# Indoor Air Pollution due to Yak Dung Combustion in Nam Co, Tibet

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Paper currently in review

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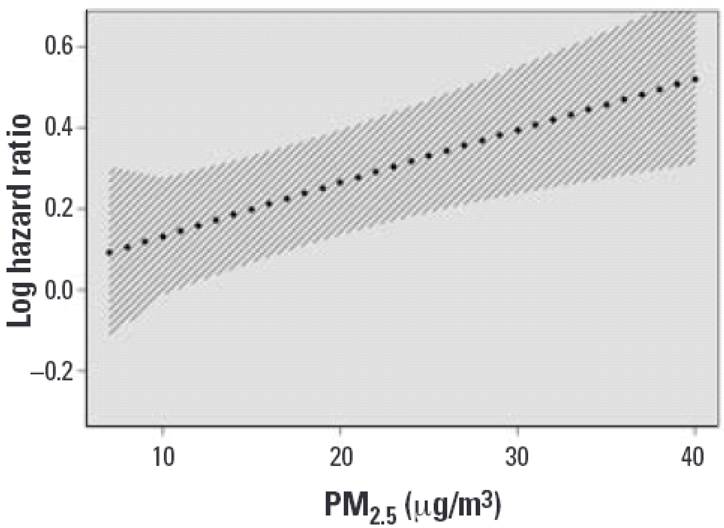
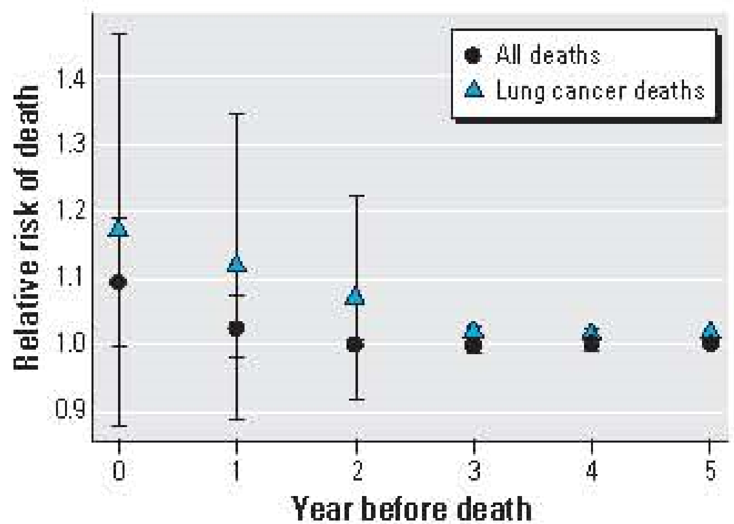
# Adverse Health Impacts of $PM_{2.5}$

- Association between $PM_{2.5}$ ambient concentrations and increased risk of adverse health impacts
  - Are linear
  - Have no threshold
- Mortality associated with 10 μg/m$^3$ increase in $PM_{2.5}$ occur within 2 years of exposure – reductions in air pollution can improve public health almost immediately




[Pope, 2002, Schwartz et al.,2008]

# Background

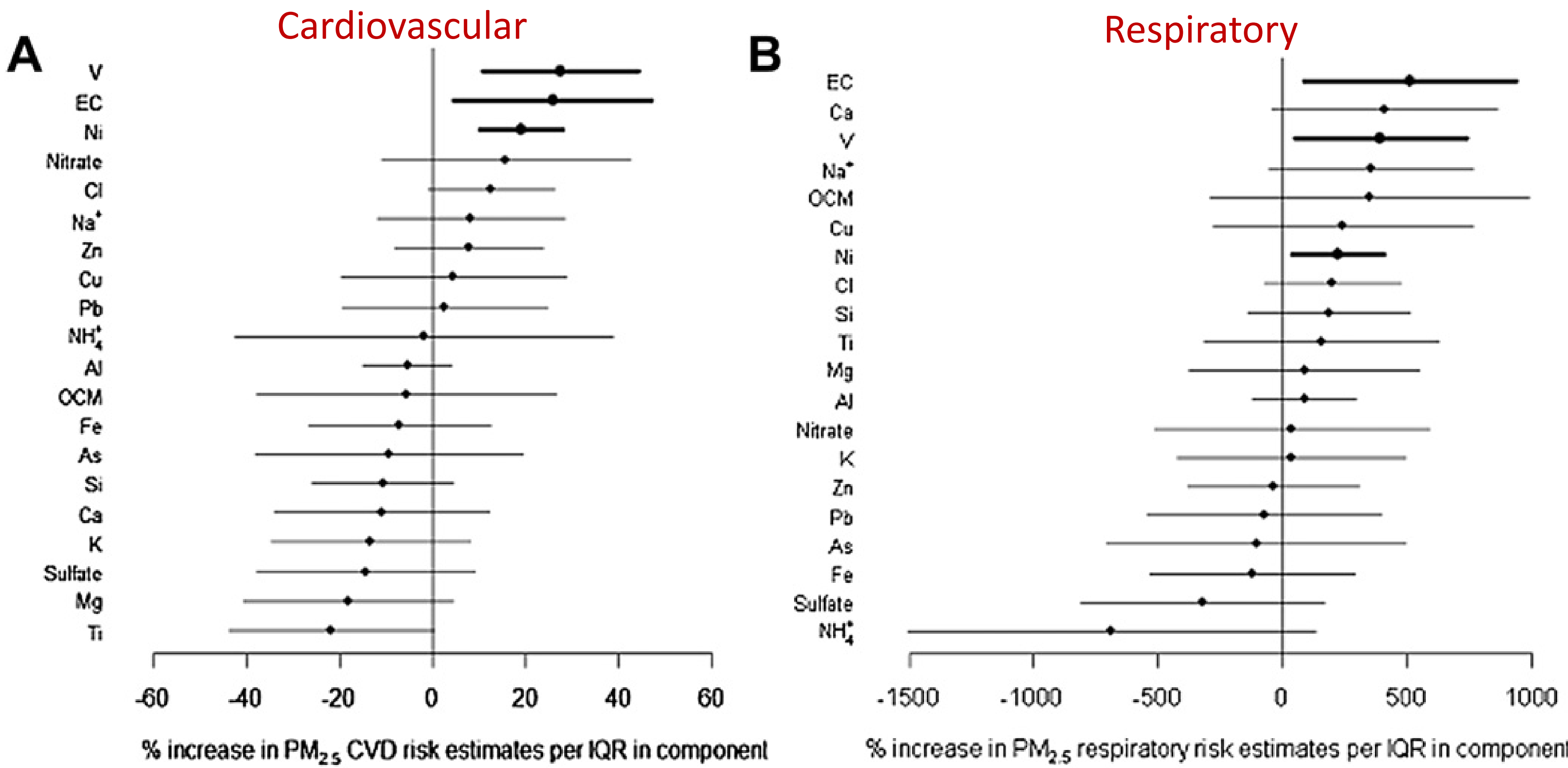
- Fine particulate matter $PM_{2.5}$ and $O_3$ have harmful effects on global air quality & human health
- $PM_{2.5}$ and $O_3$ affect radiative forcing on climate
- China is a major emitter of $PM_{2.5}$ and $O_3$ precursors

