THE WORLD BANK

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A KNOWLEDGE NOTE SERIES FOR THE ENERGY PRACTICE

2014/5

85126

THE BOTTOM LINE

The energy sector contributes about 40 percent of global emissions of CO_2. Three-quarters of those emissions come from six major economies. Although coal-fired plants account for just 40 percent of world energy production, they were responsible for more than 70 percent of energy-sector emissions in 2010. Despite improvements in some countries, the global CO_2 emission factor for energy generation has hardly changed over the last 20 years.

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Understanding CO_2 Emissions from the Global Energy Sector

Why is this issue important?

Mitigating climate change requires knowledge of the sources of CO_2 emissions

Identifying opportunities to cut emissions of greenhouse gases requires a clear understanding of the main sources of those emissions. Carbon dioxide (CO_2) accounts for more than 80 percent of total greenhouse gas emissions globally,[1] primarily from the burning of fossil fuels (IFCC 2007). The energy sector—defined to include fuels consumed for electricity and heat generation—contributed 41 percent of global CO_2 emissions in 2010 (figure 1). Energy-related CO_2 emissions at the point of combustion make up the bulk of such emissions and are generated by the burning of fossil fuels, industrial waste, and nonrenewable municipal waste to generate electricity and heat. Black carbon and methane venting and leakage emissions are not included in the analysis presented in this note.

Where do emissions come from?

Emissions are concentrated in a handful of countries and come primarily from burning coal

The geographical pattern of energy-related CO_2 emissions closely mirrors the distribution of energy consumption (figure 2). In 2010, almost half of all such emissions were associated with the two largest global energy consumers, and more than three-quarters were associated with the top six emitting countries. Of the remaining energy-related CO_2 emissions, about 8 percent were contributed by other high-income countries, another 15 percent by other middle-income countries, and only 0.5 percent by all low-income countries put together.

Coal is, by far, the largest source of energy-related CO_2 emissions globally, accounting for more than 70 percent of the total (figure 3). This reflects both the widespread use of coal to generate electrical power, as well as the exceptionally high CO_2 intensity of coal-fired power (figure 4). Per unit of energy produced, coal emits significantly more CO_2 emissions than oil and more than twice as much as natural gas.

Figure 1. CO_2 emissions by sector

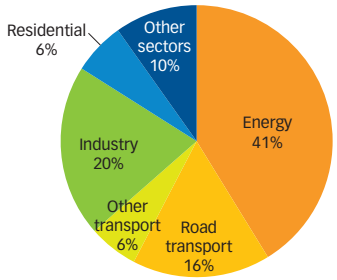
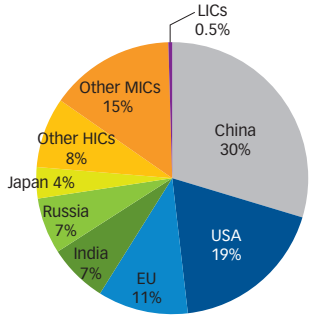


Figure 2. Energy-related CO_2 emissions by country



Notes: Energy-related CO2 emissions are CO2 emissions from the energy sector at the point of combustion. Other Transport includes international marine and aviation bunkers, domestic aviation and navigation, rail and pipeline transport; Other Sectors include commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere; Energy = fuels consumed for electricity and heat generation, as defined in the opening paragraph. HIC, MIC, and LIC refer to high-, middle-, and low-income countries.

Source: IEA 2012a.

[1] United Nations Framework Convention on Climate Change, Greenhouse Gas Inventory Data—Comparisons By Gas (database). http://unfccc.int/ghg_data/items/3800.php

"The geographical pattern of CO_2 emissions closely mirrors the distribution of energy consumption."

Figure 3. Energy-related CO_2 emissions by fuel

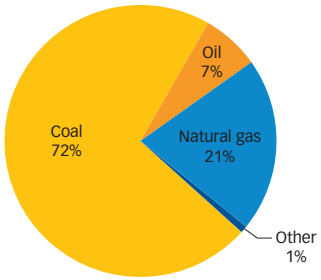
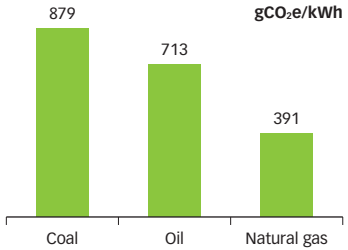


Figure 4. CO_2 intensity by fuel



Notes: Energy-related CO2 emissions refer to CO2 emissions from the energy sector at the point of combustion, as defined in the opening paragraph. Other includes emissions from industrial waste and nonrenewable municipal waste. CO_2 emissions from renewable energy are insignificant and not presented here.

Sources: IEA 2012a and 2012c.

What have been historical trends?

