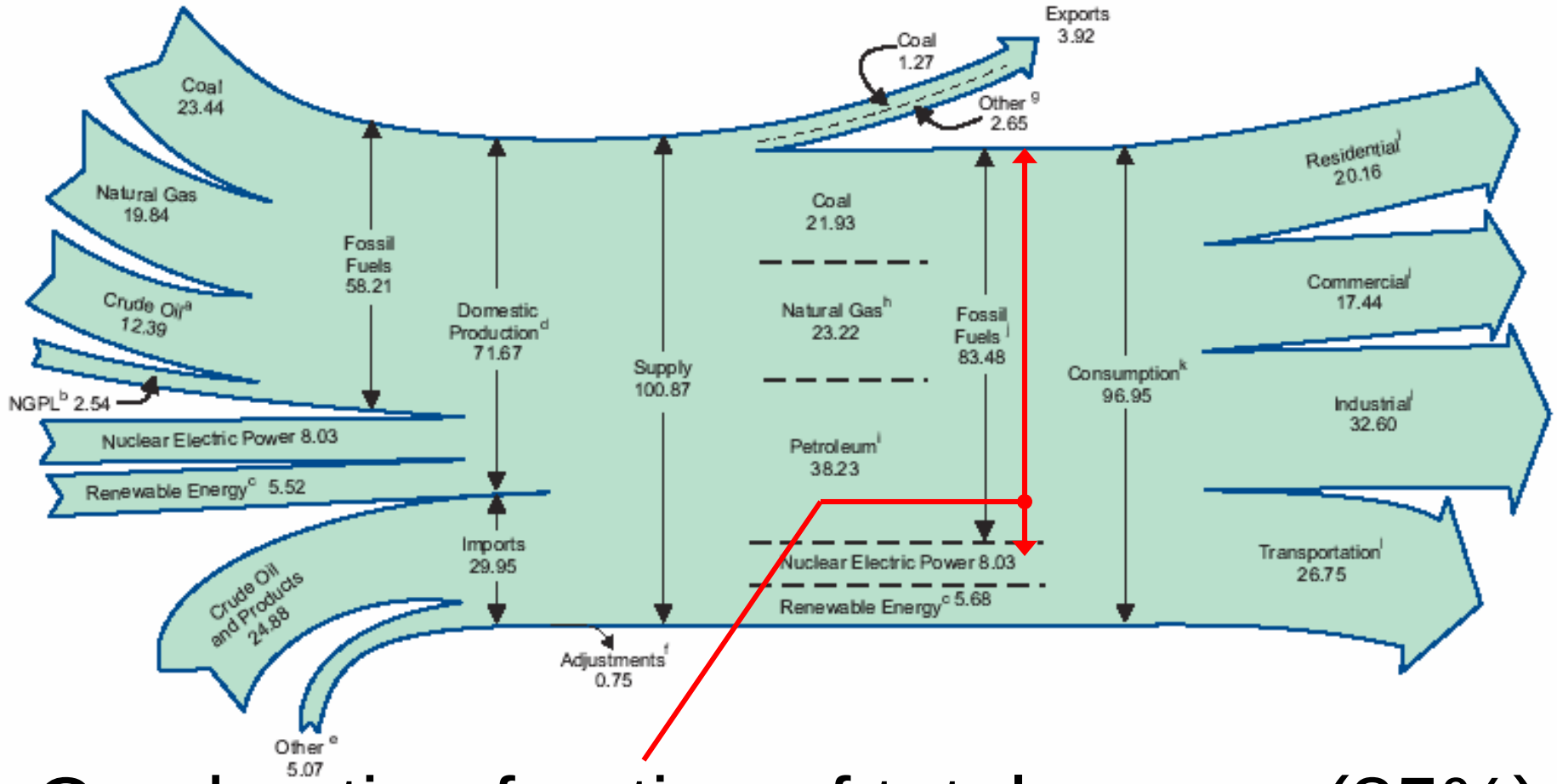
US Energy Flow Diagram - 2001

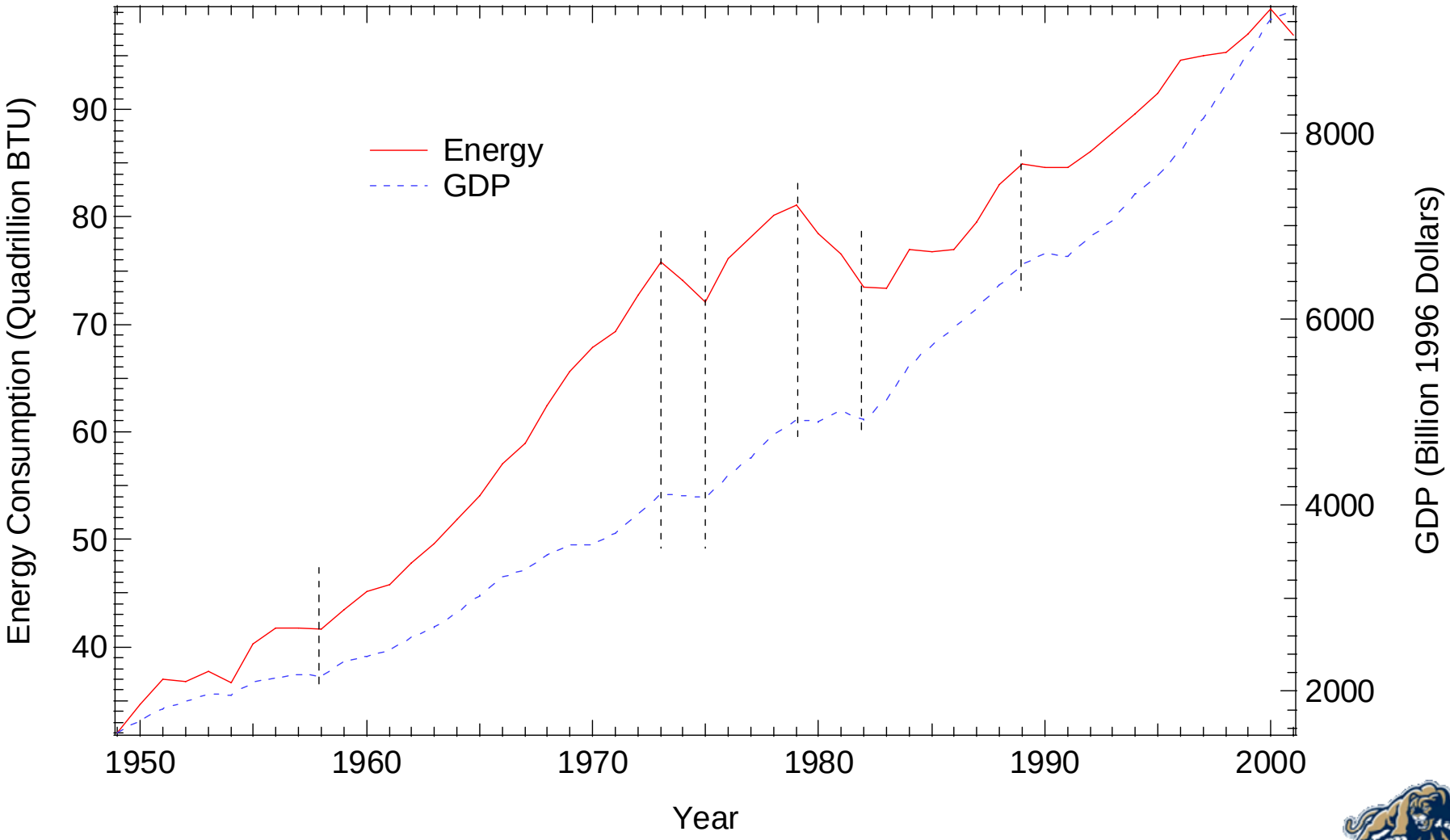


Combustion fraction of total energy (85%)