Beijing, China

The Denver Post, February 26, 2014

# Different Toxicity?

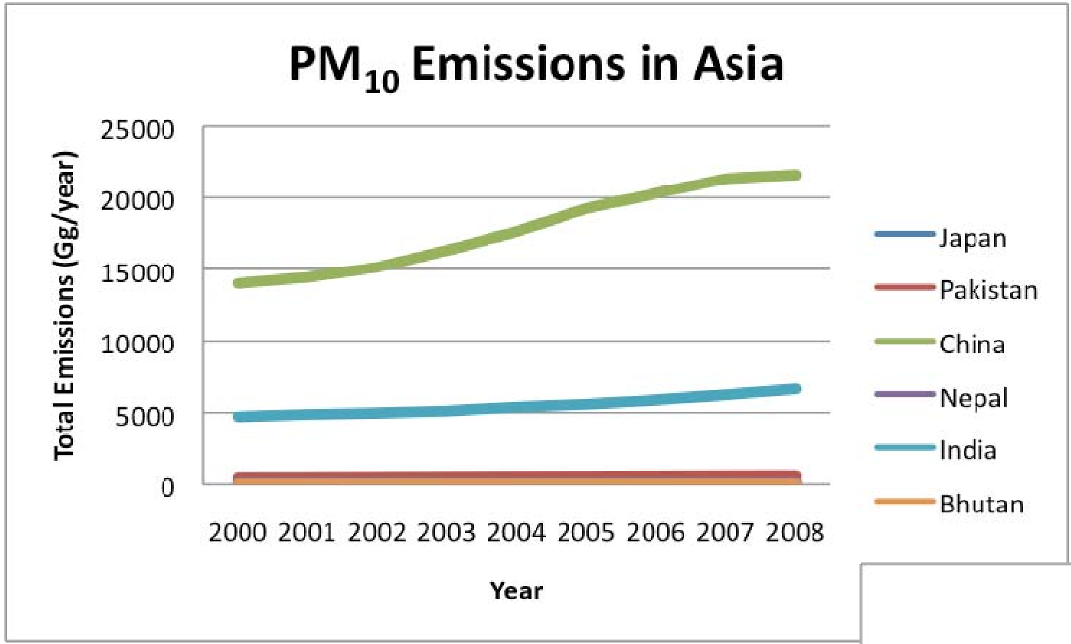
Is toxicity of PM related to composition or emission sources?

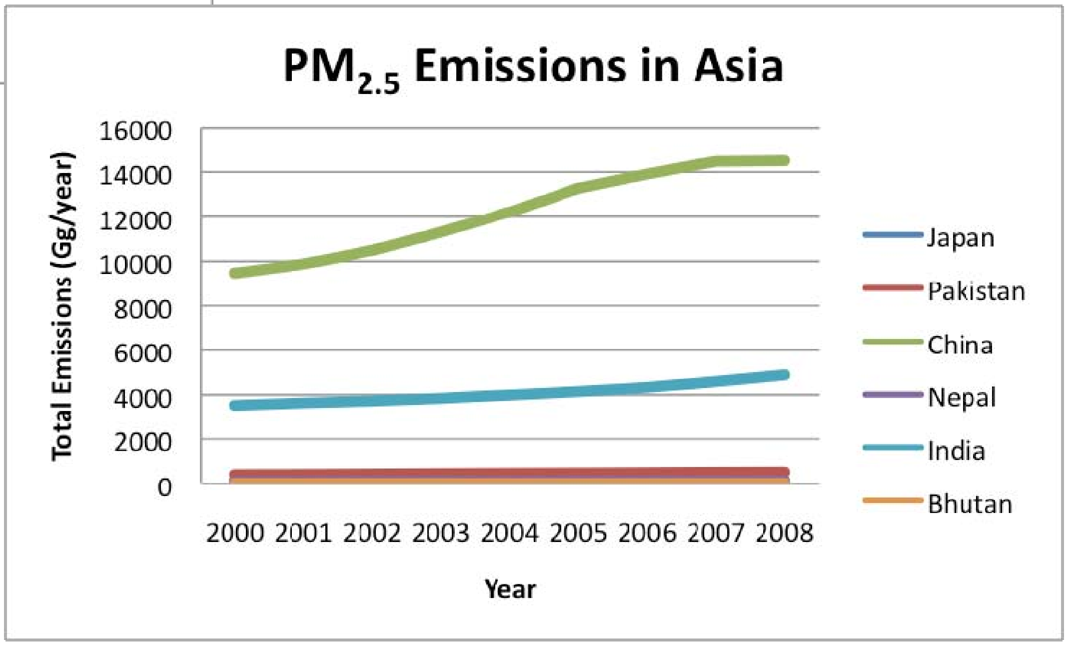



[Kelly and Fussell, 2012]

Hints that negative health outcomes more strongly associated with motor vehicle emissions, ultrafine particles and specific metals, but more work is needed.

