Atmospheric Emissions of Carbon Dioxide From Fossil Fuels

some thoughts on the magnitude and distribution of emissions and the uncertainty of emissions estimates

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Human Perturbation of the Global Carbon Budget

Global Carbon Project 2009; Le Quéré et al. 2009, Nature Geoscience
Fossil Fuel Emissions and Cement Production

[1 Pg = 1 Petagram = 1 Billion metric tonnes = 1 Gigatonne = 1x10^{15}g]

Growth rate: 3.4% per year

2008:
Emissions: 8.7 PgC
Growth rate: 2.0%
1990 levels: +41%

2000-2008
Growth rate: 3.4%

Le Quéré et al. 2009, Nature Geoscience; CDIAC 2009
Components of FF Emissions

Le Quéré et al. 2009, Nature Geoscience
Fossil Fuel Emissions: Top Emitters (>4% of Total)

China

USA

Russia

India

Japan

Global Carbon Project 2009; Data: Gregg Marland, CDIAC 2009
# Cumulative Fraction of Total FF Emissions 2008

<table>
<thead>
<tr>
<th>Number of Countries</th>
<th>Country</th>
<th>Cumulative Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>.232</td>
</tr>
<tr>
<td>2</td>
<td>USA</td>
<td>.419</td>
</tr>
<tr>
<td>3</td>
<td>India</td>
<td>.477</td>
</tr>
<tr>
<td>4</td>
<td>Russia</td>
<td>.530</td>
</tr>
<tr>
<td>5</td>
<td>Japan</td>
<td>.573</td>
</tr>
<tr>
<td>6</td>
<td>Germany</td>
<td>.599</td>
</tr>
<tr>
<td>7</td>
<td>Canada</td>
<td>.617</td>
</tr>
<tr>
<td>8</td>
<td>UK</td>
<td>.633</td>
</tr>
<tr>
<td>9</td>
<td>South Korea</td>
<td>.652</td>
</tr>
<tr>
<td>10</td>
<td>Iran</td>
<td>.668</td>
</tr>
<tr>
<td>20</td>
<td>Poland</td>
<td>.800</td>
</tr>
<tr>
<td>50 (2005)</td>
<td>Belarus</td>
<td>.941</td>
</tr>
<tr>
<td>100 (2005)</td>
<td>Moldova</td>
<td>.992</td>
</tr>
<tr>
<td>210</td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

- 3 countries (50% Global Emissions)
- 10 countries (2/3 Global Emissions)
- Top 5 + EU (80% Global Emissions)

Gregg Marland, CDIAC 2009
Regional Shift in Emissions Share

Regional Shift in Emissions Share

Regional Shift in Emissions Share

Regional Shift in Emissions Share
Per Capita CO₂ Emissions

Developed countries continue to lead with the highest emission per capita

Le Quéré et al. 2009, Nature Geoscience; CDIAC 2009
### Sources of CO$_2$ from FF by sector - 2006

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>China</th>
<th>Germany</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (Mt C)</td>
<td>1552</td>
<td>1528</td>
<td>224</td>
<td>13</td>
</tr>
<tr>
<td>Utilities (%)</td>
<td>41</td>
<td>49</td>
<td>37</td>
<td>18</td>
</tr>
<tr>
<td>Other energy (%)</td>
<td>6</td>
<td>5</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Transport (%)</td>
<td>32</td>
<td>7</td>
<td>19</td>
<td>46</td>
</tr>
<tr>
<td>Industry and construction (%)</td>
<td>11</td>
<td>31</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Other (%)</td>
<td>10</td>
<td>8</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>(residential)</td>
<td>(5)</td>
<td>(4)</td>
<td>(15)</td>
<td>(2)</td>
</tr>
<tr>
<td>CO$_2$/cap (t C/cap)</td>
<td>5.2</td>
<td>1.2</td>
<td>2.7</td>
<td>1.4</td>
</tr>
<tr>
<td>CO$_2$/GDP (t C/$ PPP)</td>
<td>0.14</td>
<td>0.18</td>
<td>0.10</td>
<td>0.05</td>
</tr>
</tbody>
</table>

(from IEA, 2008)
Sources of US anthropogenic CO$_2$ emissions - 2006

- Fossil fuel combustion 1537.5 Tg C
- Non-energy use of fossil fuels 37.6
- Iron and steel manufacture 13.4
- Cement production 12.5
- Gas flaring/venting/leakage 7.8
- Other industrial processes 22.9

- Total 1631.7

From US EPA, 2008
COUNTRY TOTALS OF CO₂ EMISSIONS FROM FOSSIL FUELS

\[ CO₂ = (\text{Fuel Consumed}) (\text{FO}) (C) \]

**Fuel Consumed** = Primary Production
- Imports (Primary Fuel and Secondary Products)
- Exports (Primary Fuel and Secondary Products)
- Net Change in Storage (Primary Fuel and Secondary Products)
- Secondary Products that will not be oxidized
- Fuel Loadings for International Transport
Carbon Content versus Heating Value

1063 Samples from the Penn State Coal Database

Lignite C Content (dry, %)

125 lignites

Net Heating Value (dry, BTU/lb)

938 coals
Fraction of fossil fuel use - 2000

• Non-fuel uses = 5.8%
• Bunker fuels = 3.2%
China

Russian Federation

EU27 (ex. Malta)

Japan

USA

CO₂ per year (billion tons)

0

1

2

3

4

5

6

7

-1

-2
Figure 1: Domestic fossil and cement emissions averaged 2003-2005, tree vegetation sink, domestic fossil and process emissions, net CO2 responsibility.
Per Capita Emissions