Source: Energy Information Administration, Annual Energy Review 2001

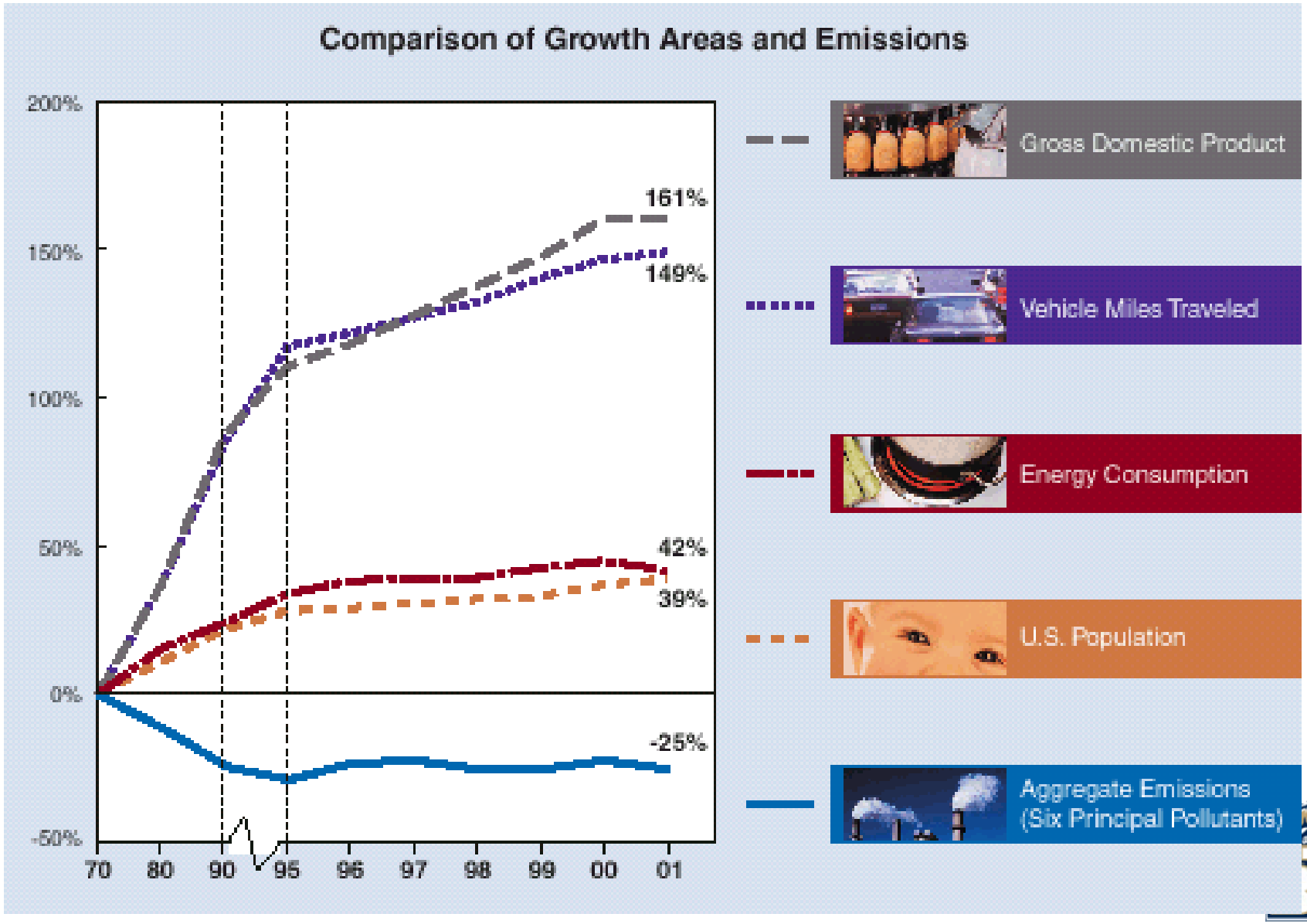
Units in Quads

Energy and Economy

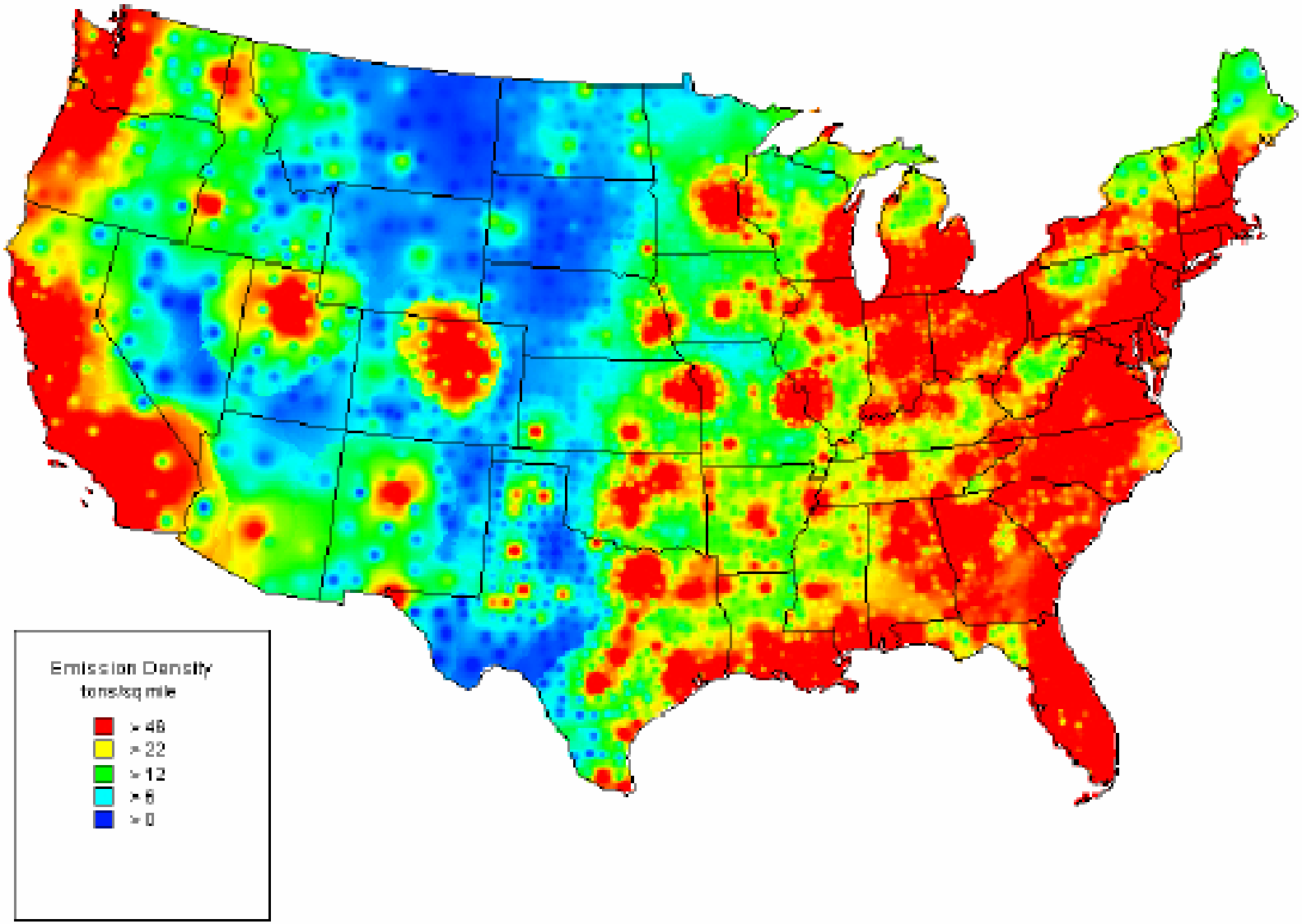


(linear correlation coefficient = 0.95)

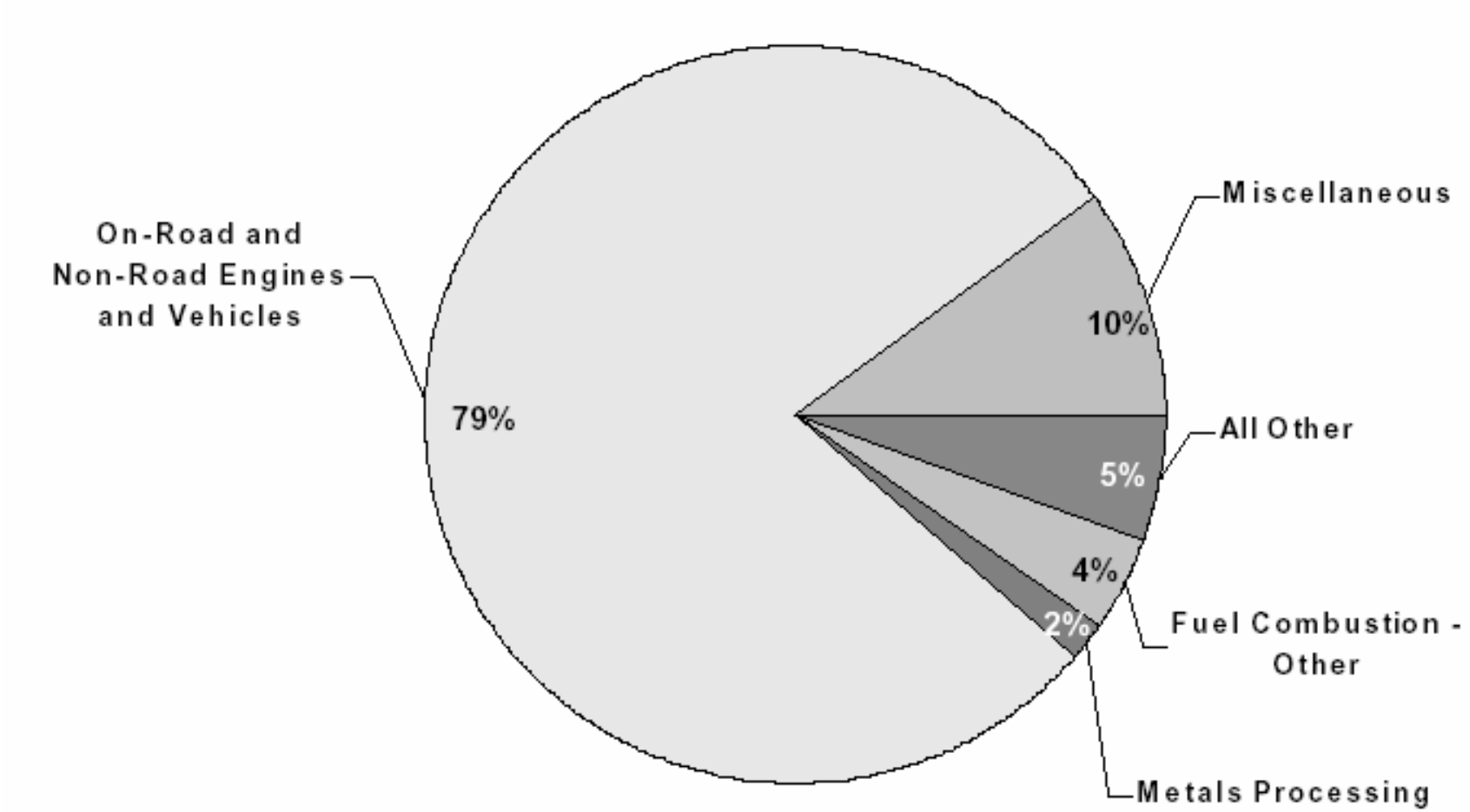
Environmental Impacts



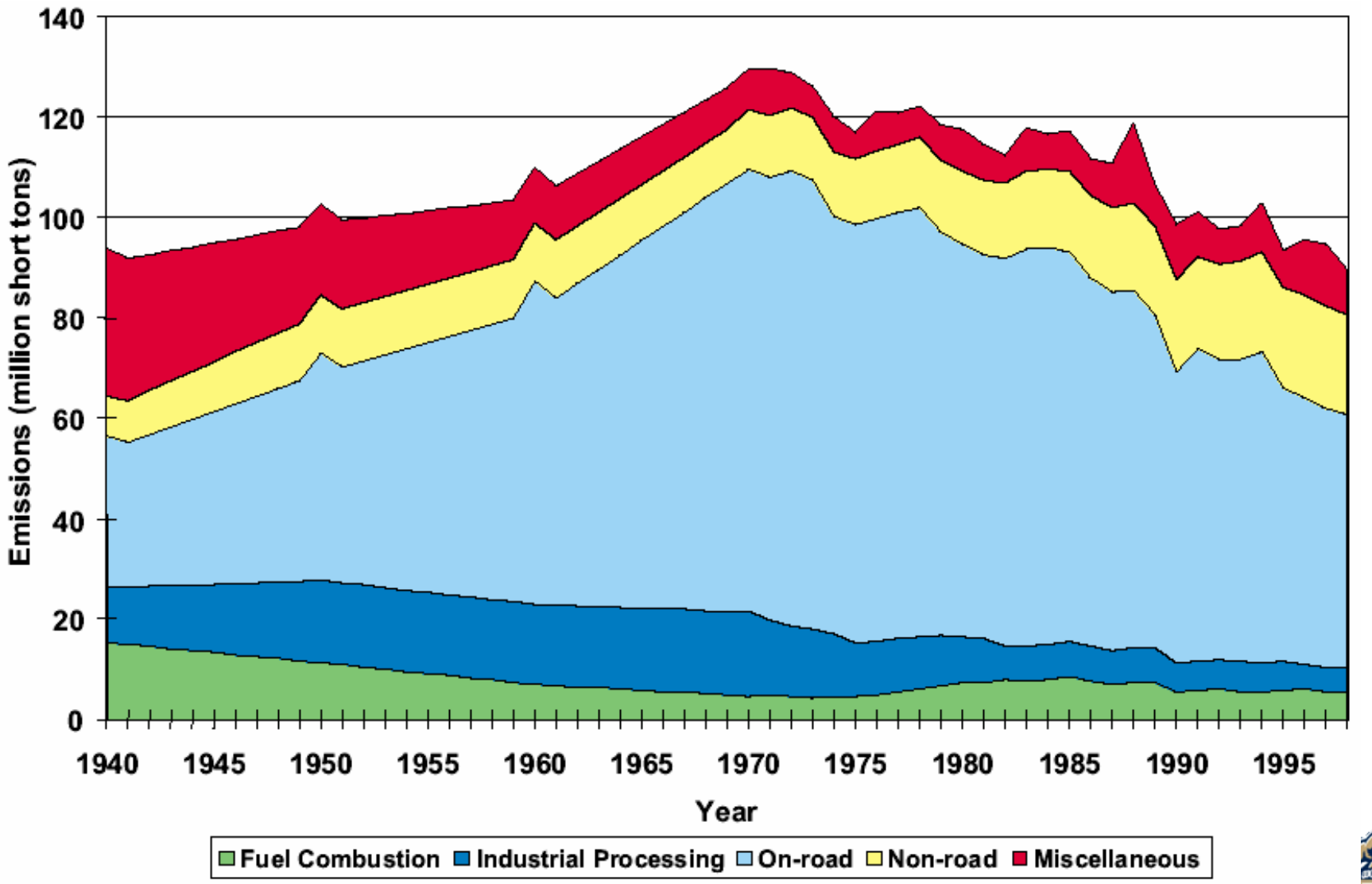
CO Emissions (1998)



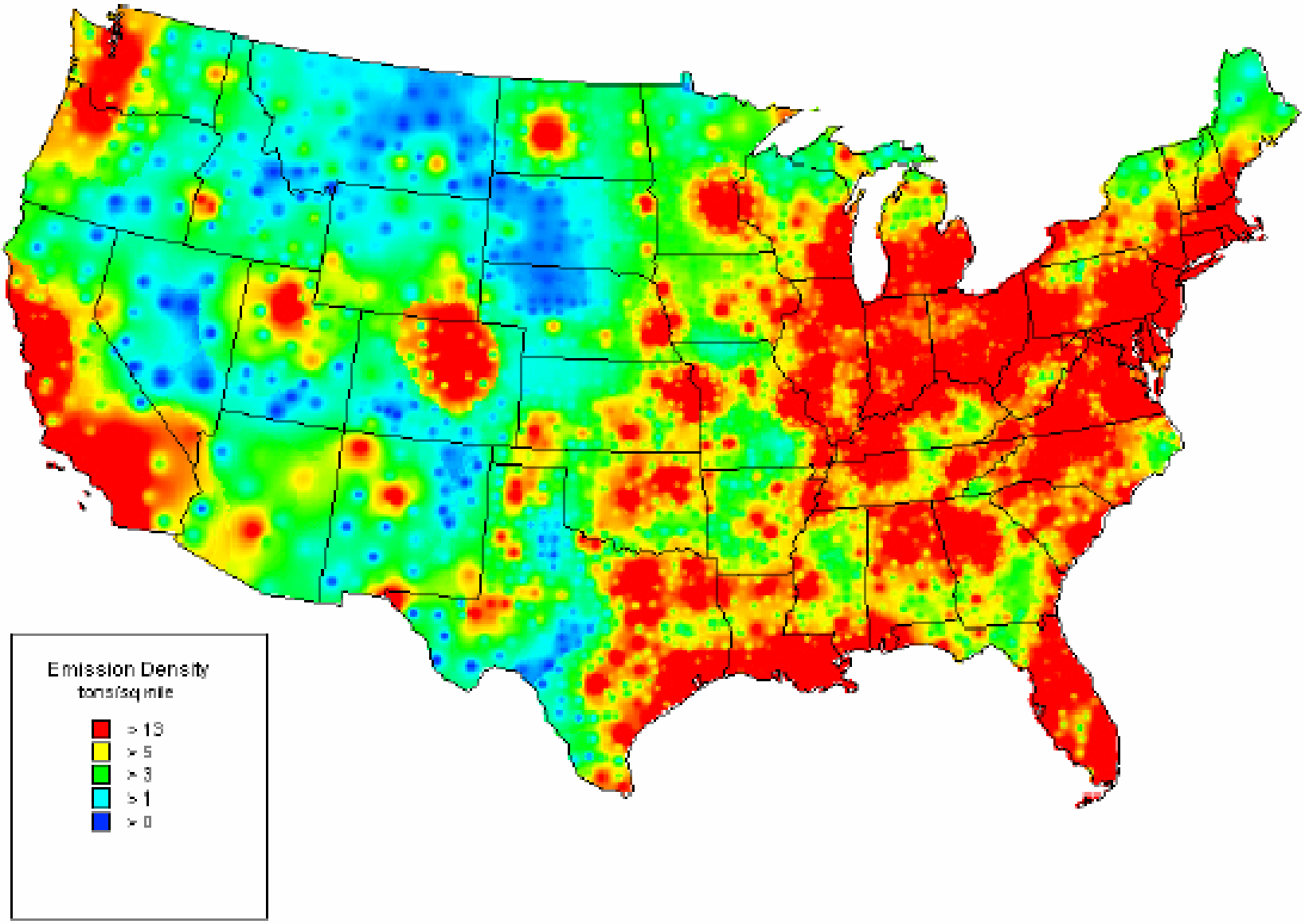
CO Sources


On-Road and Non-Road Engines and Vehicles
79%
Miscellaneous
10%
All Other
5%
4%
2%
Fuel Combustion - Other
Metals Processing