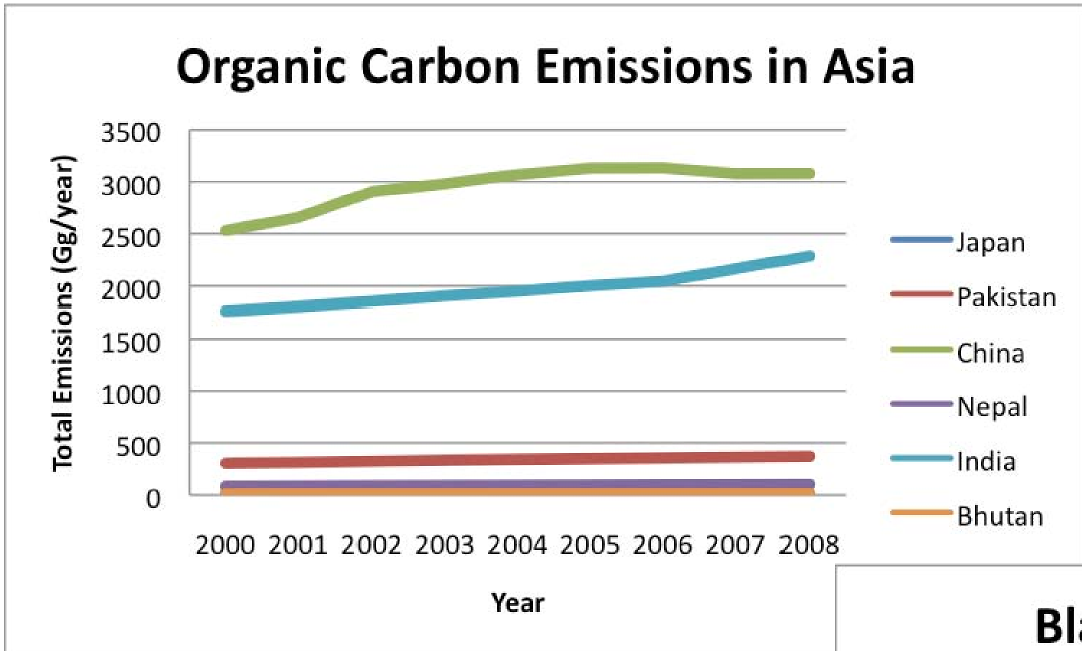
# PM increasing rapidly in Asia

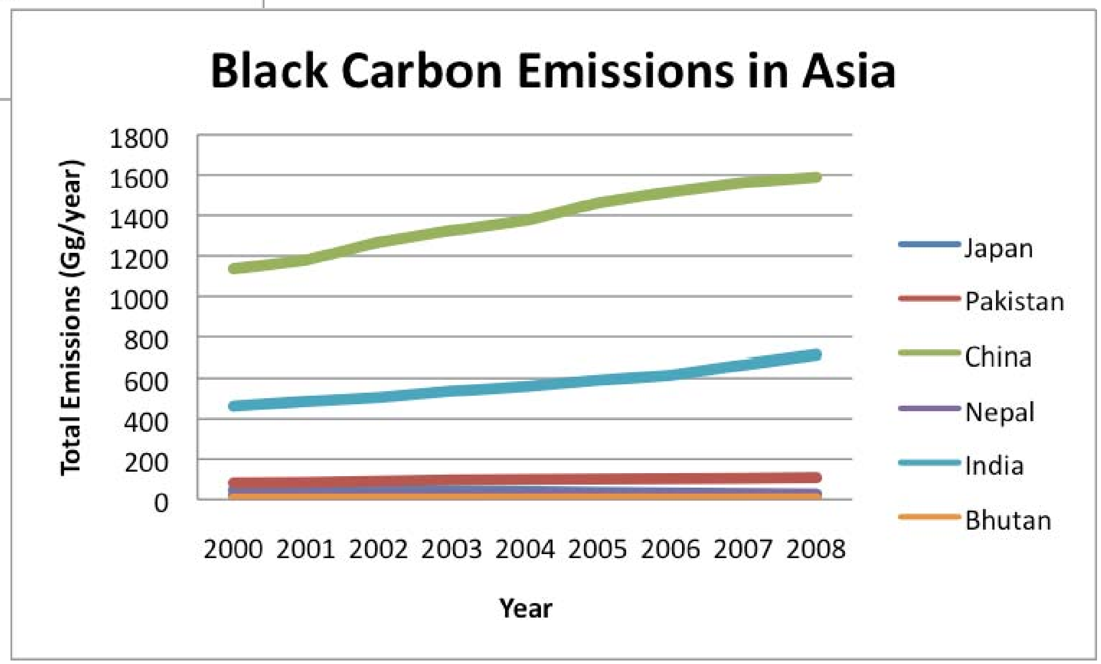



[Kurokawa et al., 2013]

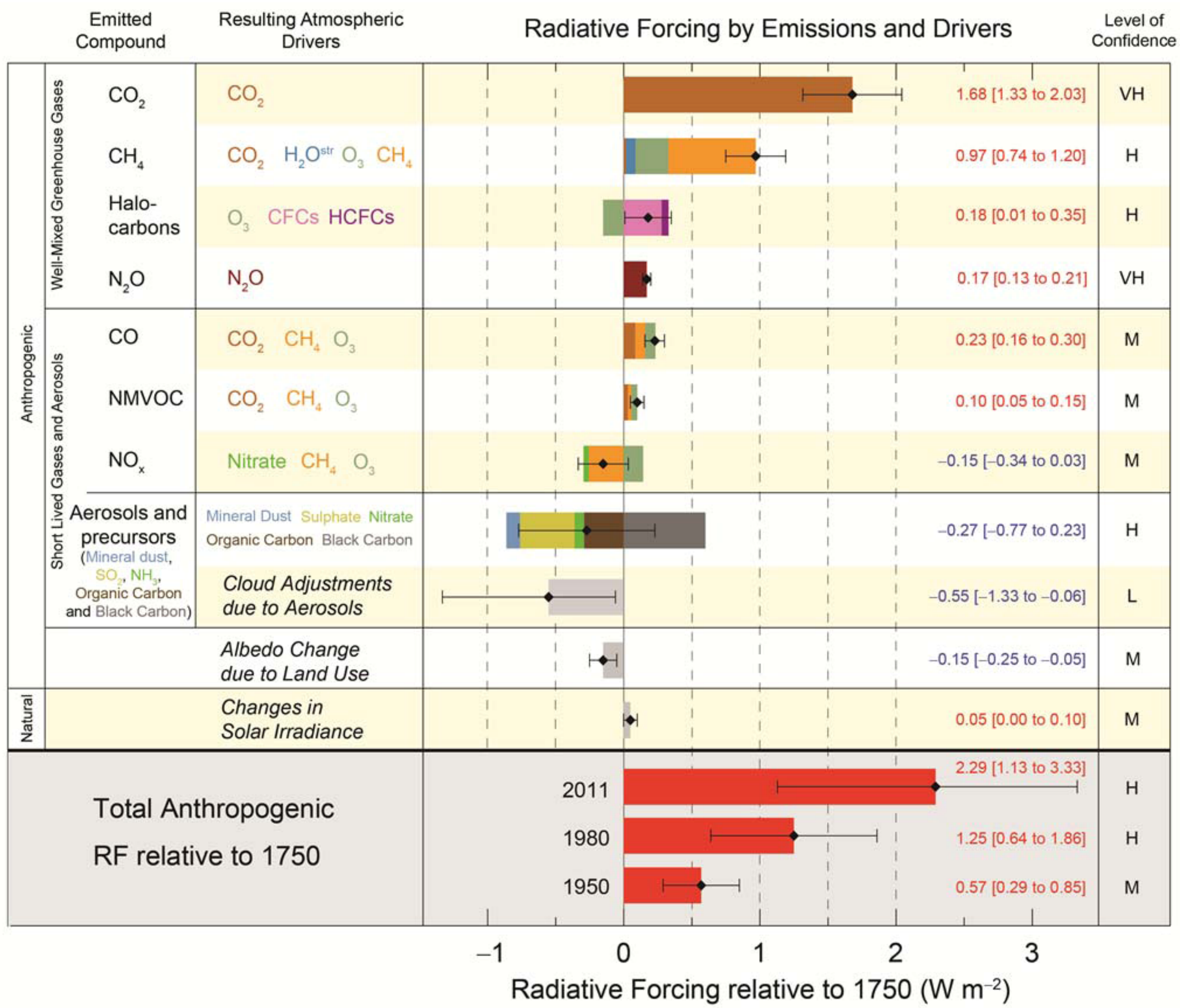
# So are OC and BC…




[Kurokawa et al., 2013]

