



# Emissions Intensity

**E**missions intensity is the level of GHG emissions per unit of economic activity, usually measured at the national level as GDP.<sup>25</sup> Intensities vary widely across countries, owing to a variety of factors that are explored in this chapter. GHG intensities for the major emitters, as well as recent trends, are shown in Figure 5.1. Table 3 shows carbon intensity and its constituent factors—energy intensity and carbon content of fuels—for the top 25 emitting countries.

## Intensity Levels and Trends

Not surprisingly, emission intensities vary widely across countries. Among the major emitters, GHG intensity varies almost seven-fold—from 344 tons per million dollars GDP in France, to 2,369 tons in Ukraine. France—with relatively low energy intensity, and very low carbon intensity, owing to its reliance on nuclear power—generates only 1.5 percent of global CO<sub>2</sub> emissions while producing 3.3 percent of global GDP. Ukraine—with high coal consumption and one of the world's most energy-intensive economies—generates 1.4 percent of global CO<sub>2</sub> emissions from only 0.5 percent of global GDP. As the country data suggests, however, intensity levels are unconnected with the size of a country's economy or population. A large or wealthy country may have a low GHG intensity, and vice-versa.

Like absolute and per capita emission levels, relative emission intensities vary depending on which gases are included. The inclusion of non-CO<sub>2</sub> gases boosts all countries' intensity levels, but in significantly different proportions. Aggregate CO<sub>2</sub> intensities are similar for developing and developed countries, while GHG intensities (using all six GHGs) in developing countries are about 40 percent higher, on average, than those in developed countries. Likewise, reported intensity levels depend on how GDP is measured. GDP may be expressed in a national currency, U.S. dollars, international dollars (using purchasing power parity conversions), or other common currency. Further, currencies may be inflation-adjusted to different base years. (To facilitate international comparisons, figures here use GDP measured in purchasing power parity expressed in constant 2000 international dollars.)

Historically, emissions intensities fell between 1990 and 2002 for most countries, including three-fourths of the major emitters (Figure 5.1 and Table 3).<sup>26</sup> Among the top 25 emitters, carbon intensity dropped

**Figure 5.1. Emissions Intensity Levels and Trends**  
Top 25 GHG Emitting Countries

Country	GHG Intensity, 2000	% Change, 1990–2002	
	Tons of CO <sub>2</sub> eq. / \$mil. GDP-PPP	Intensity (CO <sub>2</sub> only)	GDP
Ukraine	2,369	-6	-50
Russia	1,817	-5	-26
Iran	1,353	17	64
Saudi Arabia	1,309	45	32
Pakistan	1,074	4	55
China	1,023	-51	205
South Africa	1,006	-3	27
Poland	991	-43	47
Australia	977	-16	51
Turkey	844	-2	42
Indonesia	799	22	62
Canada	793	-15	40
India	768	-9	87
South Korea	729	-2	100
United States	720	-17	42
Brazil	679	17	35
Argentina	659	-18	33
Mexico	586	-9	41
Spain	471	5	37
Germany	471	-29	22
EU-25	449	-23	27
United Kingdom	450	-29	32
Japan	400	-6	16
Italy	369	-10	20
France	344	-19	24
<b>Developed</b>	<b>633</b>	<b>-23</b>	<b>29</b>
<b>Developing</b>	<b>888</b>	<b>-12</b>	<b>71</b>
<b>World</b>	<b>715</b>	<b>-15</b>	<b>36</b>

**Notes:** GHG intensity includes emissions from six gases. GHG intensity and CO<sub>2</sub> intensity exclude CO<sub>2</sub> from international bunker fuels and land use change and forestry. GDP is measured in terms of purchasing power parity (constant 2000 international dollars).

an average 15 percent, helping to drive a global decline of a commensurate amount. The most striking decline was in China, where intensity dropped 51 percent over the 12-year period. However, preliminary data for 2003 and 2004 shows that this trend is reversing, with emissions growing at twice the rate of economic output.<sup>27</sup> Carbon intensity rose significantly from 1990 to 2002 in Saudi Arabia, Indonesia, Iran, and Brazil.<sup>28</sup>

## Drivers of Emissions Intensity

Chapter 2 identified population and GDP as major determinants of a country's emissions and changes in its emissions over time. Emissions intensity<sup>29</sup>—the level of greenhouse gas emissions per unit of economic output—is a composite indicator of two *other* major factors contributing to a country's emissions profile, namely energy intensity and fuel mix (Equation B).