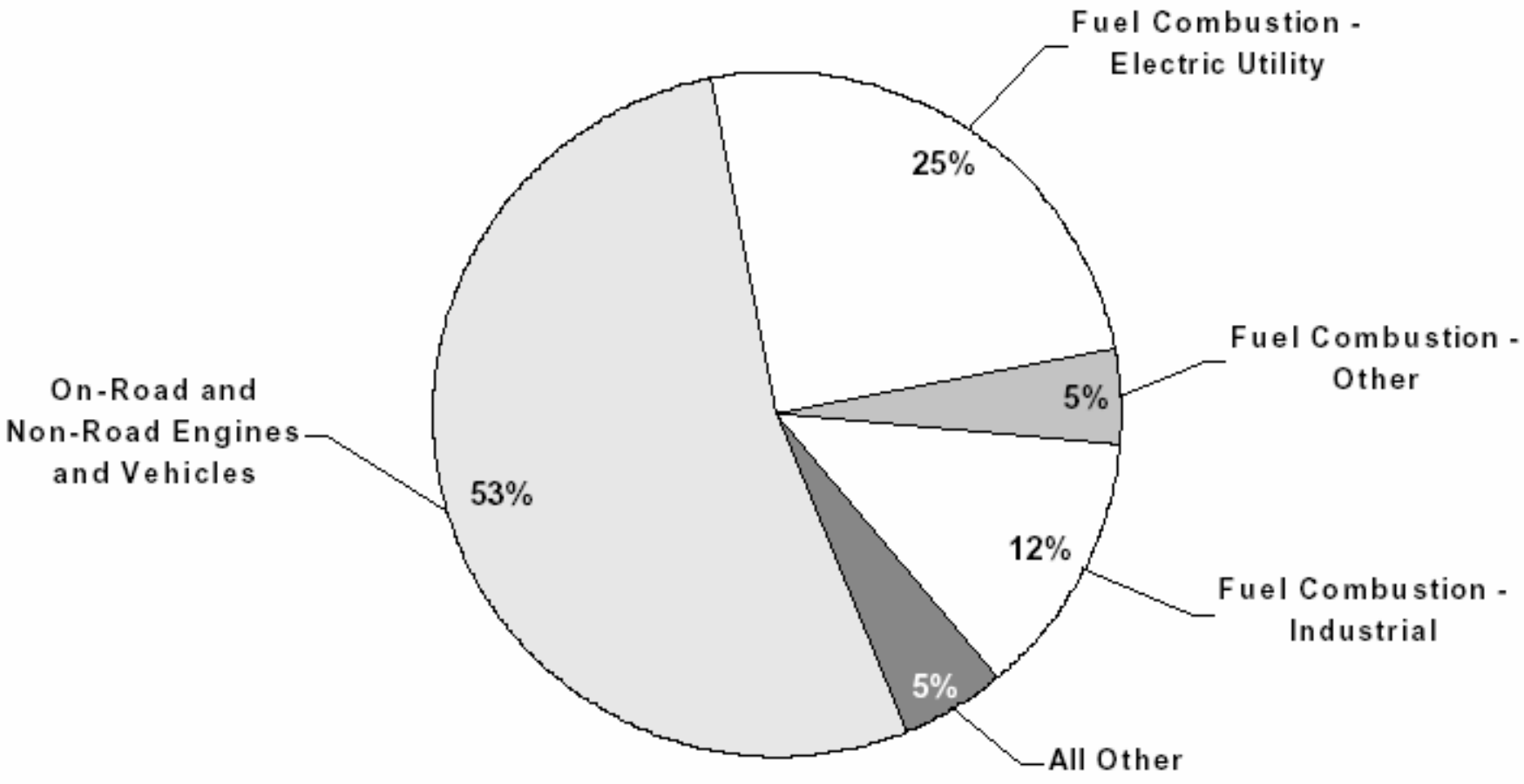
CO Trends


Emissions (million short tons)
140
120
100
80
60
40
20
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous

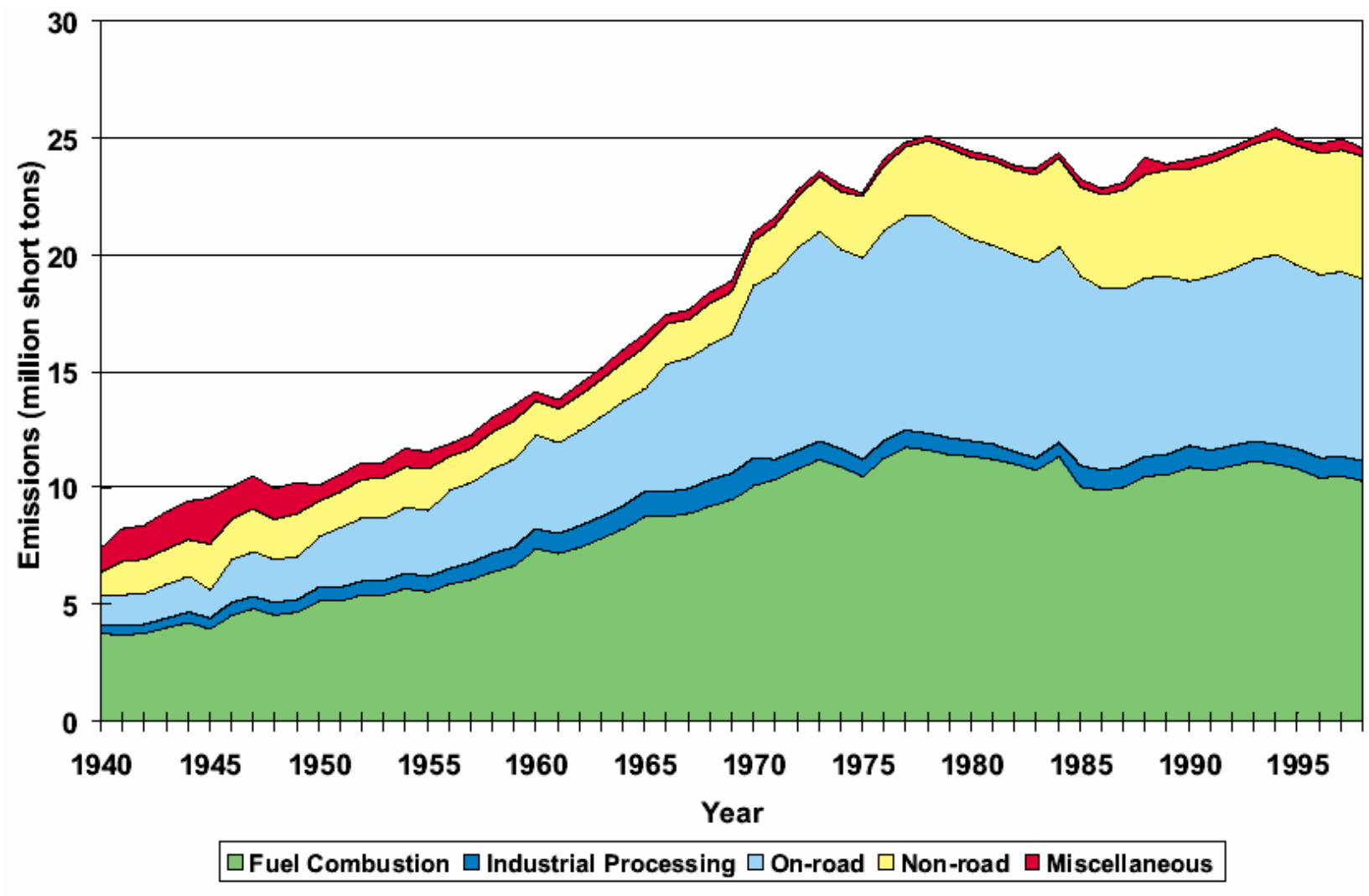
NO_x Emissions (1998)



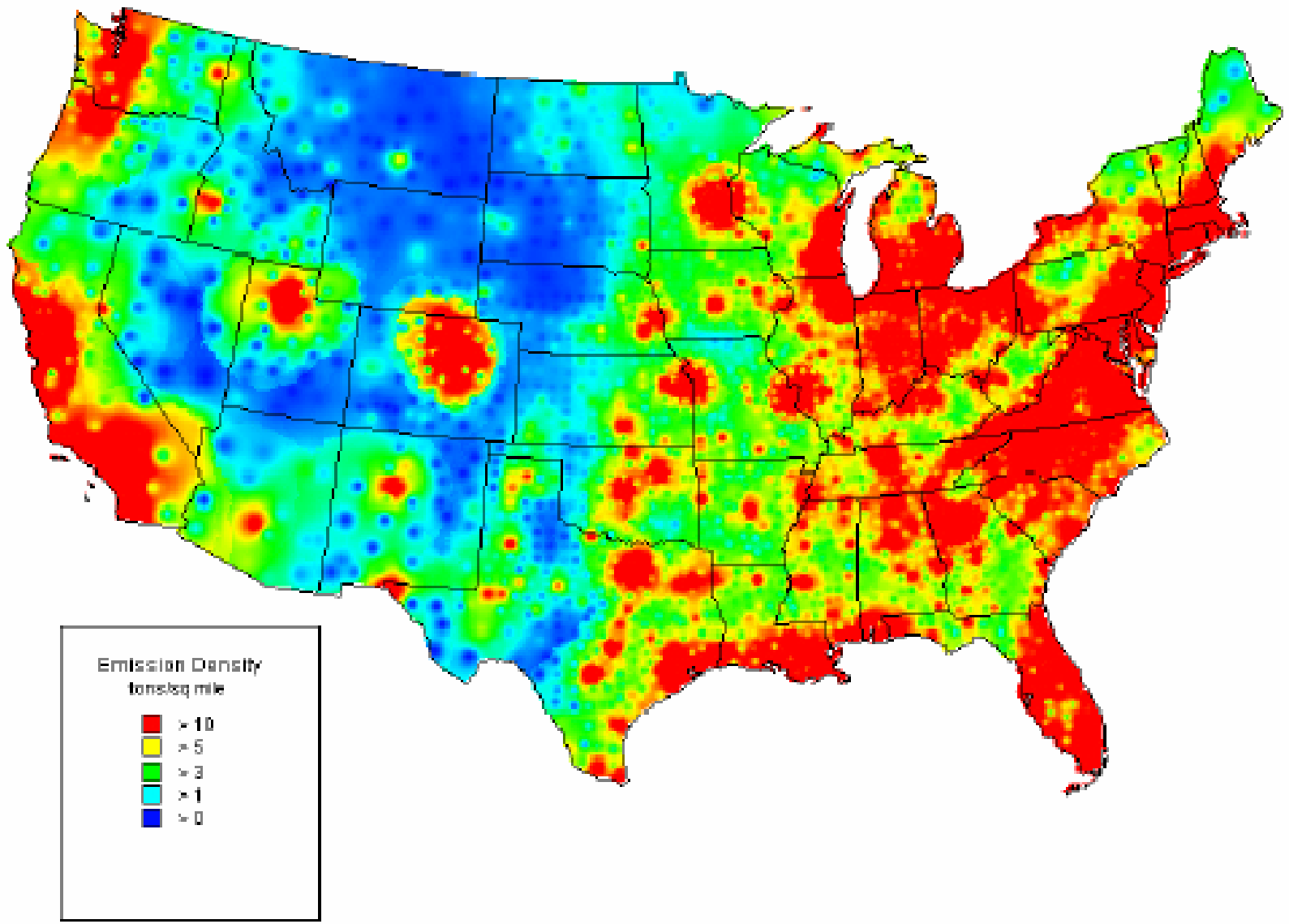
NO_x Sources (1998)