# Global radiative forcings due to emissions of aerosols and precursor changes from 1750



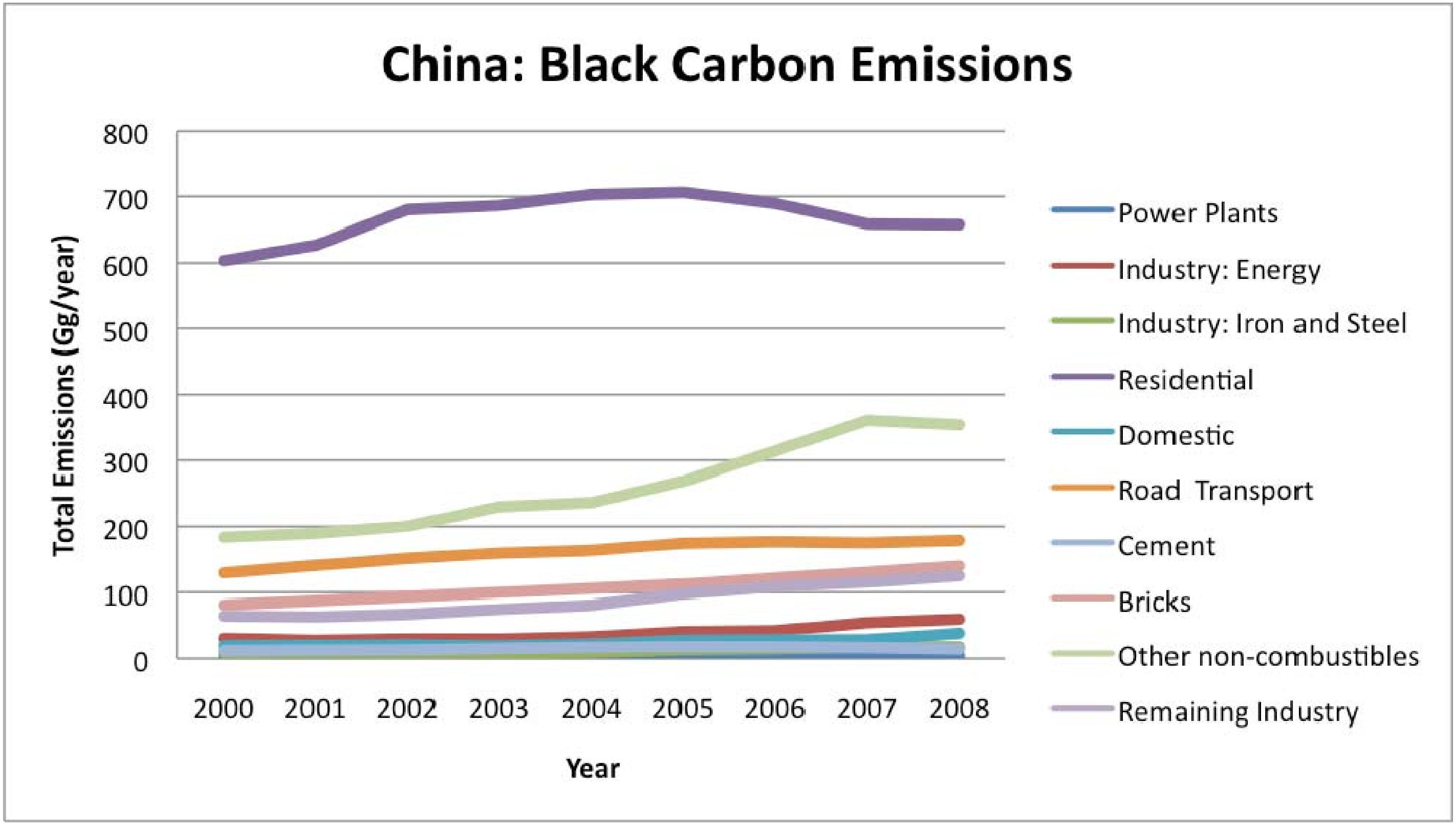

BC and $O_3$ have positive radiative forcing

Sulfate and organic carbon have negative radiative forcing

Indirect effects of aerosols are negative

[IPCC, *WG1 5th Assessment Report*, 2013]

# Key: Residential Sector




[Kurokawa et al., 2013]