**Equation B**

$$\begin{array}{ccc}
 \text{Carbon Intensity} & & \text{Energy Intensity} & & \text{Fuel Mix} \\
 \downarrow & & \downarrow & & \downarrow \\
 \frac{\text{CO}_2}{\text{GDP}} & = & \frac{\text{Energy}}{\text{GDP}} & \times & \frac{\text{CO}_2}{\text{Energy}}
 \end{array}$$

Following on Equation A in Box 2.1, CO<sub>2</sub> emissions intensity is a function of two variables. The first variable is *energy intensity*, or the amount of energy consumed per unit of GDP. This reflects both a country's level of energy efficiency and its overall economic structure, including the carbon content of goods imported and exported. An economy dominated by heavy industrial production, for instance, is more likely to have higher energy intensity than one where the service sector is dominant, even if the energy efficiencies within the two countries are identical. Likewise, a country that relies on trade to acquire (import) carbon-intensive goods will—when all other factors are equal—have a lower energy intensity than those countries that manufacture those same goods for export.

Energy-intensity levels are not well correlated with economic development levels (Table 3). Transition economies, such as Russia and Ukraine, tend to have the highest energy (and carbon) intensities. Intensities in developing countries tend to be somewhat higher than in industrialized countries, owing largely to the fact that developing countries generally have a higher share of their GDP coming from energy-intensive manufacturing industries, such as basic metals. Industrialized countries, on the other hand, have greater shares of their economies comprised of lower-carbon service sectors.

The second component of emissions intensity is *fuel mix* or, more specifically, the carbon content of the energy consumed in a country (see Chapter 8). Coal has the highest carbon content, followed by oil

and then natural gas (Figure 8.5, p.43). Accordingly, if two nations are identical in energy intensity, but one relies more heavily on coal than the other, its carbon intensity will be higher. Figure 5.2 shows the breakdown of fuel mixes for selected countries. Countries vary widely in their use of fuels. Coal dominates in some countries (for example, China and South Africa), gas prevails in others (Russia), while other fuels—like hydropower, biomass, and other renewable sources presumed carbon-neutral—are significant in still other countries (Brazil, India).<sup>30</sup> “Other renewable energy,” which includes solar, wind, and geothermal, accounts for no more than 3.5 percent of total primary energy supply in any of the major emitting countries. Fuel mixes, it should be further noted, are highly correlated with countries’ natural endowments of coal, oil, gas, and hydropower capacity, a topic addressed further in Chapter 8.

Table 3 highlights the relative contribution of energy intensity and fuel mix to overall carbon intensity changes. In the EU, declining carbon intensity reflects reductions in both energy intensity and carbon content (for example, the switch from coal to gas in the U.K.). In the United States, declines stem almost entirely from reduced energy intensity. In some cases, the two factors counterbalance one another. In India, for instance, the increased carbon content of fuels has nearly entirely offset the effect of reduced energy intensity.<sup>31</sup> South Korea’s case is virtually the opposite: the switch to lower carbon fuels has nearly offset a sizable increase in energy intensity. Globally, the decline in overall carbon intensity stems more from reduced energy intensity than from changes in fuel mix.

Using the decomposition analysis introduced in Chapter 2, Figure 2.8 (p.15) shows in more detail the relative effects of energy intensity and fuel mix in shaping *absolute* emission trends. In several countries, it can be seen that declines in intensity were accompanied by significant increases in GDP, leading to increases in absolute CO<sub>2</sub> levels. The most notable case is China, where the effect of significant intensity declines was more than offset by substantial GDP growth. Likewise, the U.S. decline in carbon intensity (17 percent) was offset by increases in population and GDP.