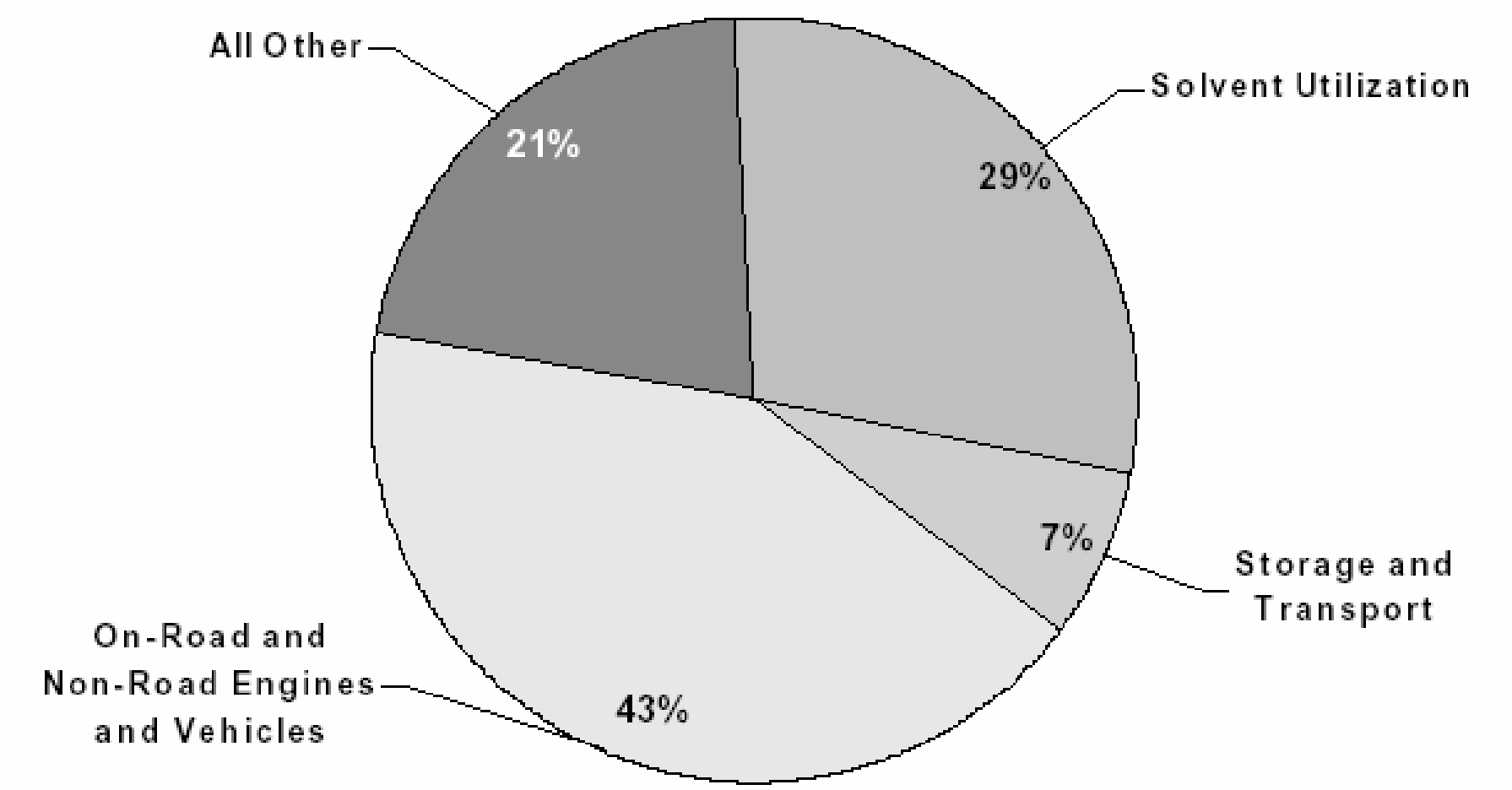
NO_x Trends


30
25
20
15
10
5
0
Emissions (million short tons)
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous

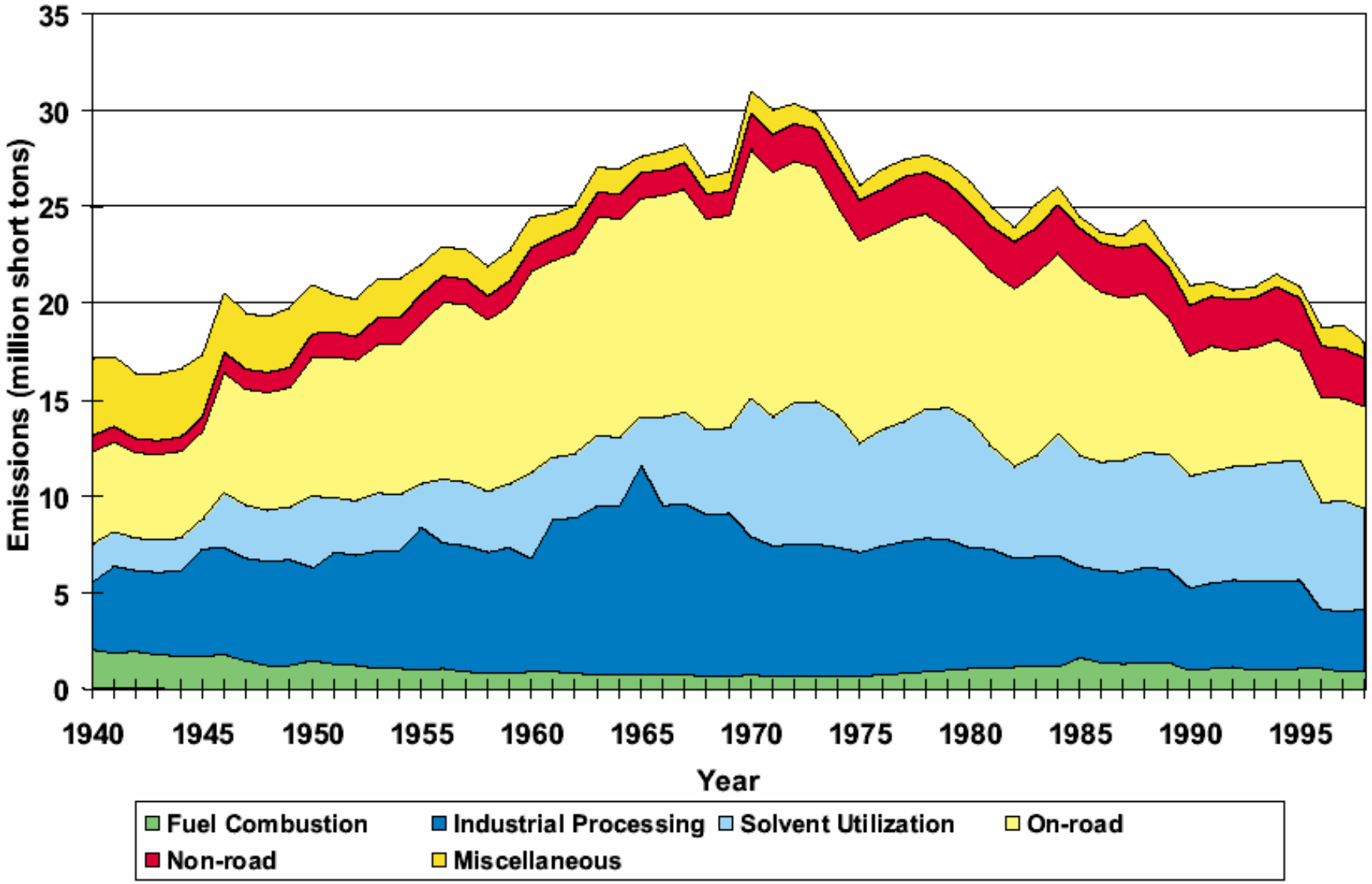
VOC Emissions (1998)



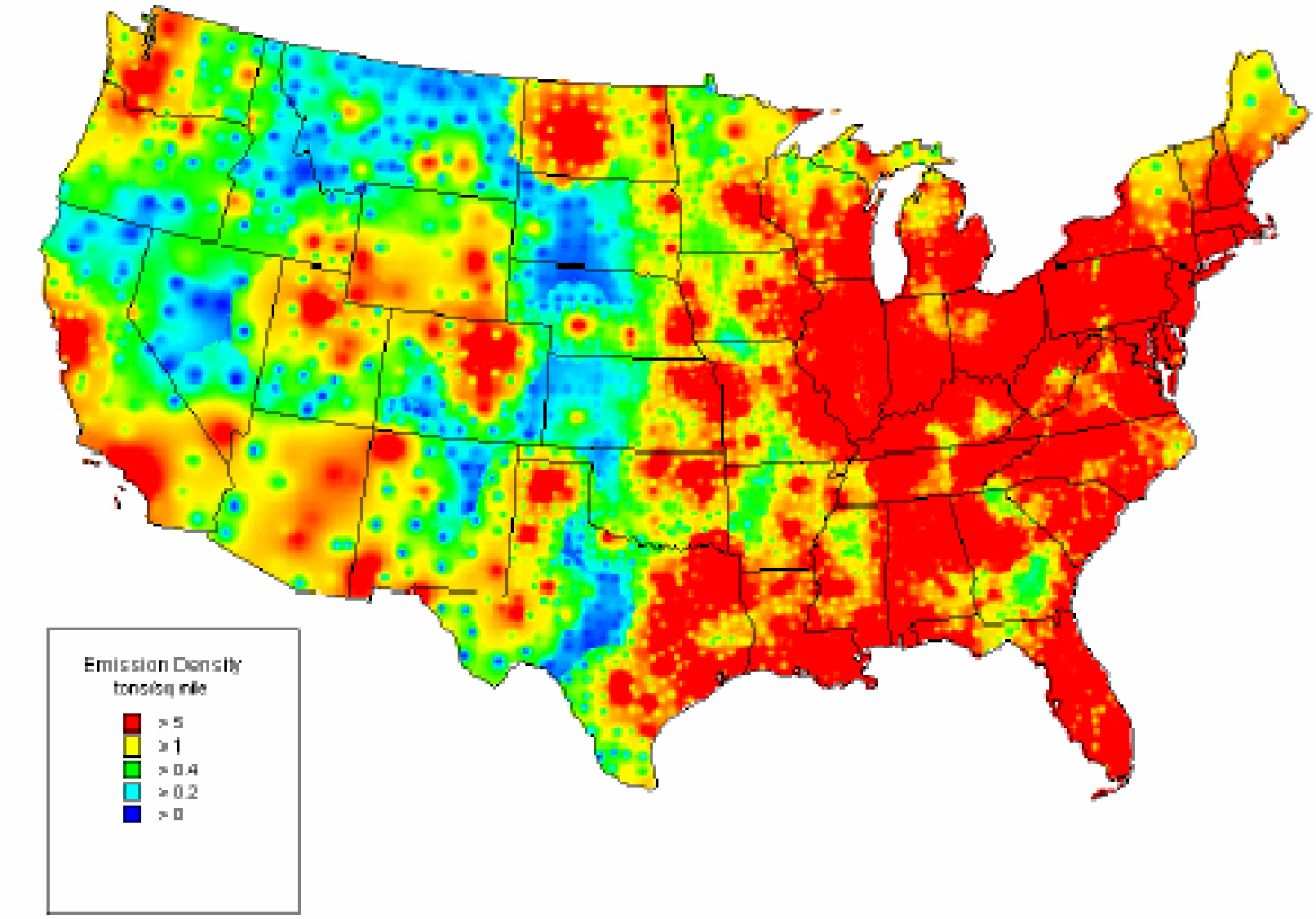
VOC Emission Sources (1998)



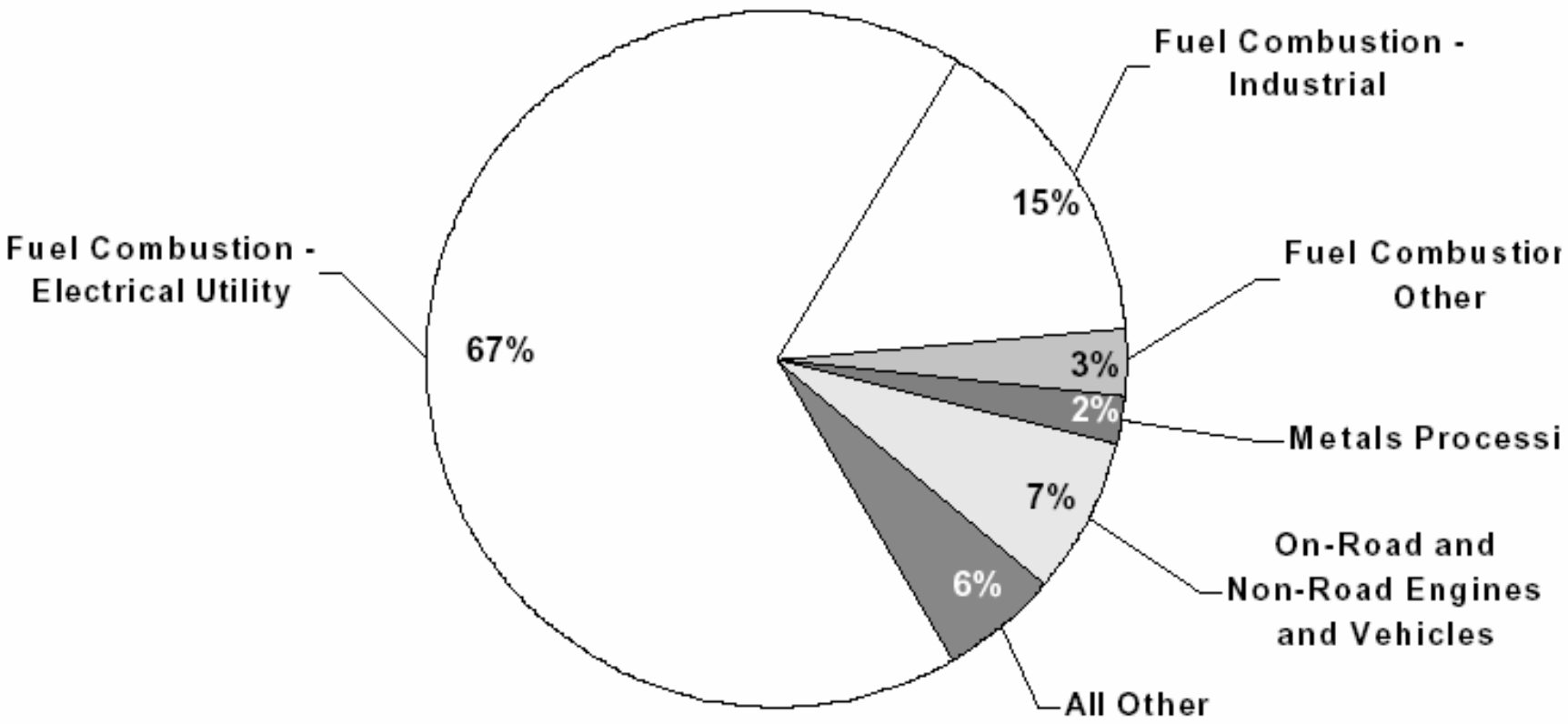
VOC Trends


Emissions (million short tons)
35
30
25
20
15
10
5
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year
Fuel Combustion
Industrial Processing
Solvent Utilization
On-road
Non-road
Miscellaneous