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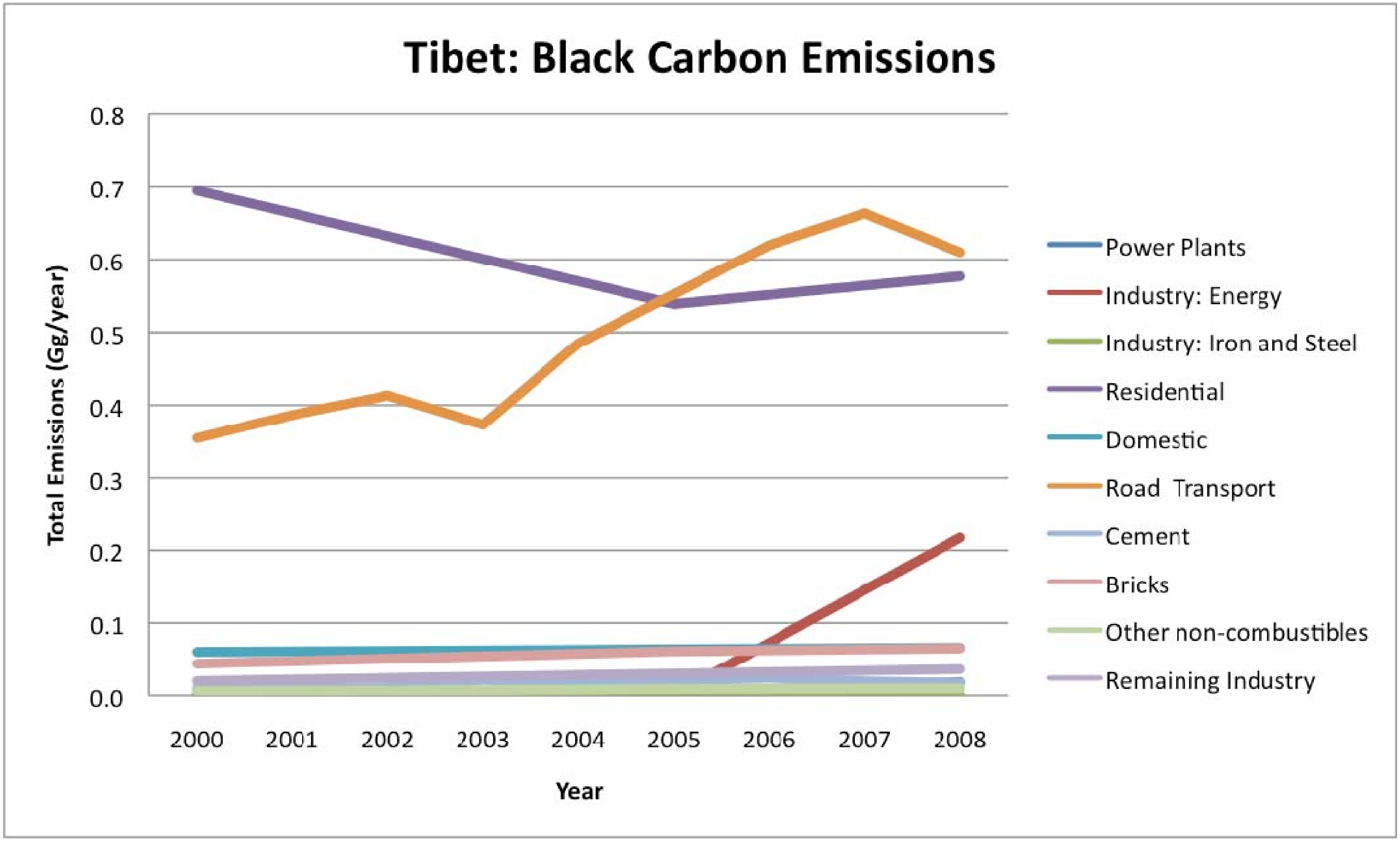
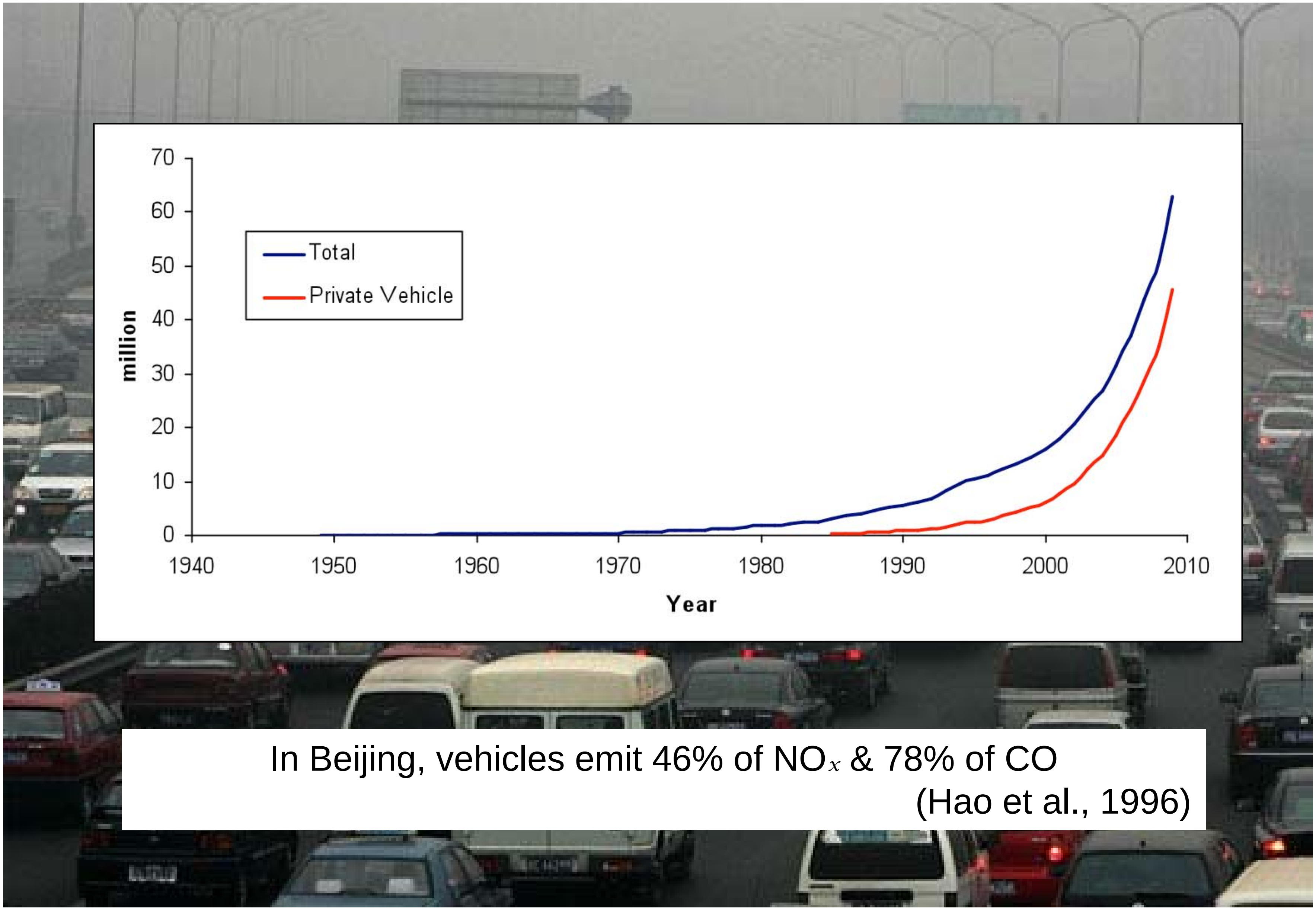



[Kurokawa et al., 2013]