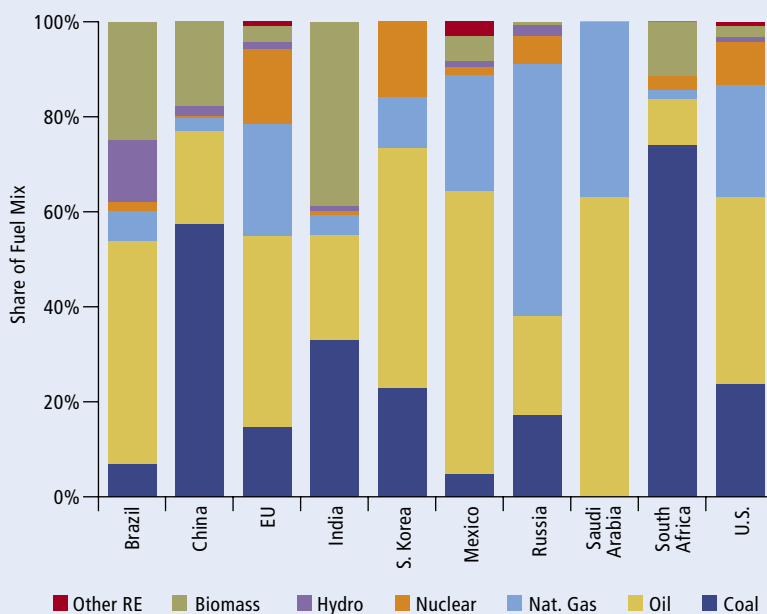
When non-CO<sub>2</sub> gases are considered, additional factors beyond energy intensity and fuel mix affect emissions intensities and trends. For instance, CH<sub>4</sub> and N<sub>2</sub>O emissions from agricultural sources might be influenced significantly by commodity prices and shifts in international livestock and grain markets. Land-use change and forestry emissions might also be influenced by domestic and international forces unrelated to the factors discussed above.

## GDP Changes and Projections

Emissions intensities, at least with respect to energy and industrial emissions, are influenced primarily by shifts in energy intensity, economic structure, and fuel mix. It follows that emission intensities are not directly correlated with changes in activity levels (GDP and population). Even in the event of major GDP changes, changes in intensity levels may be modest. Absolute emission levels, on the other hand, are most strongly influenced by GDP shifts (Chapter 2). When GDP rises, emissions also tend to rise correspondingly. This correlation is illustrated in Figure 5.3 for South Korea, where the effect of the 1998 Asian financial crisis is clearly apparent. GDP and CO<sub>2</sub> moved in tandem while carbon intensity was less affected. Because of this correlation, projections of carbon intensity tend to exhibit less uncertainty than absolute emission forecasts.

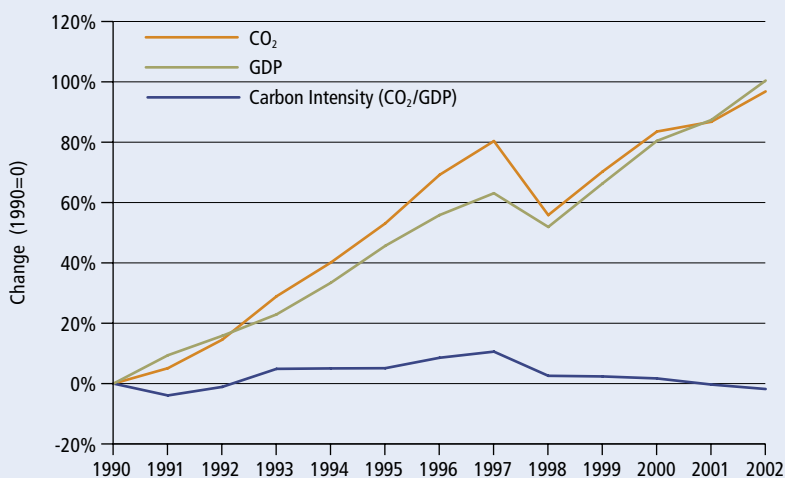
○ In several countries, declines in emissions intensity were accompanied by significant increases in GDP, leading to increases in absolute CO<sub>2</sub> levels. China and the U.S. are notable cases.

