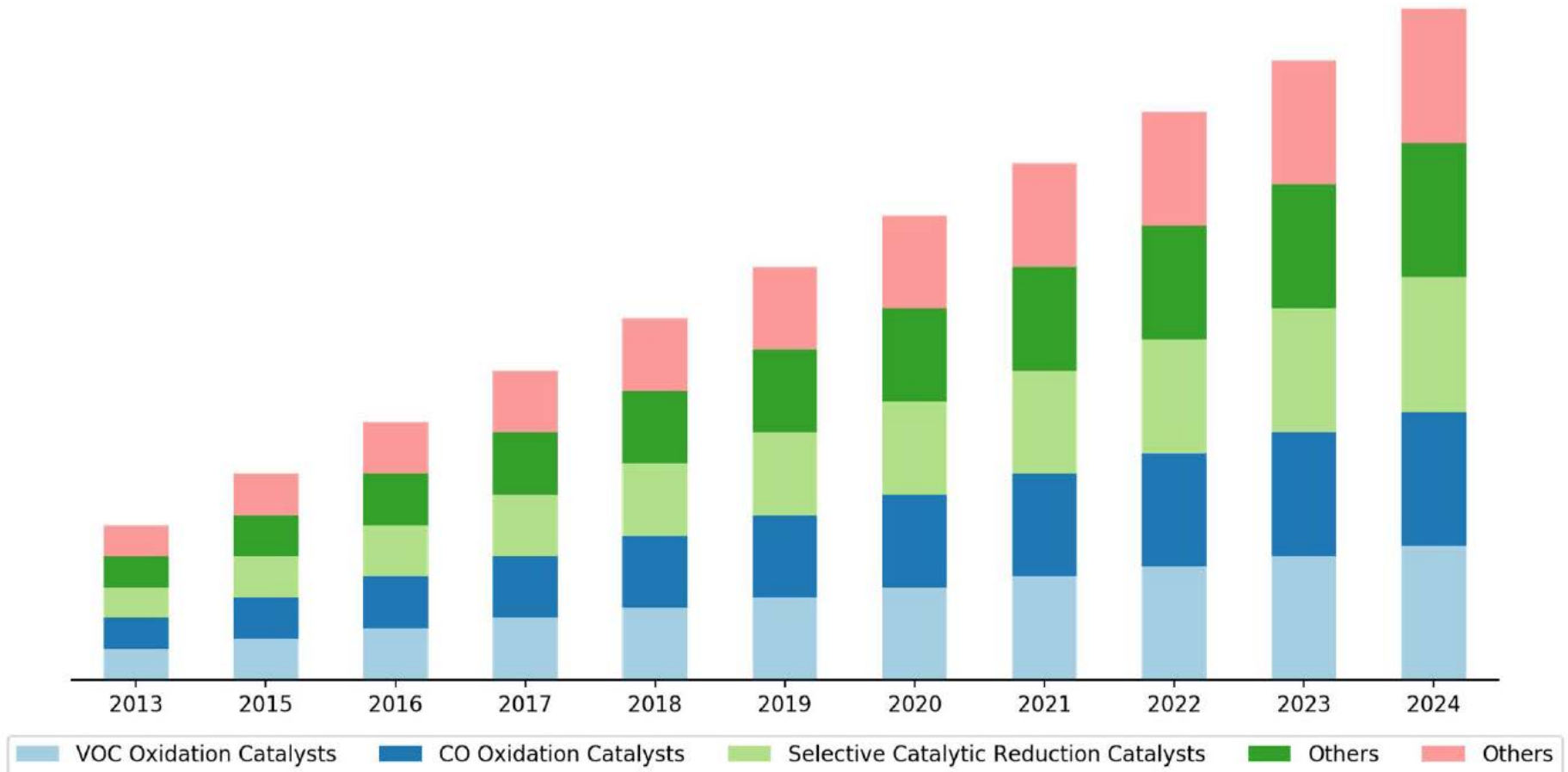
Power generation

Refineries

Municipal waste remediation, etc.

# Global environmental catalysts market size

Market Intellica, “Global Environmental Catalysts Market Analysis 2013-2018 and Forecast 2019-2024”



# Key marketpayers in environmental catalysts

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- BASF**
- Applied Catalysts**
- Clariant**
- Dorf Ketal Chemicals**
- Dow Chemicals**
- EmeraChem**
- Environmental Catalyst Technology**
- Evonik Industries**
- Johnson Matthey**
- Treibacher Industrie**
- CRI Catalyst Company**
- Axens Group**

# Environmental catalysts market size by players

HTF MI, “Global Environmental Catalysts Market Study Forecast till 2026”