# Vehicles are becoming a major source



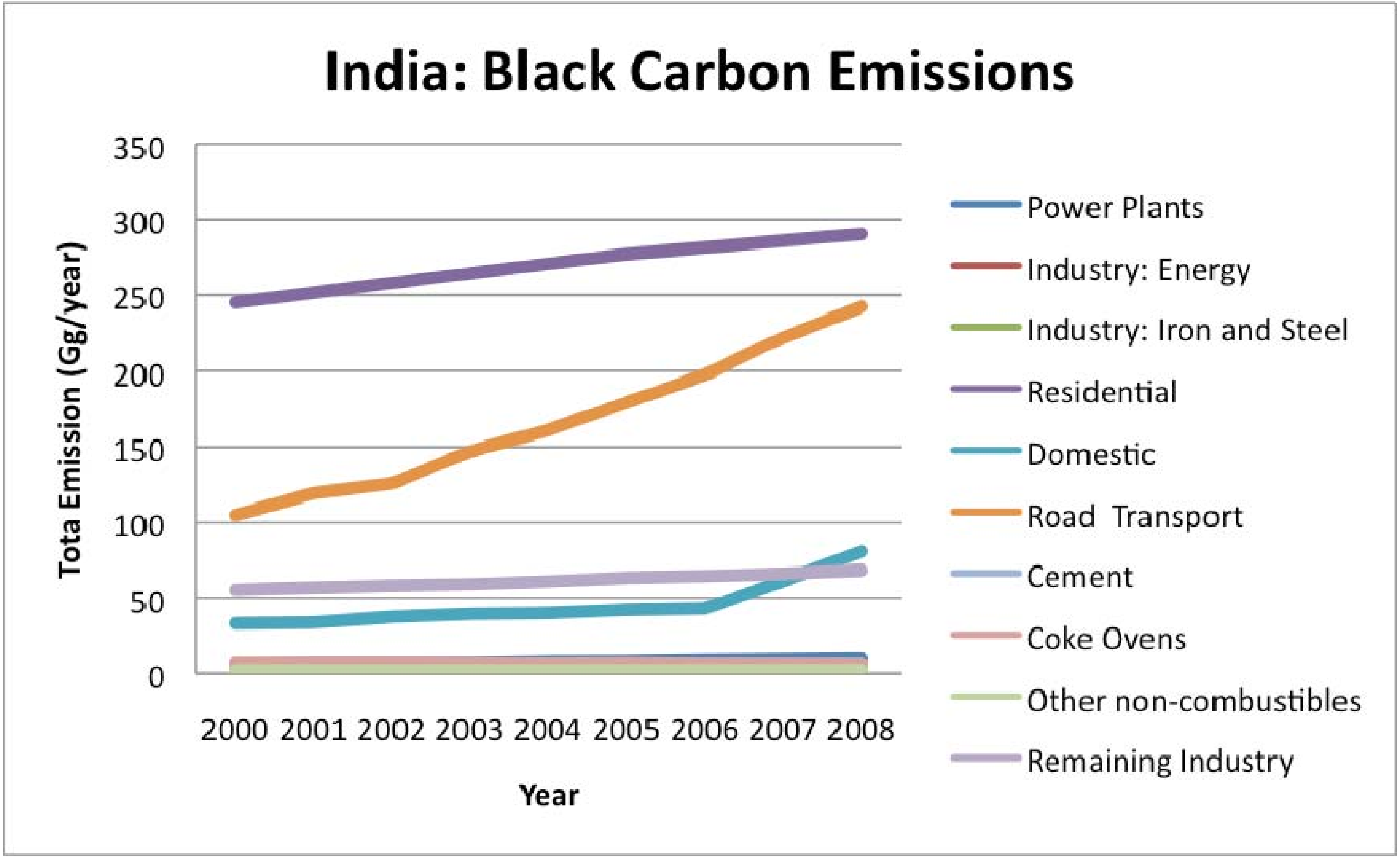

In Beijing, vehicles emit 46% of $NO_x$ & 78% of CO

(Hao et al., 1996)

# Cookstoves are important sources!

Courtesy: Qingyang Xiao

# Not only in China…




[Kurokawa et al., 2013]

# Objectives

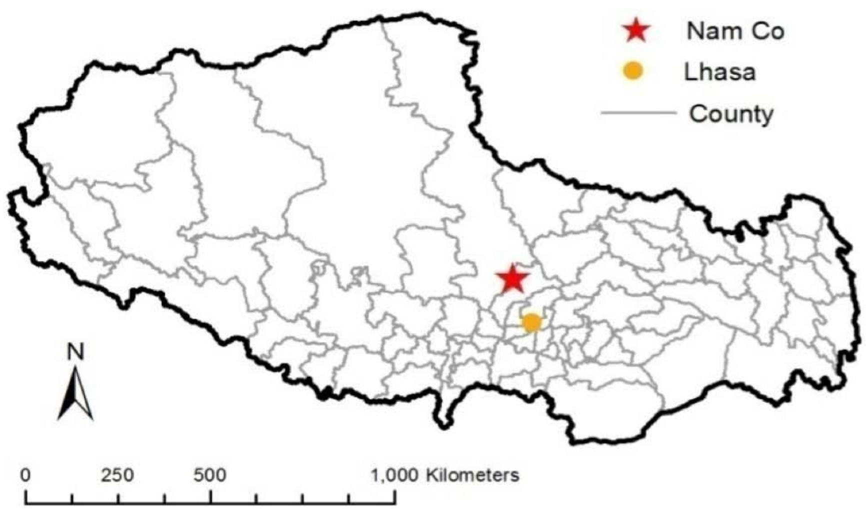
- Quantify indoor air pollution in Tibet
- Assess residents' awareness of air pollution and health problems
- Understand the impact of stove types and houses on indoor air pollution in Tibet
- Estimate emissions from yak dung burning in Tibet

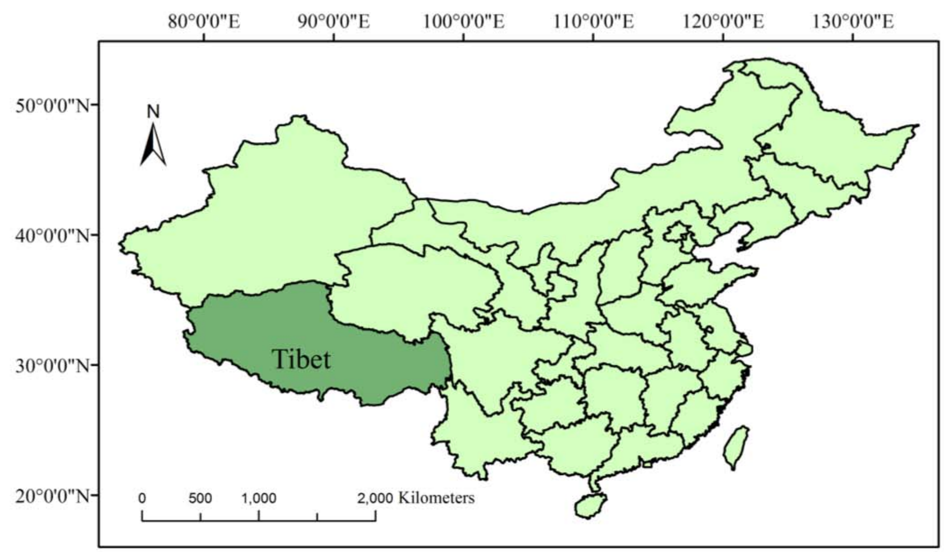
# Methodology

- Conduct a survey in Nam Co, Tibet, on their living conditions and their awareness on health impacts