Figure 5.2. Fuel Mix in Energy Supply, 2002  
Relative shares, selected major GHG emitters



Source: WRI, based on IEA, 2004b.

Figure 5.3. South Korea: Relationship Between CO<sub>2</sub> and GDP, 1990–2002



Sources & Notes: WRI, CAIT. CO<sub>2</sub> includes fossil fuels and cement only.

This conclusion, however, may not hold in some instances. First, intensity projections may be less certain for countries whose national emissions profile includes large shares of non-CO<sub>2</sub> gases or LUCF-related emissions. As discussed above, these emissions are likely to be shaped by a different set of factors, many of which are difficult to predict. In general, non-CO<sub>2</sub> gases and LUCF-related emissions are not as strongly correlated with GDP.<sup>32</sup>

Second, the uncertainty reduction benefits of intensity indicators may be less apparent for mature, developed economies. A simplified illustration can be made using projections from the United States EIA. Figure 5.4 shows projections in terms of absolute emissions and emissions intensity for Japan, a mature economy, and nearby South Korea, a rapidly developing economy. For each country, projections include the EIA “high” and “low” growth scenarios. It is of course possible, if not likely, that all of the projections turn out to be significantly off the mark, as discussed in Chapter 3. Nevertheless, the perceived “uncertainty” gap (i.e., difference between high and low)

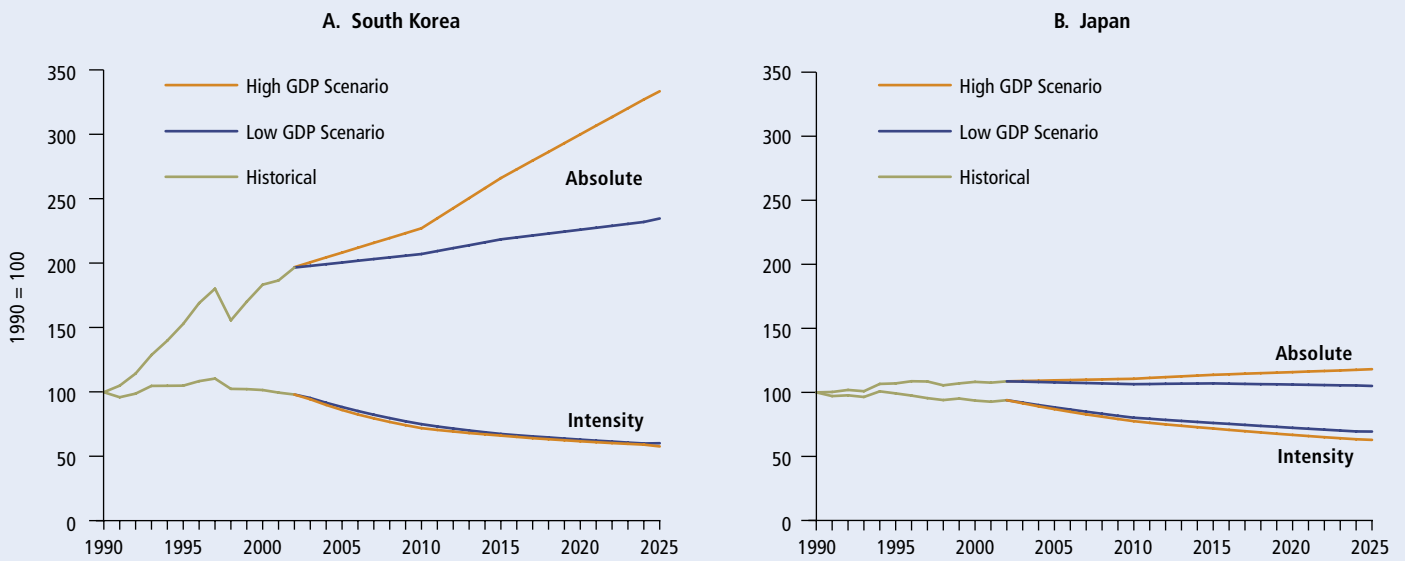
for absolute emissions is very large for South Korea, whereas the intensity gap is relatively small. In other words, according to the EIA, future emissions (in absolute terms) are highly uncertain in South Korea, whereas intensity is less so. For Japan, emissions are expected to grow between 5 and 18 percent by 2025. While not especially large, this uncertainty is not insignificant. What is notable, however, is that the uncertainty for Japan’s intensity does not seem to be much less than for absolute emissions.