Despite improvements in some countries, the global emission factor has remained steady

Since 1990, energy demand has grown strongly, while the global emission factor for energy has remained relatively stable within the range of 460–500 grams of CO_2 per kilowatt-hour. The emission factor represents average CO_2 emissions per unit of energy produced and reflects a weighted average of the technologies being used.[2] The energy sectors in South Africa, India, Australia, and Indonesia are among the most CO_2-intensive worldwide, reflecting the fact that coal accounts for more than 40 percent of their energy

[2] For the purposes of this note, emission factors (CO_2 emissions per kWh) were calculated following the IEA methodology used prior to March 2013. In that methodology, the numerator includes CO_2 emissions from fossil fuels, industrial waste, and nonrenewable municipal waste consumed to generate electricity and heat. The denominator includes electricity and heat output from all sources. This factor should be interpreted with caution for countries with significant amount of heat output (especially colder countries with district heating) because heat generation is usually more efficient than electricity generation, thus lowering the emission factors for those countries. In an effort to solve the limitations of this indicator, the IEA developed a methodology for excluding the heat component from the calculation (it is especially hard to do for CHP plants). However, for the simplicity of calculation and unavailability of enough disaggregated data to perform such calculation for future projections, this paper applies the former method.

Figure 5. Evolution of the global emission factor

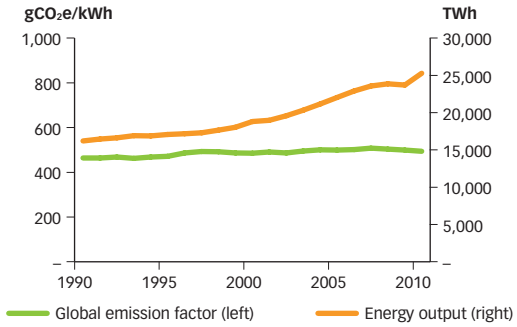
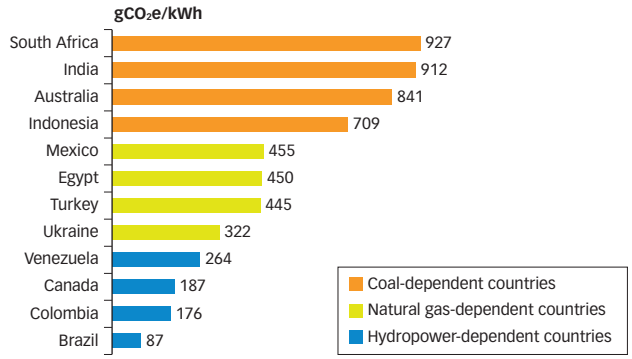


Figure 6. Emission factors for selected countries



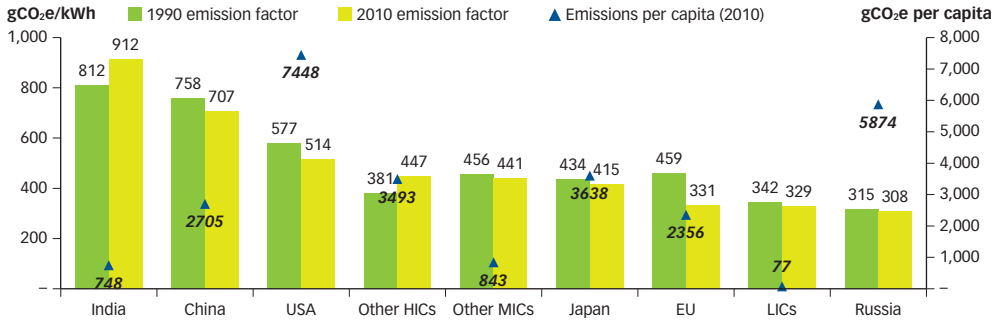
Sources: IEA 2012a and 2012c.

production, leading to emissions in excess of 900 grams of CO_2 per kilowatt-hour in the cases of South Africa and India. At the other end of the spectrum, countries such as Brazil, Colombia, Canada, and Venezuela—which obtain 60–80 percent of their energy from hydropower—achieve emissions of well below 300 grams of CO_2 per kilowatt-hour. Countries in which natural gas dominates the energy mix—such as Mexico, Egypt, Turkey, and Ukraine—have emission factors within the range of 300–500 grams of CO_2 per kilowatt-hour.

Five of the six top global emitters have slightly reduced their grid emission factor over the period 1990–2010, while India's has increased over the same period. During this time span, energy production in China and India increased at 9 percent and 6 percent per annum respectively, while Russia's production decreased 1.5 percent

"Five of the top six emitters have slightly reduced their grid emission factor over the period 1990–2010."

Figure 7. Changes in CO_2 footprint of energy generation



Note: Energy generation refers to electricity and heat generation, as defined in the opening paragraph.
Sources: IEA 2012a and 2012c.

per annum, and the rest of the top six emitters saw increases in the range of 1–3 percent annually. Despite growth in energy production in China, the United States, Japan and the European Union, emission factors in all of these areas have decreased, implying a relatively slower growth rate for energy-sector emissions relative to energy production. It is also important to note that emissions per capita for India, China, and the EU are significantly lower than for Russia and the United States.

The observed evolution of emission factors may be attributed to a variety of causes, among them improvements in the efficiency of combustion from existing energy sources as well as shifts in the energy portfolio toward sources with lower CO_2 emissions. Table 1 illustrates the extent to which shifts in the energy mix have contributed to changes in emission factors. For example, the increase in India's emission factor reflects increasing shares of fossil fuels and a declining share of renewable energy in the generation mix. Conversely, in the EU, the significant drop in the emission factor reflects lower shares of fossil fuels and a nearly two-fold increase in renewable energy in the generation mix.