- Measure $PM_{2.5}$ and BC concentrations in different households in Tibet in March
  - First non-summer measurements
  - First BC measurements

# Tibet


Nam Co
Lhasa
County
N
0
250
500
1,000 Kilometers


80°0'0"E
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100°0'0"E
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120°0'0"E
130°0'0"E
50°0'0"N
40°0'0"N
30°0'0"N
20°0'0"N
N
Tibet
0
500
1,000
2,000 Kilometers

Fabric

Stone and wood

Fabric

Profiled steel sheet

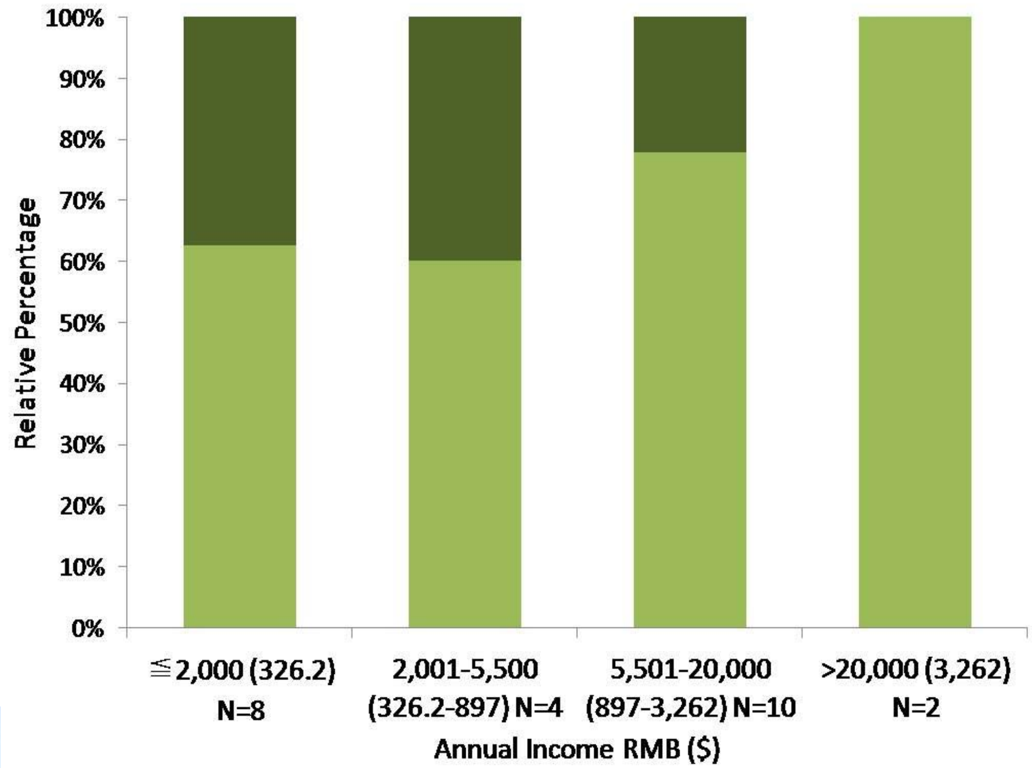
# Stove Types

Simple Stove

Chimney Stove

## Survey N = 23

| Variable | Number (%) |
|---|---|
| Live in a tent | 12 (52.2) |
| Have a simple stove without a chimney | 7 (30.4) |
| At least one smoker in the household | 15 (65.2) |
| Only use yak dung for cookstoves | 19 (82.6) |
| Use solar energy for electricity | 18 (78.3) |
| Annual median income | 5500 RMB (US$890) |
| Average hours stove is used per day | 16±1.3 |
| Average number of residents in a households | 6±1.7 |