- Winter Gas:
  - 2 - 4
  - 4 - 6
  - 6 - 8
  - 8 - 10
  - 20 - 35

- Winter Petrol:
  - 10 - 20

- Winter Coal:
  - 5 - 10
  - 10 - 20

- Summer Gas:
  - 2 - 4
  - 4 - 6
  - 6 - 8
  - 8 - 10

- Summer Petrol:
  - 5 - 10
  - 10 - 20

- Summer Coal:
  - 5 - 10
  - 10 - 20
Per Capita Emissions (Tonne C/person/yr)

- Petrolium
- Carcoal
- Eter Gas
- Petrolium

2.25 Tg C/mo

Emissions

Per Capita Emissions

2 - 4
6 - 10
4 - 6
10 - 16
Seasonal Cycle of North America C Emissions from Natural Gas, by Latitude
Monthly distribution follows number of days per month:

North America Emissions from Petroleum
Seasonal Cycle of North America C Emissions from Petroleum, by Longitude

Difference in Estimated C Emissions vs. Flat Distribution (%)

West  East
Sample Results

Max Difference in Mean Total Monthly Emissions (t C/km²)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2.5
- 2.5 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 100

North America Map with color gradient representing emissions levels.
Insight into uncertainty of CO$_2$ emissions estimates

• 1 – compare estimates by independent methods
• 2 – compare estimates by different analysts
• 3 – compare estimates by the same analyst over time
Input Data: Emissions Inventories

US Emissions from Fossil Fuel (Gas, Petroleum, Coal) Consumption

- CDIAC
- BP
- EIA
- Blasing State by State
- Blasing US Monthly
Input Data: Emissions Inventories

Canada Annual Emissions from Coal

Coal C Emissions (kt C/year)

Years: 1975 to 2008

BP, StatCAN, CDIAC
## CO₂ emissions in millions of metric tons of carbon

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>1990</th>
<th>1998</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>CDIAC 1305</td>
<td>CDIAC 1501</td>
<td>CDIAC 1580</td>
</tr>
<tr>
<td></td>
<td>IEA 1320</td>
<td>IEA 1497</td>
<td>IEA 1545</td>
</tr>
<tr>
<td></td>
<td>USEPA 1316</td>
<td>USEPA 1478</td>
<td>USEPA 1534</td>
</tr>
<tr>
<td>CANADA</td>
<td>CDIAC 112</td>
<td>CDIAC 119</td>
<td>CDIAC 139</td>
</tr>
<tr>
<td></td>
<td>IEA 117</td>
<td>IEA 136</td>
<td>IEA 145</td>
</tr>
<tr>
<td></td>
<td>Canada 117</td>
<td>Canada 133</td>
<td>Canada 144</td>
</tr>
<tr>
<td>MEXICO</td>
<td>CDIAC 99</td>
<td>CDIAC 96</td>
<td>CDIAC 100</td>
</tr>
<tr>
<td></td>
<td>IEA 80</td>
<td>IEA 96</td>
<td>IEA 100</td>
</tr>
<tr>
<td></td>
<td>Mexico 81</td>
<td>Mexico 96</td>
<td>Mexico NA</td>
</tr>
</tbody>
</table>

SOCCR Report, 2007
Correlation of Countries’ Total Emissions as calculated by EDGAR and ORNL

X and Y axes are in logscale in graph

Linear regression: \( \text{EDGAR}(y) = 316 + 0.97 \times \text{ORNL}(x) \)

\( R^2 = 0.99 \)
Figure 2. Country Total Emissions.
<table>
<thead>
<tr>
<th>Table 1. The Average Signed and Average Absolute Differences Relative to the Mean for the Subsets of Individual Power Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>average signed difference, relative to mean (%)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Whole data set</td>
</tr>
<tr>
<td>Nonconventional fuel plants</td>
</tr>
<tr>
<td>Coal-, oil- and gas-fired plants</td>
</tr>
<tr>
<td>Monitoring method (conventional-fuel data set)</td>
</tr>
<tr>
<td>Stack measurements</td>
</tr>
<tr>
<td>Stack or fuel calc (combo)</td>
</tr>
<tr>
<td>Fuel calculations</td>
</tr>
<tr>
<td>CHP plants (conventional-fuel data set)</td>
</tr>
<tr>
<td>CHP plants</td>
</tr>
<tr>
<td>Non-CHP plants</td>
</tr>
<tr>
<td>Fuel calculation subset (conventional-fuel data set)</td>
</tr>
<tr>
<td>All plants in this subset</td>
</tr>
<tr>
<td>CHP plants</td>
</tr>
<tr>
<td>Non-CHP plants</td>
</tr>
</tbody>
</table>

* All values shown are for 2004. o Positive average signed differences indicate that, on average, the eGRID values are larger than the EIA values, and vice versa for negative average signed differences.

Ackerman and Sundquist, 2008
CO$_2$ emissions without LULUCF estimates.
Data from: European Community National Inventory Reports.
EU-15: 1990 emissions estimates relatively to 2004 (in absolute terms)
Revisions of Global Total Emissions

- 1985
- 1990
- 1995
- 2000
- 2005
CO2 from China, revisions

fractional change from initial estimate

- 1986: 1.05
- 1987: 1.1
- 1988: 1.15
- 1989: 1.2
- 1990: 0.95
- 1991: 1
- 1992: 1.05
- 1993: 0.95
- 1994: 1
- 1995: 1.1
- 1996: 1.15
- 1997: 1.2
- 1998: 1.05
- 1999: 1
- 2000: 1.15
- 2001: 1.2
- 2002: 1.3
- 2003: 1.25
- 2004: 1.3
- 2005: 1.25
Revisions of Global Total without China