Putting all of these factors together, the global CO_2 footprint of the energy sector in 2010 can be portrayed as in figure 8, where the height of the bars represents the grid emission factor (or CO_2 intensity) of energy generation and their width represents the volume of energy generated. The area of the chart thus represents the contribution of each country and fuel to the global CO_2 footprint of the energy sector.

Table 1. Share of coal, gas, nuclear and renewables of energy generation (%)

	India		China		USA		Other HICs		Other MICs		Japan		EU		LICs		Russia	
Technology	1990	2010	1990	2010	1990	2010	1990	2010	1990	2010	1990	2010	1990	2010	1990	2010	1990	2010
Coal	66	68	68	78	53	45	22	24	24	22	14	27	45	27	19	9	21	19
Oil	3	3	12	1	4	1	12	11	20	10	30	9	11	3	5	9	14	4
Natural gas	3	12	1	3	12	25	10	26	31	37	20	28	10	26	16	26	57	60
Nuclear	2	3	4	2	19	19	13	11	4	3	24	26	24	23	0	0	3	6
Renewables	25	14	15	15	11	10	43	27	22	27	12	10	10	19	60	56	6	7
Other	0	0	0	0	1	0	0	0	0	0	0	0	1	2	0	0	0	4

Note: Renewables include hydropower.
Source: IEA 2012c.

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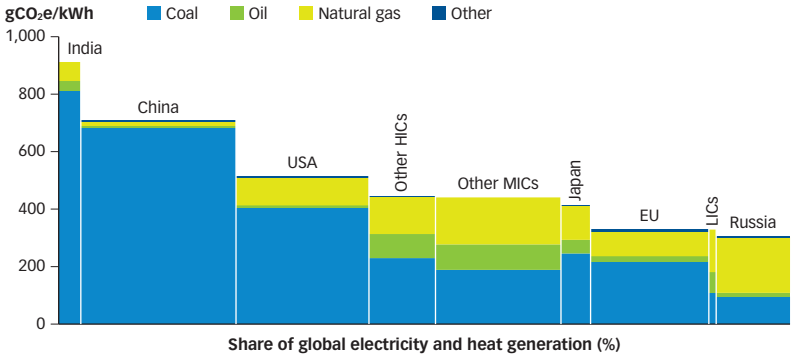
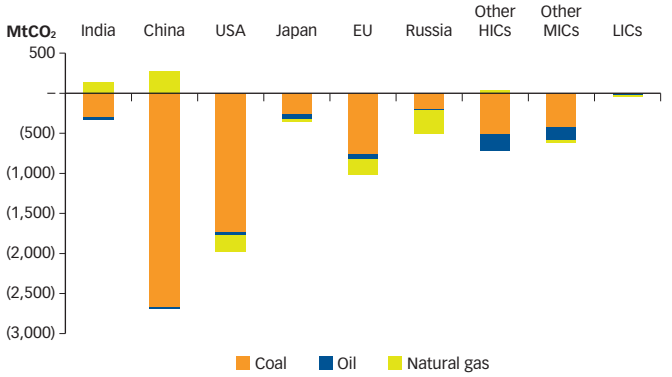
Figure 8. CO_2 footprint of energy generation globally, 2010



Notes: Emission factor is broken down by fuel by prorating the associated CO_2 emissions.
Source: IEA 2012a and 2012c.

Figure 9. Required changes in emission profiles to limit warming to two degrees Celsius (2010–35)



Source: IEA 2012d.

Where will action be most critical?

The greatest impact would come from cutting coal-based emissions in the largest economies

To limit global warming to two degrees Celsius, energy-sector CO_2 emissions will need to *decline* at an annual rate of 3.8 percent (IEA 450 Scenario), compared with a projected annual *increase* of 1.9 percent (IEA Current Policies Scenario from IEA 2012d).[3] Assuming a consistent growth rate for heat output based on trends between 1990 and 2010, the global average CO_2 intensity for the energy sector will need to be reduced to 134 grams of CO_2 per kilowatt-hour in 2035 for the two-degree limit to hold.

By comparing country emission profiles between the starting point in 2010 and a scenario compatible with no more than two degrees of warming by 2035, it is possible to highlight the changes that would be needed in the generation portfolios of specific countries (figure 9). By far the largest reductions are needed in China, the United States, and the European Union, particularly with respect to coal-fired power. Interestingly, net emissions from natural gas are projected to increase in China, India, and other high-income countries even in a two degrees of warming scenario for 2035.

[3] Projections for heat output as well as disaggregated carbon emissions from heat and electricity are not reported by the IEA.

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The peer reviewers for this note were Charles Feinstein (sector manager, East Asia Region) Christophe de Gouvello (senior energy specialist, Latin America Region), and Ashish Khanna (senior energy specialist, South Asia Region). The authors gratefully acknowledge comments from Irina Bushueva (investment analyst, IFC).