# $CO_2$ emissions – drivers across time and countries

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*Carbon dioxide ($CO_2$) emissions from fossil fuels are the most important cause of global warming. Here we analyse recent data published by the International Energy Agency. $CO_2$ emission drivers like population, GDP, carbon intensity and energy efficiency are analysed for the time period from 1971 to 2015 for the whole world and five countries like USA, Japan, Germany, China and India. Carbon intensity of primary energy supply has not changed much, but population and GDP have increased sharply. Energy efficiency, including structural changes in economy have restricted $CO_2$ emissions to some extent, but continuous increase of GDP by developed countries will not leave much space for growth of developing countries. Emissions from road transport and residential sectors deserve special attention.*

Recently, the International Energy Agency (IEA) has published data on carbon dioxide ($CO_2$) emissions from fuel combustion[1]. Extensive data about $CO_2$ emissions for the time period from 1971 to 2015 are available for all countries. Information about the main drivers of $CO_2$ emissions is also provided. The main drivers are population, gross domestic product (GDP) – defined by GDP/capita, carbon intensity of primary energy supply given by $CO_2$/TPES (total primary energy supply) and energy efficiency defined by $CO_2$/GDP (carbon dioxide emissions per unit of gross domestic product).

In this publication, GDP is described in terms of US dollars (converted to 2010 by taking inflation into account). Population is taken at actual numbers. GDP comprises manufacturing industries, transport, agriculture and services, including residential consumption. GDP/capita is gross domestic product divided by population. Carbon intensity of energy supply is expressed in tonnes of $CO_2$/TPES, tonnes $CO_2$/terajoules ($10^{12}$ Joules). Since other publications of IEA[2] use $CO_2$/TPES in tonnes, $CO_2$/TOE tonnes of oil equivalents, $CO_2$/TJ is converted to $CO_2$/TOE by dividing $CO_2$/TJ by 23.88.

Countries with high coal use like China, India and Poland have high carbon intensity of energy supply ($CO_2$/TPES 2.5–3.0). Countries like Brazil (1.51), Norway (1.24) and Nepal (0.48) with large hydroelectricity in their primary energy supply have significantly lower carbon intensity of energy supply compared to the world average (2.3). TPES/GDP not only defines energy intensity of GDP, but also includes structural changes. As a country moves from manufacturing to services, its TPES/GDP decreases sharply (Supplementary Material).

Table 1 provides data for the world and five countries, viz. USA, Japan, Germany, China and India, regarding all important factors. All data are from IEA publications, except for GDP and population data for 1971 which are from the World Bank. All GDP data are in 2010 US dollars. $CO_2$/TPES is in tonnes of $CO_2$/tonnes of oil equivalent. $CO_2$/GDP is in kg $CO_2$/US dollars (2010). $CO_2$/capita is in tonne of $CO_2$/per capita. All GDP data are used with exchange rate conversion. GDP data are also expressed in terms of purchasing power parity. This is a separate topic of discussion. Let us draw some broad inferences from Table 1.

For the world as a whole GDP/capita has nearly doubled from 1971 to 2015, showing growth across all countries. Carbon intensity of energy supply has not changed much, but declines marginally from 2.52 to 2.37. Fossil fuels, coal, oil and gas still supply 80% of primary energy, as was the case 45 years ago. Share of oil has decreased and share of natural gas has increased. Energy efficiency and structural changes in economy lead to a decrease in $CO_2$/GDP from 0.69 to 0.43, i.e. almost 40% reduction. Thus, doubling of GDP/capita with marginal decrease in carbon intensity and significant improvement in energy efficiency indicates that $CO_2$/capita increases only marginally from 3.71 to 4.4.

However, the world population has increased from 3762 million in 1971 to 7334 million in 2015. Total $CO_2$ emissions have risen from 13,942.2 to 32,294.2 million tonnes (Table 2). Population of India has more than doubled (2.31 times) from 1971 to 2015. The population of China has increased by 60% (1.6 times), while that of USA by 59% (1.54 times). The population of Japan has increased by 20% while that of Germany remained constant.

Doubling of population and of GDP/capita should have normally led to four times the emission. Energy efficiency has made significant changes, but still total emissions have increased by 231%. This also shows that not only population needs to be controlled, but GDP/capita cannot rise indefinitely. Countries with high GDP will have to control excessive consumption, allowing developing countries some room for achieving a reasonable standard of living.

Let us now analyse these trends for different countries.

For USA, GDP/capita more than doubles (240%), carbon intensity drops from 2.70 to 2.28, $CO_2$/GDP drops to nearly one-third. Thus $CO_2$/capita reduces marginally from 20.65 to 15.53. However, total $CO_2$ emissions rise from 4288 to nearly 5000 million tonnes. Energy efficiency and carbon intensity are now difficult to reduce significantly, so GDP/capita growth has to remain marginal for emission control.