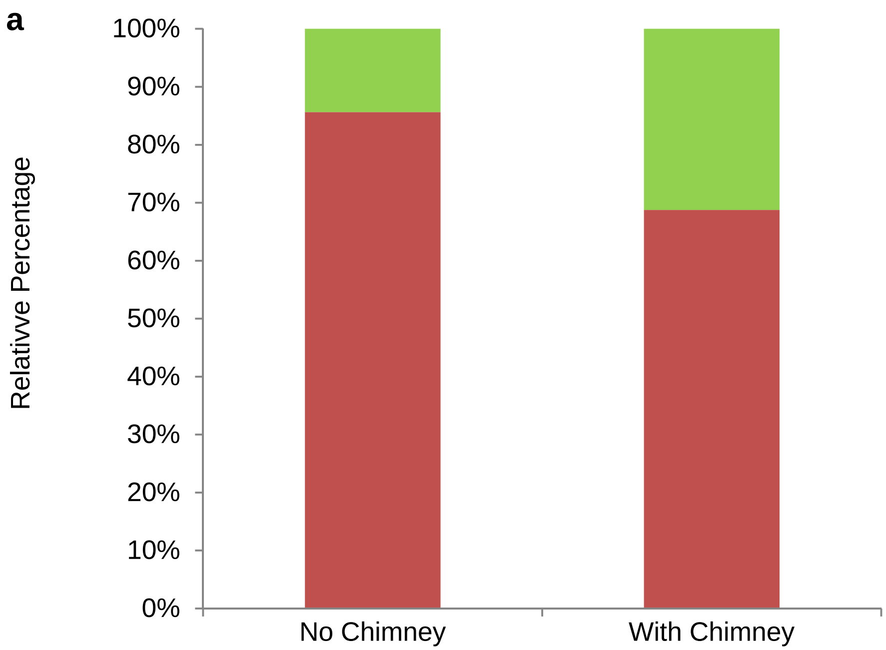



Dark green: simple stoves
Light green: chimney stoves

Xiao et al., in review

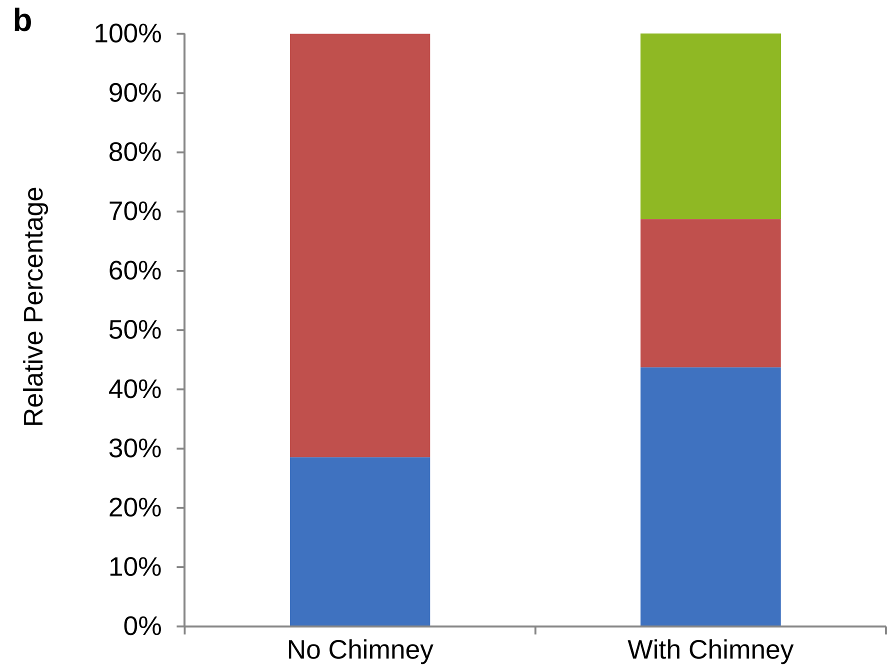
# Survey Results

Red: being aware of health problems
Green: being unaware of health problems



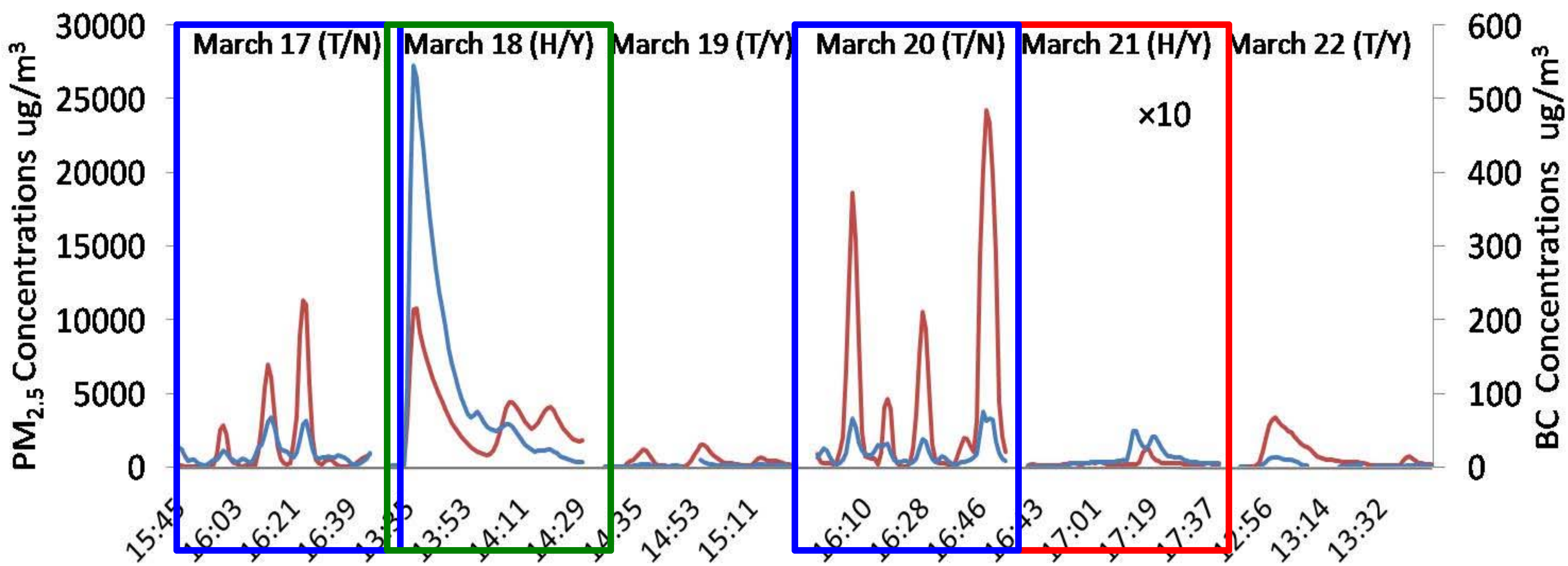

Awareness of adverse health impacts from burning fuel indoors relative to residents' stove type.

Blue: not-worried; Red: worried
Green: worried until the installation of a chimney




Percentage of local residents being worried about their health consequences due to indoor stove usage relative to the total number of households using simple/chimney stove.

| ID | Measured Date | Household | Chimney | Using gas for cooking (Yes/No) | Average $PM_{2.5}$ concentration $\mu g/m^3$ | Average BC concentration $\mu g/m^3$ | Average $BC/PM_{2.5}$ Ratio | Correlation coefficient of BC and $PM_{2.5}$ concentration |
|---|---|---|---|---|---|---|---|---|
| 1 | March 17th | Traditional Tent | No | No | 956.02 | 17.82 | 0.069 | 0.47 |
| 2 | March 20th | Traditional Tent | No | No | 1531.97 | 8.7 | 0.024 | 0.87 |
| 3 | March 22th | Traditional Tent | Yes | No | 179.00 | 1.12 | 0.023 | 0.91 |
| 4 | March 19th | Advanced Tent | Yes | No | 203.97 | 1.42 | 0.017 | 0.84 |
| 5 | March 18th | Stone House | Yes | No | 693.46 | 19.60 | 0.047 | 0.82 |
| 6 | March 21st | Simple House | Yes | Yes | 42.90 | 0.46 | 0.017 | 0.67 |



# BC emission factor

- Our total $BC/PM_{2.5}$: 0.006 – 0.028 (0.013)
  - Lower than Bond et al., 2004, but similar to Venkataraman et al., 2005, Reddy et al., 2002, and Liousse et al., 1996
- Estimated emission factor for dung for BC: ~0.3g/kg, using 22.9g total carbon (TC)/kg of dung (Keene et al., 2006)

# Estimated BC emissions in Tibet

- Census data: 4,291 residents
- Estimated yak dung combustion per capita: 1,640kg/year
- Emission factor for total particulate carbon from dung combustion: 22.9gC/kg (Keene et al., 2006)
- Our estimate is 2.1t/year, with our mean $BC/PM_{2.5}$ ratio 0.013.

# What does this mean?

- Residential BC emissions in Tibet in REAS: 0.695Gg/year in 2000
  - Without emissions from yak dung burning
- Nam Co only holds 0.2% of the rural population
- It is possible 1.1Gg/year of additional BC may be missing.

# Summary

- Significant indoor air pollution in Tibet.
- Combustion efficiency plays a key role in BC & OC emissions.
- We may be missing 1.1 Gg/year BC emissions in current inventories.
- More measurements are necessary to understand indoor air quality problem in Tibet.
- Needs a better mitigation strategy to reduce both BC and OC.

# Acknowledgments

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  - University of Georgia
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