**Energy use and economic growth**

The Kaya identity expresses a general truth about the relationship between socio-economics and environmental pollution that is useful when thinking about different future scenarios for the global economy, energy system, and environment. It states:

C = P \* (G/P) \* (E/G) \* (C/E)

Where C is carbon emissions resulting from energy use, P is population, (G/P) is GDP per capita, (E/G) is the energy intensity of GDP (e.g., the number of kilowatt-hours of energy it takes on average to increase GDP by one dollar), and (C/E) is the carbon intensity of emissions (e.g., the kilograms of CO2 emitted per kWh of energy.) Notice that it is an identity – if you multiply through all the terms on the right, you necessarily get C – so it is just a mathematical truth. But we can look at past trends and project future possibility for each of the four terms of the right in a way that is more grounded to reality than simply trying to project C based only on past levels of C.

In 2010, global population P was about 6.9 billion, energy-related carbon emissions C were about 34 Gt CO2 (or, equivalently, 34 \* 12/4 = 9 Gt C), global gross domestic product G was about $89 trillion (at purchasing-price parity), and global primary energy use was about 146,000 TWh.

1. Compute G/P, E/G and C/E for the world in 2012. Record in the first row of Table 1.
2. The carbon intensity of primary energy from natural gas and oil is about 0.2 kg CO2/kWh, and that of coal is about 0.3 kg CO2/kWh. How do you explain your global estimated C/E ratio based on your answer to the above?
3. Table 1, which draws upon World Bank data, shows population, carbon emissions, GDP, and primary energy use for the U.S. and several other regions in 2010. Compute GDP/capita (G/P), energy intensity of GDP (E/G), and carbon intensity of energy (C/E) for the US and record in the appropriate row.
4. How do you explain the differences in these parameters between the U.S. and the world at large?
5. Compute the same calculations for the other regions. What patterns do you see? How do you explain these patterns?
6. Appended to this exercise are charts showing P, G/P, E/G and C/E for the United States and the world from 1800 to 2010. Data are from Delong (1998), IEA, EIA, CDIAC, and the Measuring Worth website. What is the dominant pattern in each plot?
7. In the rightmost column of table 1, indicate the year in which the U.S.’s GDP/capita was comparable to each region’s current GDP/capita.
8. Suppose the entire world were as wealthy as the United States today and had a similarly structured economy and energy system. By how much would world carbon emissions go up?
9. Suppose you had a world in which average income was comparable to that of the United States. Quantitatively describe four strategies for limiting carbon emissions in such a world to their present level.

1. Assume population stabilizes at 10 billion. How does this affect your answer to the last question?

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|  | **P (million)** | **G (bilion $, PPP)** | **E (TWh)** | **C (Mt CO2)** | **G/P ($/cap)** | **E/G (kWh/$)** | **C/E (kg CO2/kWh)** | **US-equiv G/P year** |
| World | **6,884** | **89,193** | **145,558** | **33,615** |  |  |  |  |
| United States | **309** | **15,252** | **25,766** | **5,433** |  |  |  |  |
| European Union | **505** | **16,620** | **20,053** | **3,710** |  |  |  |  |
| China | **1,338** | **12,348** | **29,270** | **8,287** |  |  |  |  |
| India | **1,206** | **5,592** | **8,417** | **2,009** |  |  |  |  |
| Sub-Saharan Africa | **865** | **2,689** | **5,845** | **708** |  |  |  |  |

*Source: World Bank. Data for 2010.*