For Japan, GDP/capita increases sharply (245%). Carbon intensity reduces marginally (nuclear reactors have stopped since the Fukushima accident). Energy efficiency, which was very high even in 1971, has nearly doubled. Japan remains the most energy efficient economy among major countries. $CO_2$/capita increases somewhat due to GDP increases. Total emissions rise by about 50% due to GDP/capita increases. Population in Japan has increased from 105 million in 1971 to 127 million in 2015.

For Germany, GDP/capita has increased by 225% but carbon intensity has reduced from 3.20 to 2.71, showing

**Table 1.** $CO_2$ emission drivers

| | GDP/capita (US$; 2010) | | | $CO_2$/TPES (tonnes $CO_2$/TOE) | | | $CO_2$/GDP (kg $CO_2$/US$) | | | $CO_2$/capita (tonnes/person) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | 1971 | 1990 | 2015 | 1971 | 1990 | 2015 | 1971 | 1990 | 2015 | 1971 | 1990 | 2015 |
| World | 5,272.46 | 7,181 | 10,290 | 2.52 | 2.34 | 2.37 | 0.69 | 0.54 | 0.43 | 3.71 | 3.88 | 4.4 |
| USA | 23,851.2 | 36,321 | 57,500 | 2.70 | 2.51 | 2.28 | 0.87 | 0.53 | 0.30 | 20.65 | 19.20 | 15.53 |
| Japan | 19,180.95 | 37,880 | 47,130 | 2.80 | 2.38 | 2.66 | 0.37 | 0.22 | 0.19 | 7.15 | 8.43 | 8.91 |
| Germany | 20,205.74 | 32,360 | 45,820 | 3.20 | 2.68 | 2.37 | 0.62 | 0.37 | 0.20 | 12.49 | 11.85 | 8.93 |
| China | 237.84 | 730 | 6,650 | 1.99 | 2.38 | 3.04 | 3.90* | 2.50 | 1.01 | 0.93 | 1.83 | 6.59 |
| India | 362.77 | 540 | 1,750 | 1.19 | 1.74 | 2.43 | 0.87 | 1.12 | 0.90 | 0.32 | 0.61 | 1.58 |

*Seems to be incorrect.

**Table 2.** $CO_2$ emissions and population

| | 1971 | | 1990 | | 2015 | |
|---|---|---|---|---|---|---|
| Country | $CO_2$ emissions (million tonnes) | Population (million) | $CO_2$ emissions (million tonnes) | Population (million) | $CO_2$ emissions (million tonnes) | Population (million) |
| World | 13,942.2 | 3,762.19 | 20,509.0 | 5278.4 | 32,294.2 | 7,334 |
| USA | 4,288.1 | 207.66 | 4,802.5 | 250.8 | 4,997.5 | 321.7 |
| Japan | 750.7 | 105.69 | 1,042.0 | 123.61 | 1,141.6 | 127 |
| Germany | 978.2 | 78.31 | 940.3 | 79.36 | 729.8 | 81.7 |
| China | 780.2 | 841.1 | 2,075.9 | 1135.19 | 9,040.7 | 1,379 |
| India | 181.0 | 566.22 | 530.4 | 870.6 | 2,066.0 | 1,311 |

significant reduction in coal use and increase in share of renewables. Energy efficiency also increases three times leading to a drop in $CO_2$/capita by 33%.

China shows a massive rise in GDP/capita, 28 times GDP/capita in 2015 compared to same in 1971. Carbon intensity also increases by 50%. Energy efficiency improves by nearly four times, leading to $CO_2$/capita rising seven times. Total emission changes from 780.2 to 9040 million tonnes, increasing 11 times. Data for 1971 seem to be doubtful. $CO_2$/GDP of 3.90 is also unusual.

For India, GDP/capita increases by five times; carbon intensity doubles due to increase in coal use. In 1971, hydroelectricity was a major energy source. Energy efficiency shows a surprisingly constant value. This may due to the rupee being quite a strong currency in 1971 (1 US$ = Rs 7 in 1971, compared to 1 US$ = Rs 64 in 2015). Total emissions rise from 181 to 2066 million tonnes..

$CO_2$ emission for fossil fuels remains a major cause for global warming. This note shows that energy efficiency and structural changes in economy have reduced emission significantly. Carbon intensity of world energy supply has not changed much. For India and China, it has increased significantly due to large coal use. Developed countries have to reduce or at least maintain consumption at reasonable levels to reduce $CO_2$ emission. Use of renewable energy sources must drive down carbon intensity of energy supply significantly. Solar and wind hydroelectricity also deserve high priority. In 2015, solar, wind and biomass waste contributed only 7% of total electricity. Hydroelectricity contributed 16%.

1. $CO_2$ emissions from fuel combustion. 2017; www.iea.org
2. Key world energy statistics, 2017; www.iea.org

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