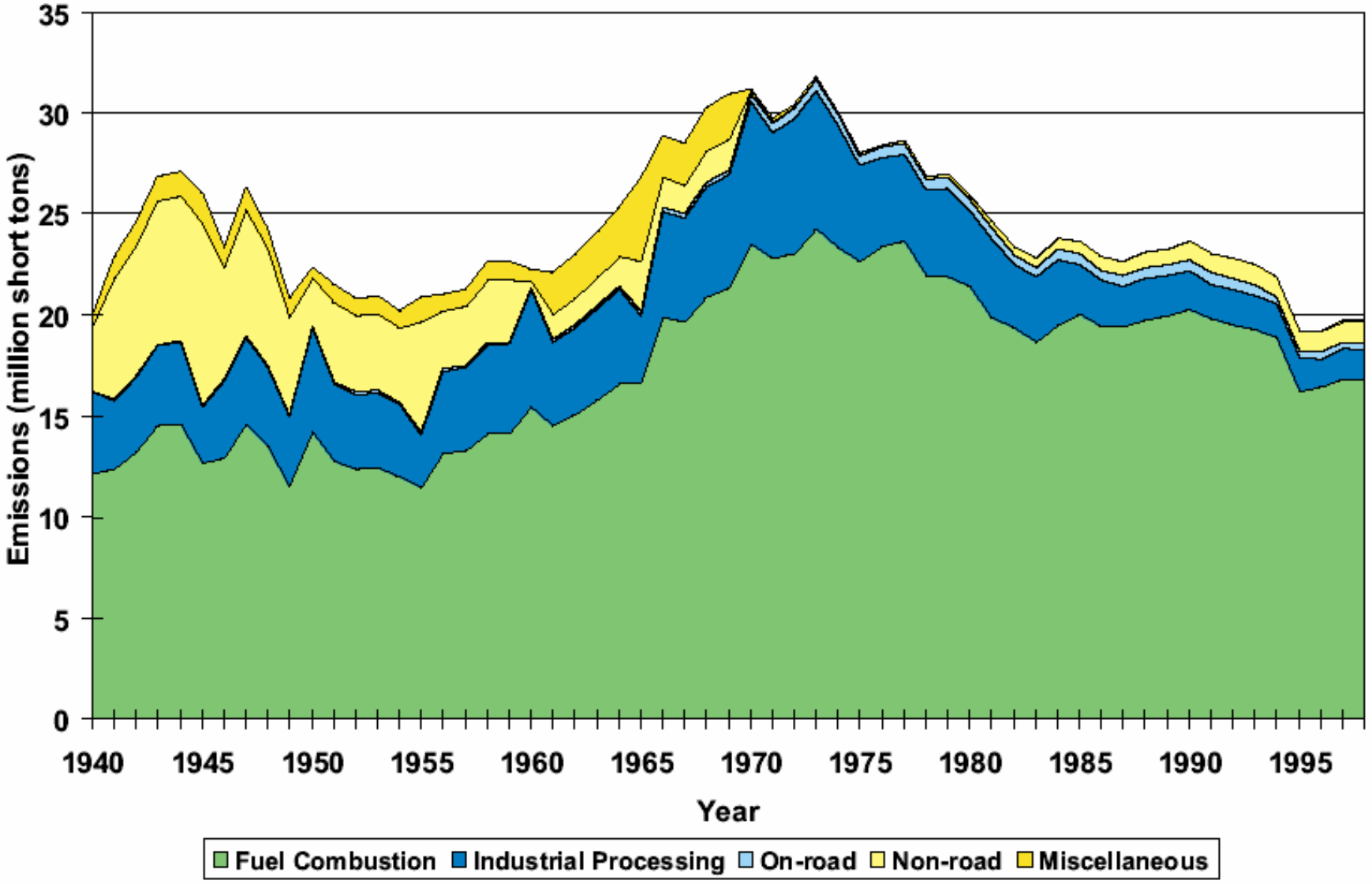
SO_2 Emissions (1998)



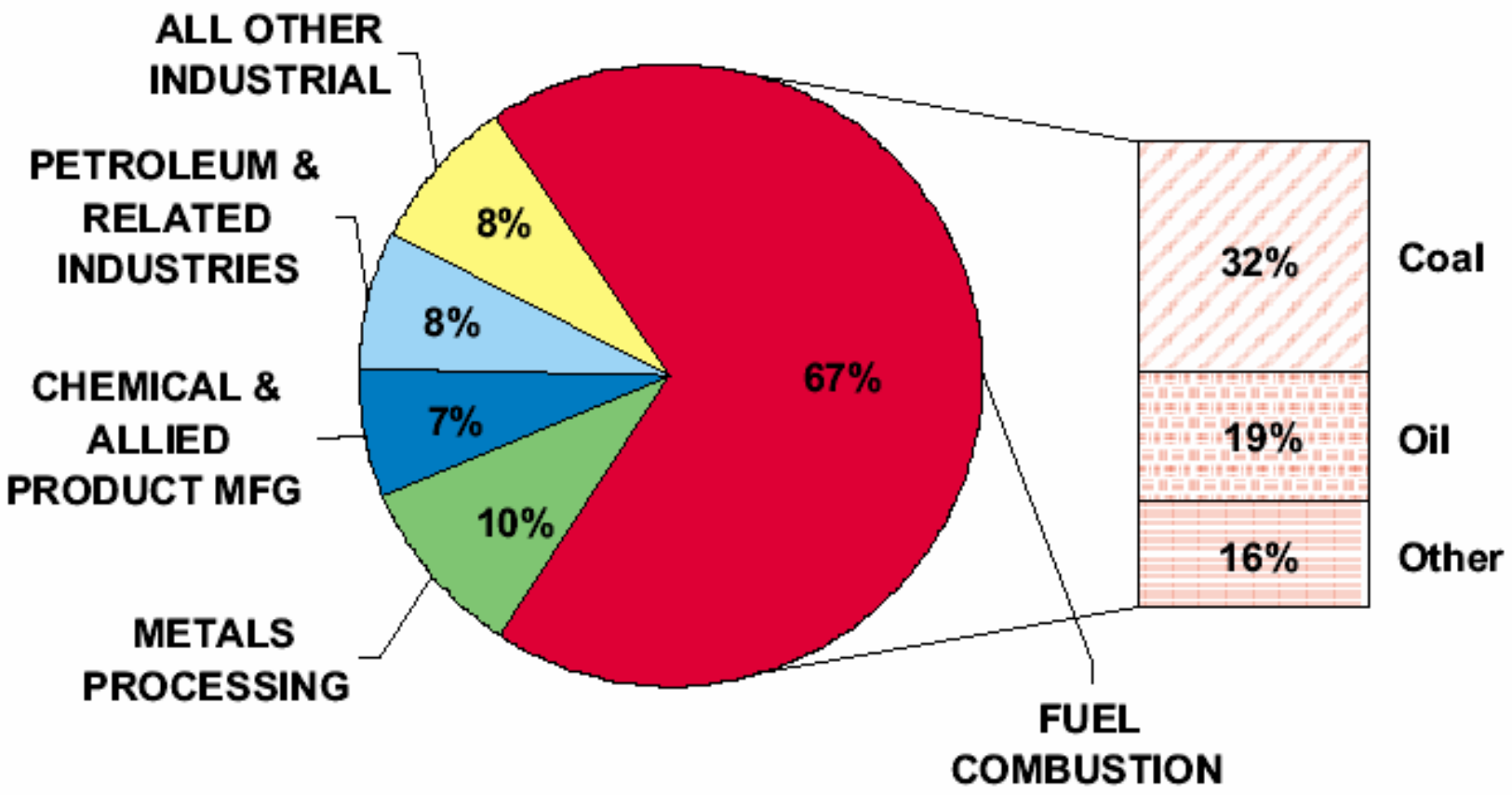
SO_2 Emission Sources (1998)



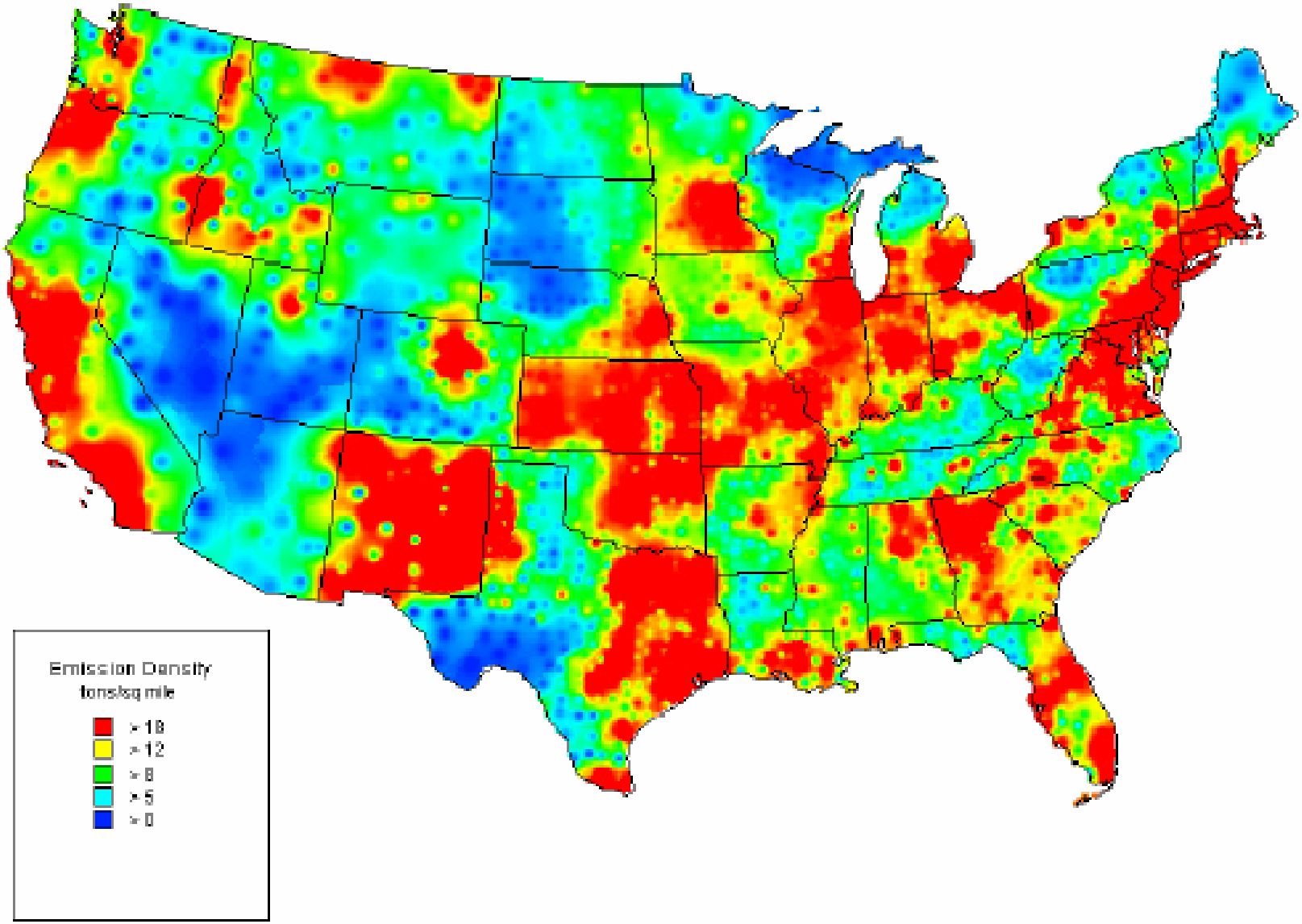
SO_2 Trends


35
30
25
20
15
10
5
0
Emissions (million short tons)
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous

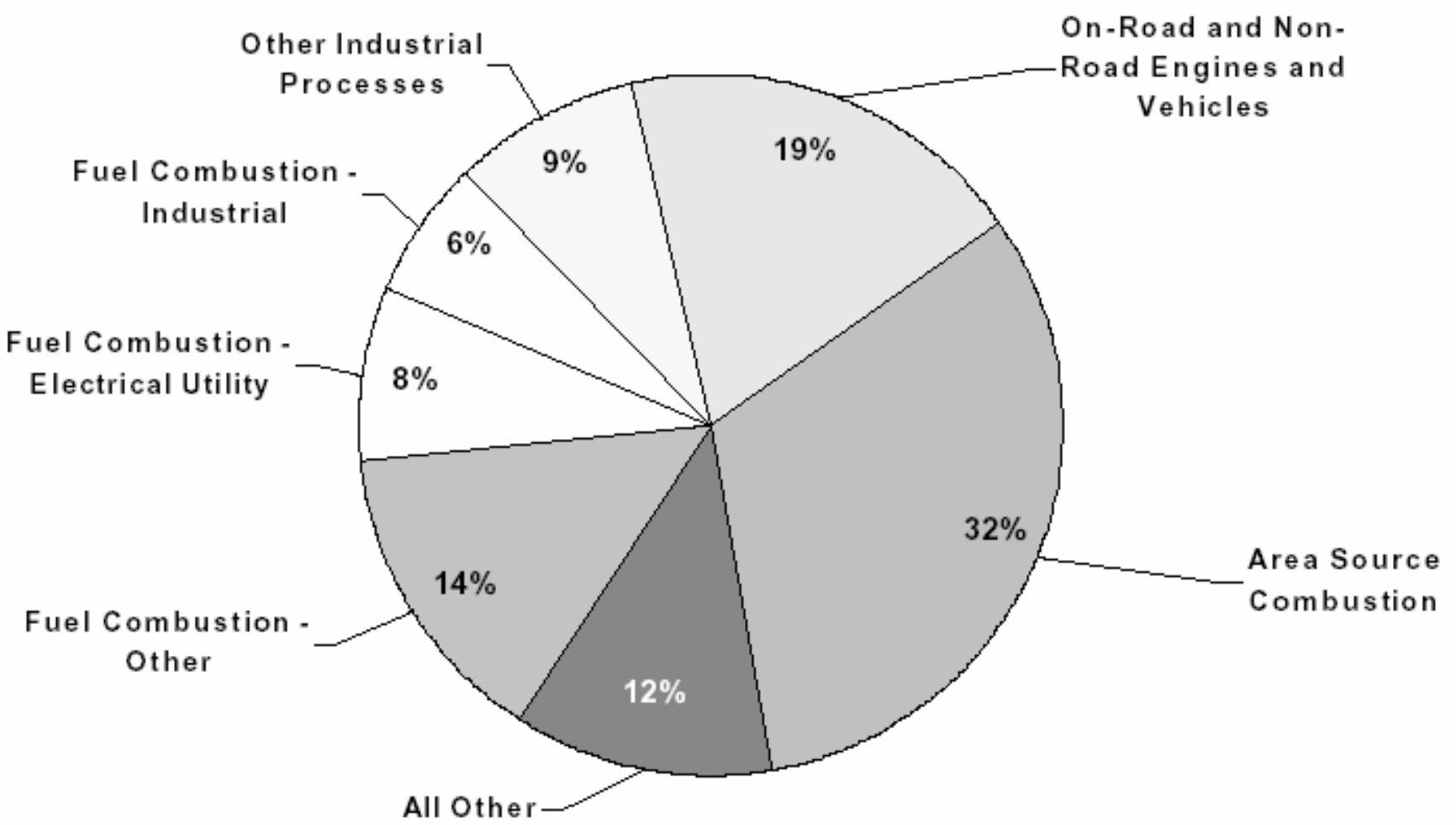
SO_2 Source Details



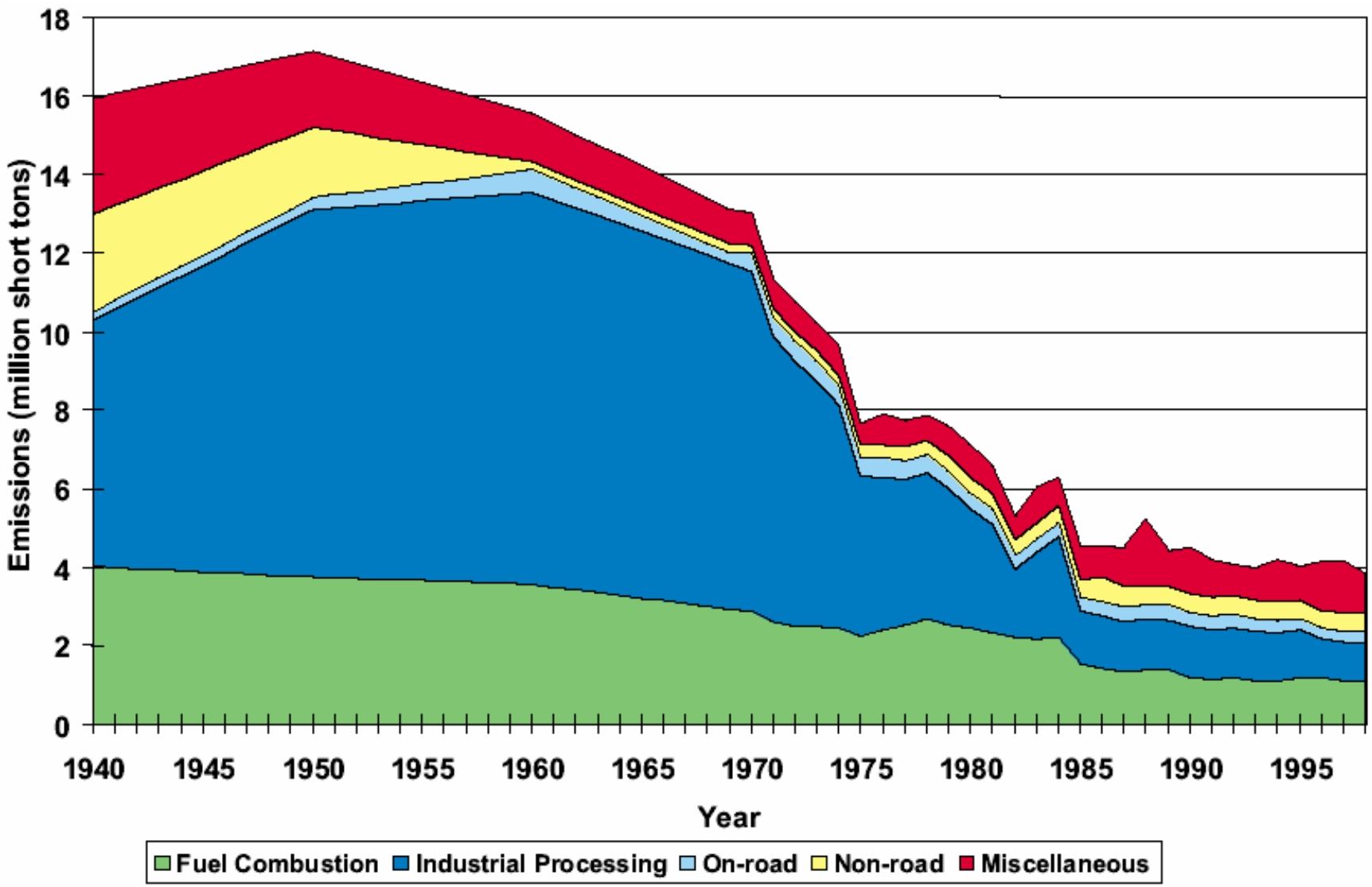
PM_{10} Emissions (1998)



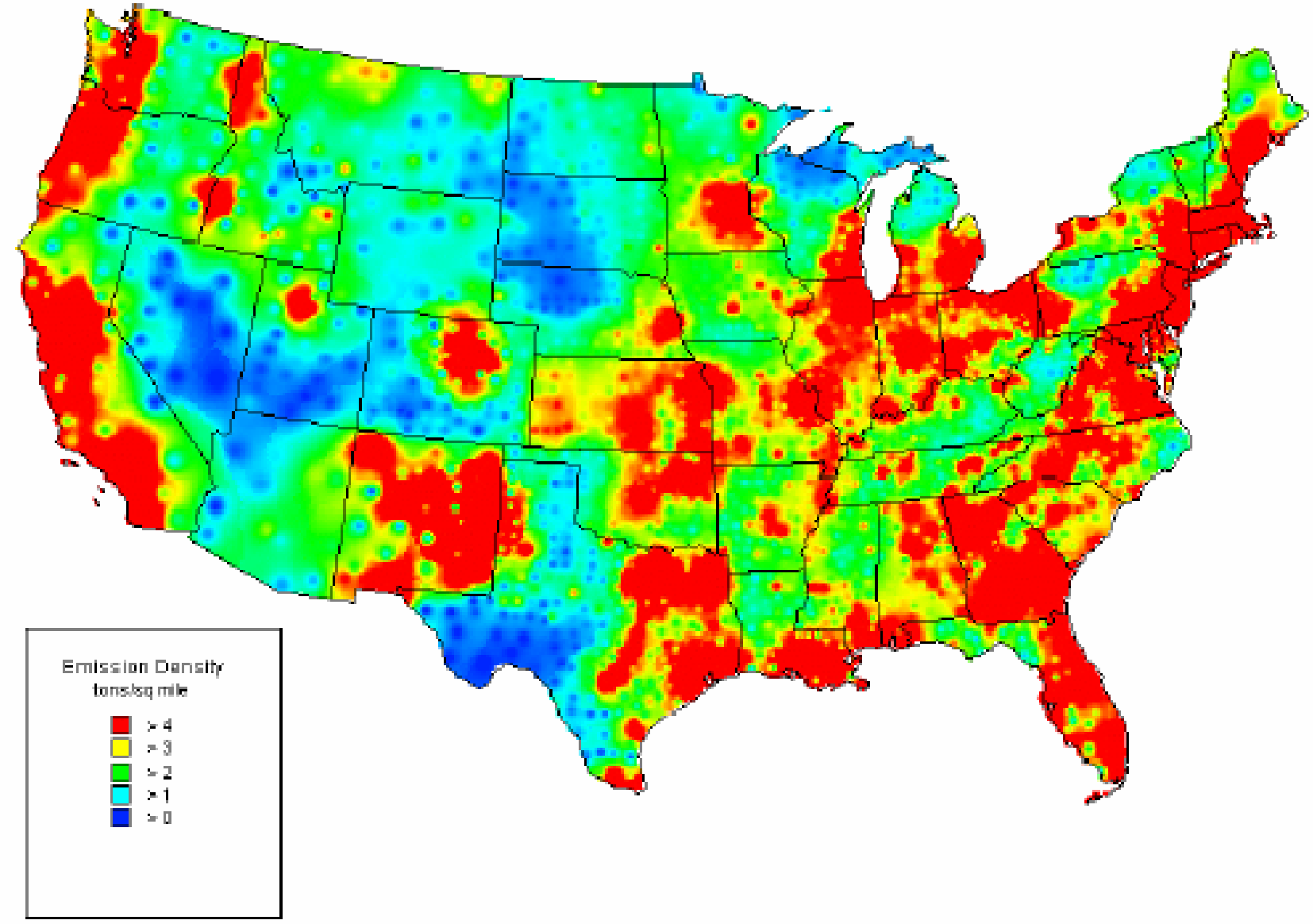
PM_{10} Emission Sources (1998)



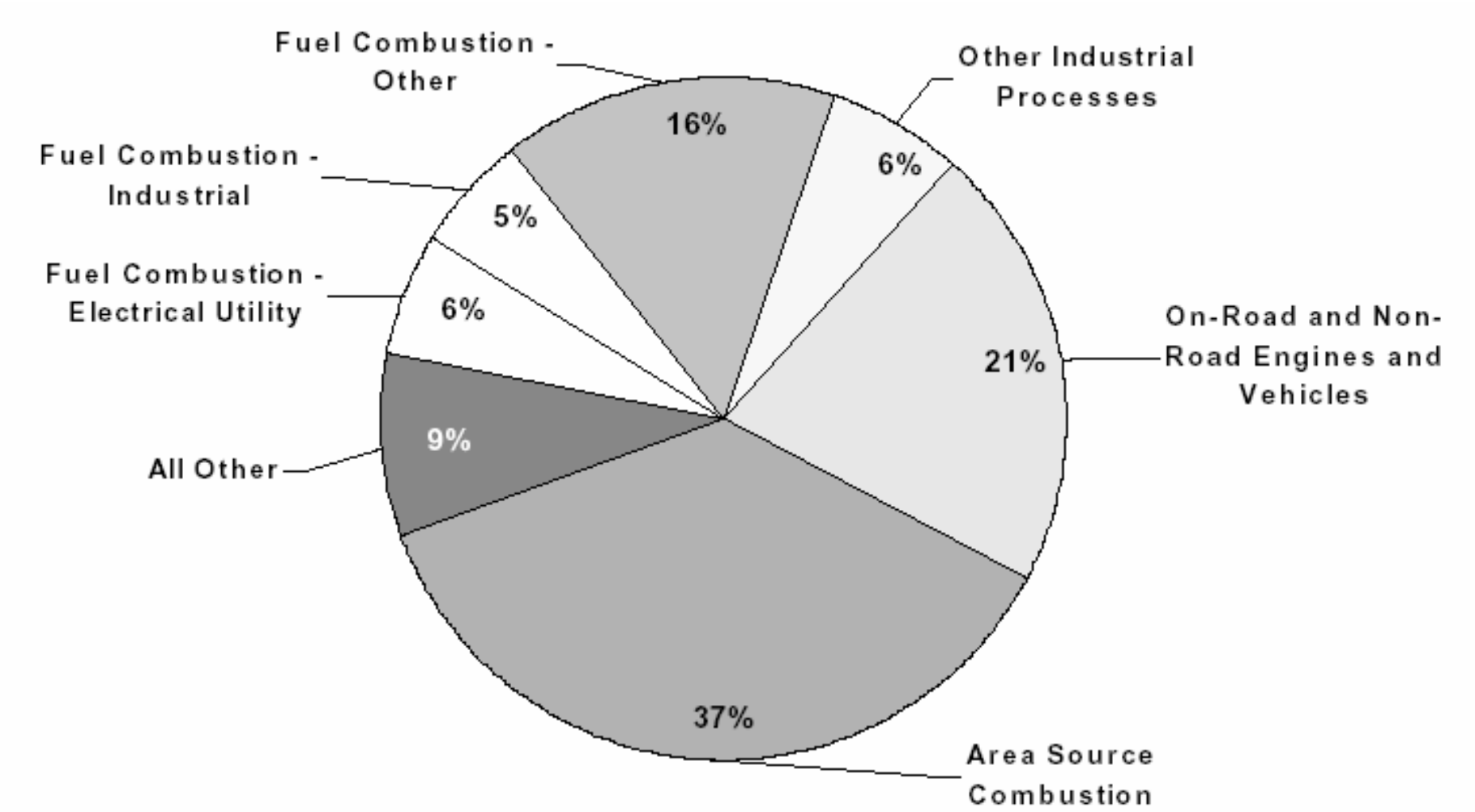
PM_{10} Trends


Emissions (million short tons)
18
16
14
12
10
8
6
4
2
0
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous

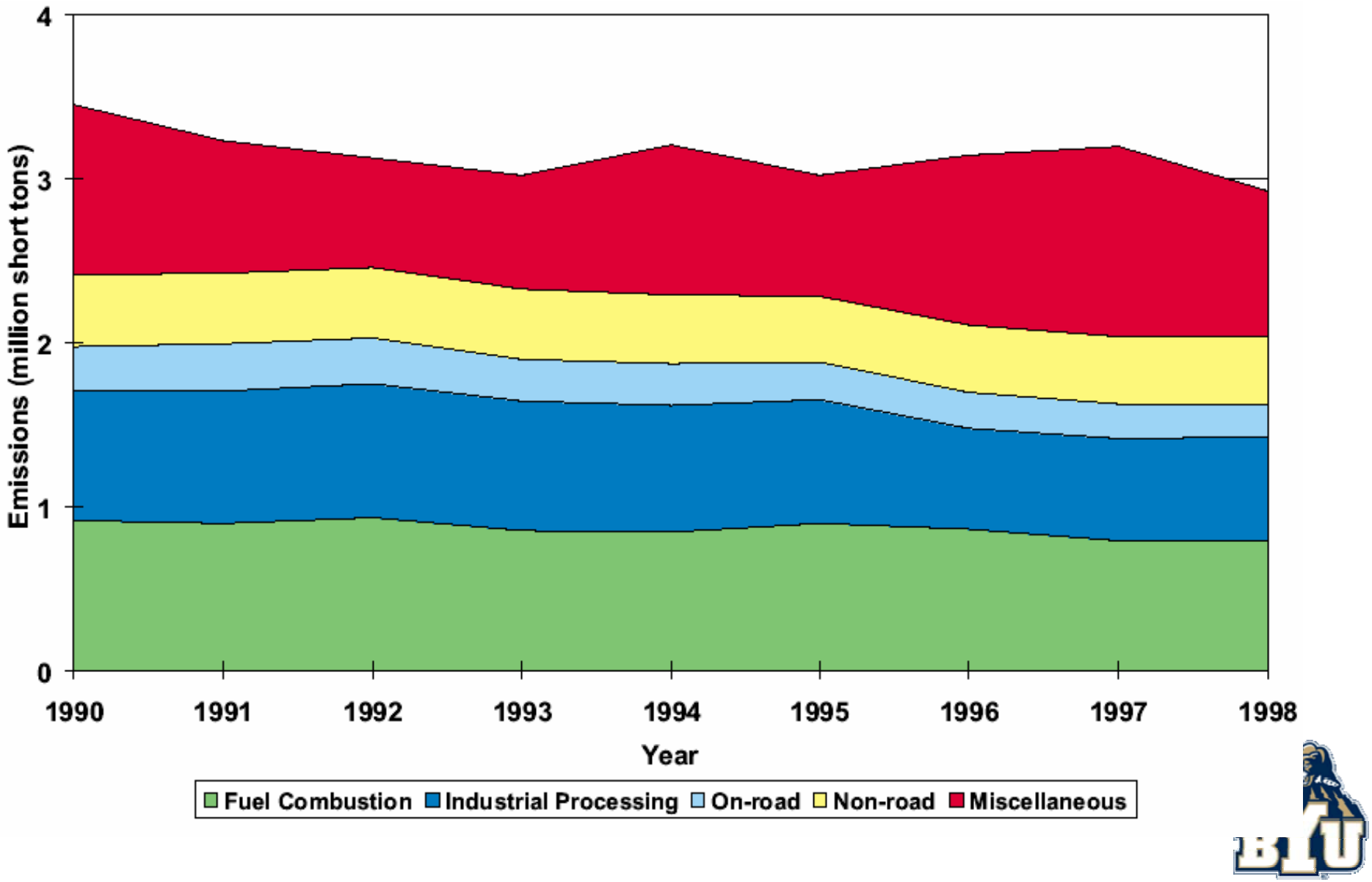
$PM_{2.5}$ Emissions (1998)



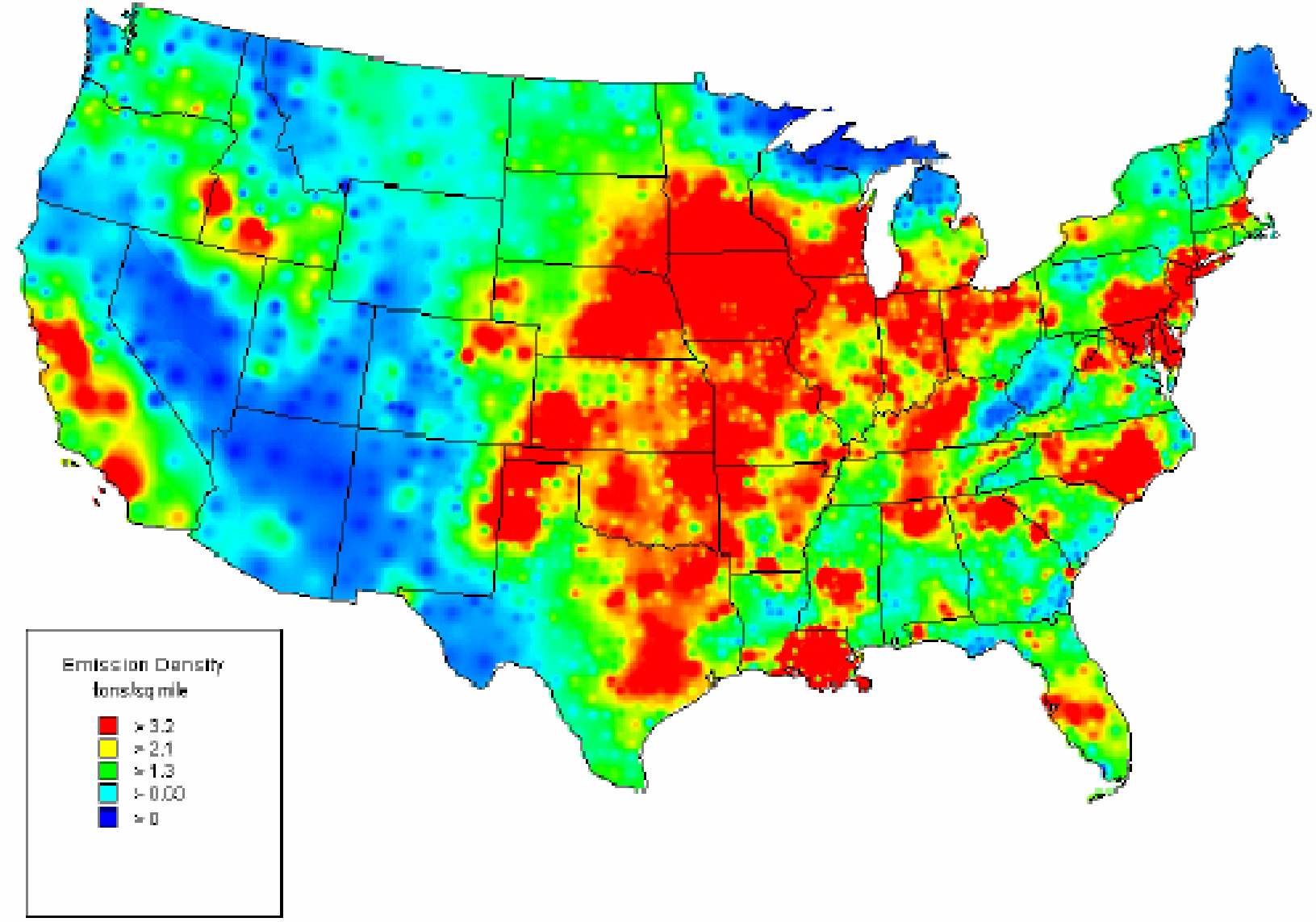
$PM_{2.5}$ Emission Sources (1998)



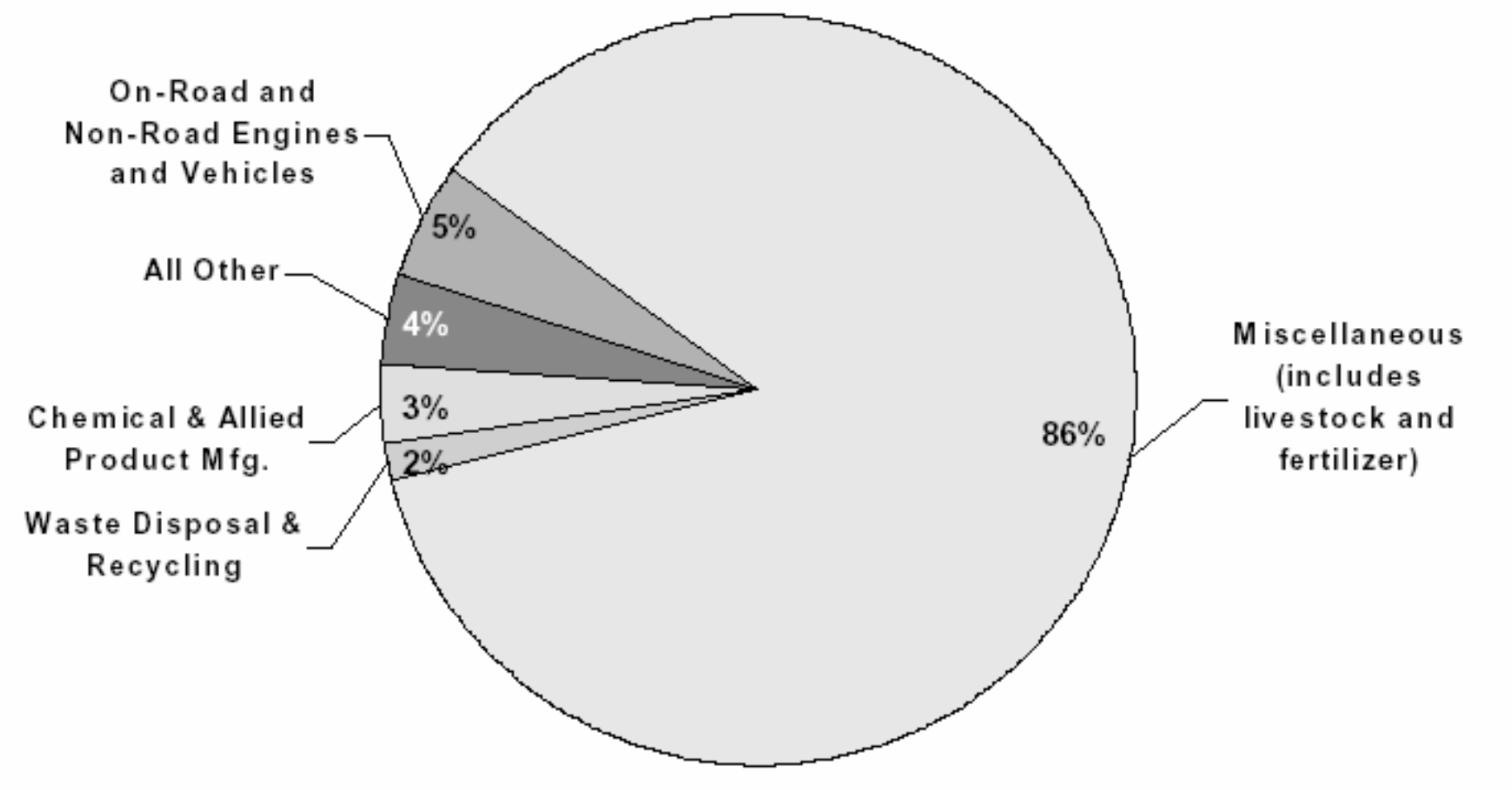
$PM_{2.5}$ Trends


4
3
2
1
0
Emissions (million short tons)
1990
1991
1992
1993
1994
1995
1996
1997
1998
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous

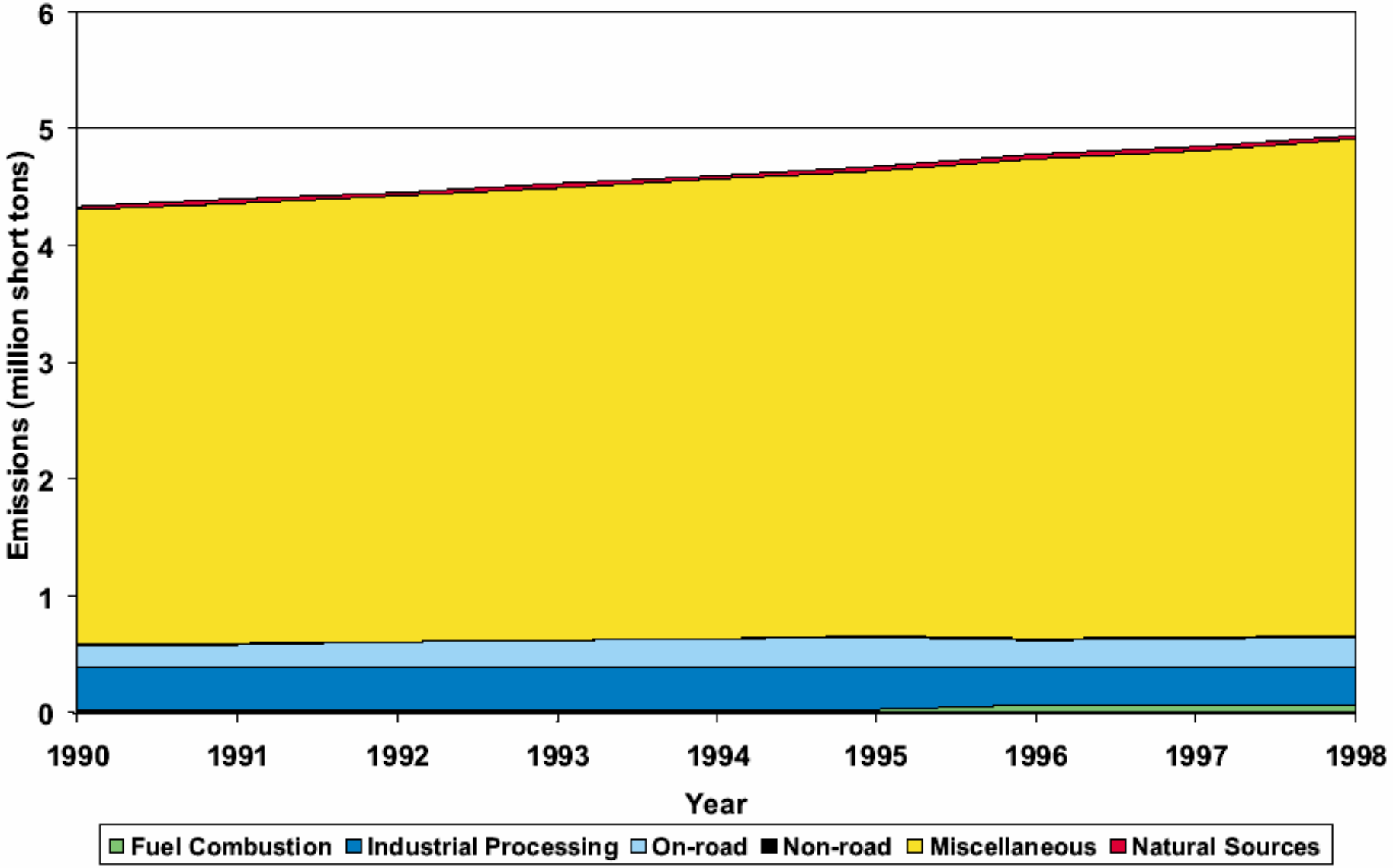
Ammonia Emissions (1998)



NH_3 Emission Sources (1998)

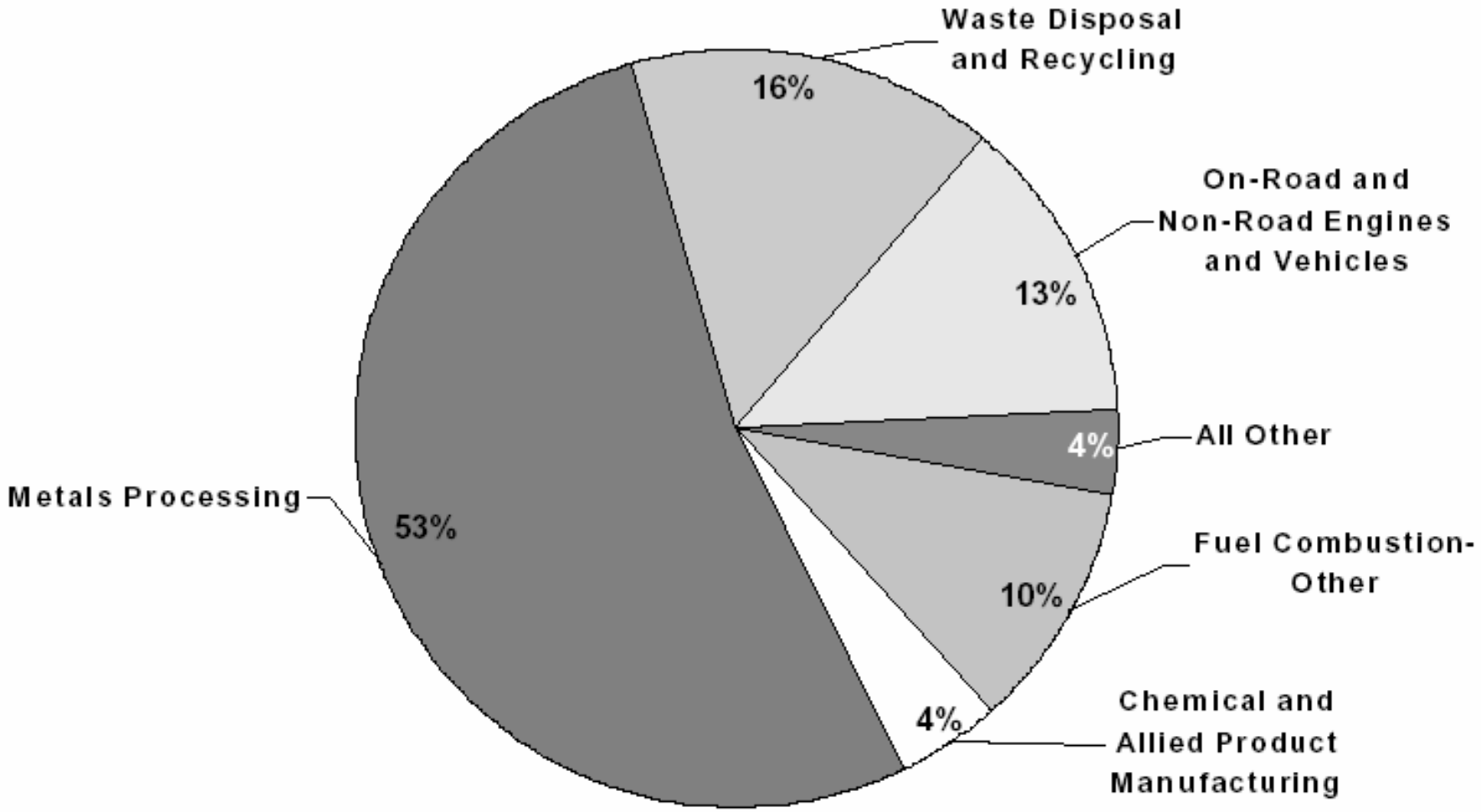


NH_3 Trends

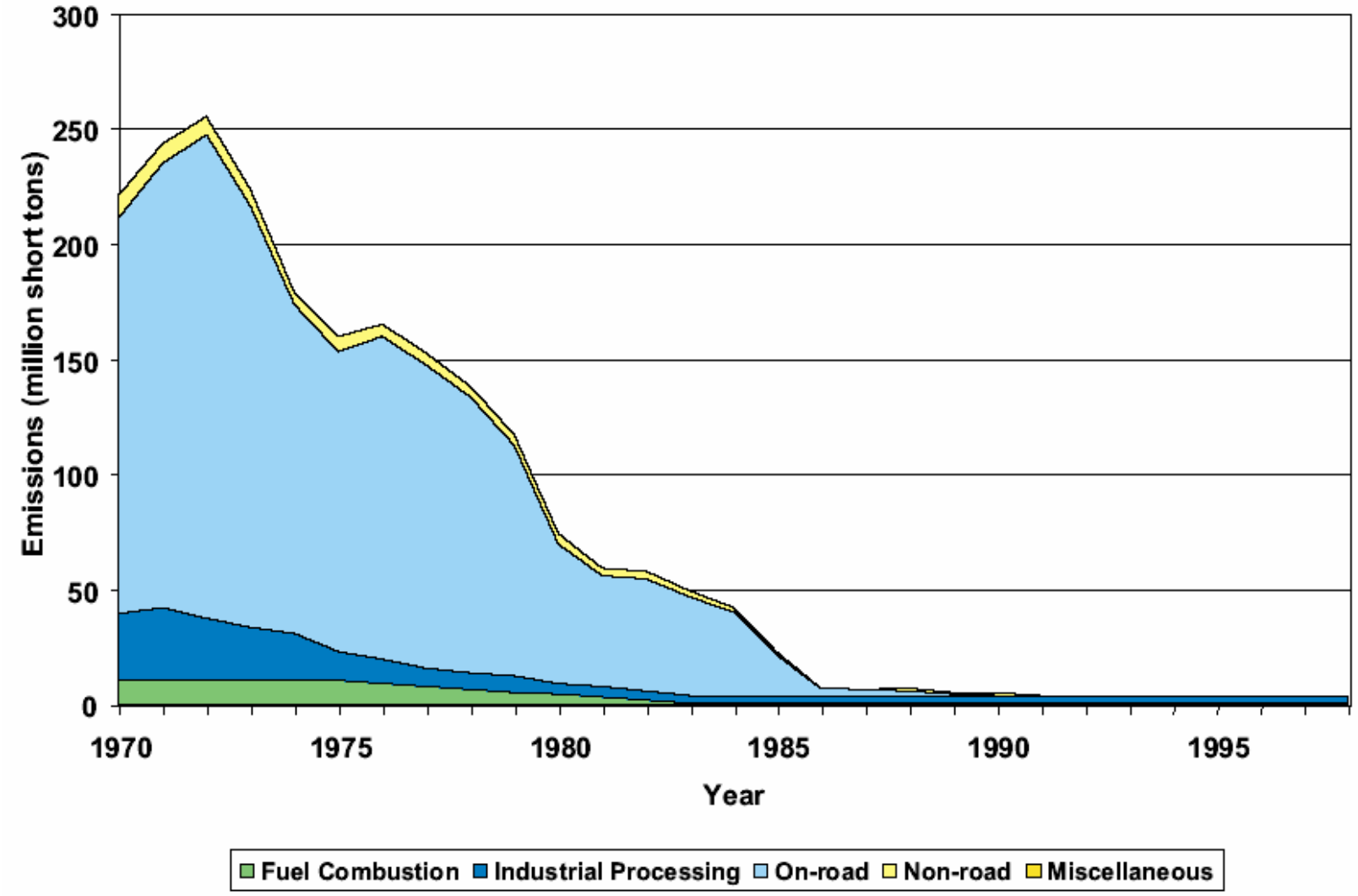

6
5
4
3
2
1
0
Emissions (million short tons)
1990
1991
1992
1993
1994
1995
1996
1997
1998
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous
Natural Sources


BYU

Pb Sources (1998)



Pb Trends


300
250
200
150
100
50
0
Emissions (million short tons)
1970
1975
1980
1985
1990
1995
Year
Fuel Combustion
Industrial Processing
On-road
Non-road
Miscellaneous

Summary

- Combustion dominates energy production world wide.
- Energy use and economies correlate strongly in developed countries.
- Combustion processes create environmental challenges, especially air quality. These include NO_x, SO_x, PM_{10}, $PM_{2.5}$, CO, O_3, CO_2, Hg, acid rain, but not NH_3 or lead.
- Improved combustion engineering has directly led to about a 25% decrease in criteria pollutant concentrations over the last 30 years even as GDP has increased 60% and population has increased 40%.
- Future challenges (global warming, toxic metals, and sustainable supplies) are more formidable than past issues.

Conclusion

- **Engineers well trained in combustion sciences are and continue to be in very high demand.**
- **Most formidable combustion challenges require technical solutions, the development of which are likely to come from engineering disciplines.**

Acknowledgements

- The data and many of the graphics used in this presentation originated from the US DOE, US EPA, US EIA, the International Energy Agency (IEA), and EPRI.