### Implications for International Climate Cooperation

**Emission targets, measured in intensity terms, can reduce cost uncertainty.** Uncertainty is perhaps the most significant problem associated with target setting, and perhaps GHG mitigation in general. Not unjustifiably, governments tend to be unwilling to adopt commitments when it is unclear what kinds of policies and costs are implicit in those commitments. Framing a target in carbon intensity terms, as illustrated above, tends to reduce that uncertainty and, accordingly, may be a more attractive option than fixed targets. However, the reduced cost uncertainty comes at the expense of greater environmental uncertainty. Furthermore, the benefits of reduced uncertainty are likely to be much greater for developing countries than for developed countries, as discussed above.

For developing countries, a high proportion of emissions may come from non-CO<sub>2</sub> gases and land-use change and forestry. When these emissions are factored into intensity targets, the benefits of reduced uncertainty tend to be lower, since these emissions are less tied to economic activity levels than CO<sub>2</sub> from fossil fuels. The case of Argentina’s proposed target illustrates this phenomenon. In 1999, Argentina sought to adopt a “dynamic” emission target under the Kyoto Protocol.<sup>33</sup> However, CH<sub>4</sub> and N<sub>2</sub>O from agriculture accounted for more than 40 percent of Argentina’s GHG emissions. Future agricultural emissions would be influenced more by the international livestock and grain market than domestic GDP. Accordingly, Argentina chose not to propose a simple “intensity” target. Instead, Argentina suggested a complex indexing methodology tailored to their particular circumstances.<sup>34</sup>

Figure 5.4. Absolute (CO<sub>2</sub>) v. Intensity (CO<sub>2</sub>/GDP) Forecasts, 1990–2002



Sources & Notes: WRI, based on projections from EIA, 2005b. Includes only CO<sub>2</sub> from fossil fuels.

***GHG targets, measured in intensity terms, may introduce complexities and reduce transparency.***

Intensity targets would make international climate negotiations (and domestic policy-making) more complex, especially if they are being adopted by many countries. Countries might try to adopt both different percentage reduction commitments (as in Kyoto) and different GDP adjustment provisions, as the Argentine case illustrates. Negotiations might become exceedingly complex, to the point that non-specialists, or indeed anyone other than climate negotiators themselves, would have difficulty understanding proposed commitments.<sup>35</sup>

The case of the Bush Administration’s GHG intensity target helps illustrate the potential for confusion with this approach. The target—an 18 percent reduction in GHG intensity over the 2002 to 2012 timeframe—was introduced as a bold new effort. Yet, in the preceding 10-year period from 1992 to 2002, U.S. GHG emissions intensity had dropped by

18.4 percent<sup>36</sup> and, assuming continued U.S. GDP growth, the target would permit U.S. emissions to rise by 14 percent over the decade.<sup>37</sup> Thus, the Bush Administration’s target is essentially a continuation of past trends; one that is likely to result in increases, not reductions, of GHG emissions in absolute terms. This has often been misunderstood or inaccurately reported in the U.S. media. Thus, more than some other metrics, intensity targets may be vulnerable to misperceptions and obfuscation.

Overall, intensity targets represent a trade-off in terms of benefits and drawbacks. In some instances intensity targets would significantly aid in uncertainty reduction, but at the expense of simplicity and transparency. Complexities of intensity targets also extend to other areas, not discussed above, such as interactions with international emissions trading.<sup>38</sup>

