Industrial Ecology and Sustainable Engineering

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EXERCISES

ANSWER KEY

CHAPTER 1

1.1 In 1983, the birthrate in Ireland was 19.0 per 1000 population per year and the death rate, immigration rate, and emigration rate (same units) were 9.3, 2.7, and 11.5, respectively. Compute the overall rate of population change.

$$R=[19.0 - 9.3] + [2.7 - 11.5] = 9.7 - 8.8 = 0.9$$

1.2 If the rate of population change for Ireland were to be stable from 1990 to 2020 at the rate computed in the above problem, compute the 2020 population. (The 1990 population was 3.72 million.)

$$P=3.7\ e^{.0009\ (30)} = 3.80 \text{ million}$$

1.3 Using the "master equation," the "Units of Measurement" section in the Appendix, and the following data, compute the 2007 GDP/capita and equivalent CO_2 emissions per equivalent US dollar of GDP for each country shown in the following table:

2007 Master Equation Data for Five Countries @

Country	Population*	GDP **	CO_2 Emissions$^+$
Brazil	188	621	106
China	1314	2512	1665
India	1095	796	338
Nigeria	132	83	114
United States	298	13220	1709

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* Millions ** Billion of US dollars + Teragrams C/yr

Solution:

Country	GDP/capita	E_{CO2}/dollar of GDP (in g C/yr)
Brasil	3303	171
China	1912	663
India	727	425
Nigeria	629	1370
United States	44360	129

1.4 Trends in population, GNP, and technology are estimated periodically by many institutions. Using the typical trend predictions below, compute the equivalent CO_2 anticipated for the years 2010 and 2025 for the five countries. Graph the answers, together with information from 2007 (previous problem), on an E_{CO2} vs. year plot. Comment on the results.

Master Equation Predicted Data for Five Countries @

Country	Population * 2000	Population * 2025	GNP growth (%/yr) 1990-2000	GNP growth (%/yr) 2000-2025	Decrease in ECO_2/GNP(%/yr)
Brazil	175	240	3.6	2.8	0.5
China	1290	1600	5.5	4.0	1.0
India	990	1425	4.7	3.7	0.2
Nigeria	148	250	3.2	2.4	0.1
United States	270	307	2.4	1.7	0.7

* Millions

@ Data for this table were drawn primarily from J.T. Houghton, B.A. Callander, and S.K. Varney, *Climate Change 1992*, Cambridge, U.K.: Cambridge University Press, 1992.

Solution:

The easiest way to find the solution is to use the following formula (taking ECO_2/GDP numbers from the previous question and dividing by 10^{12} at the end to put it into Tg):

$$(ECO_2/GDP_{2007})((1-((\%_{\text{decrease in ECO2/GNP}})/100))^{\text{years}})(GDP_{2007}*(1+(\%_{\text{increase GDP}})/100)^{\text{years}}/(10^{12})$$

Example for Brazil in 2010:

$$171*(.995)^3*(621*10^9)*(1.028)^3/10^{12}=114$$

The quickest way to do the computation is to take the 2007 E_{CO2} values and decrease them by the percentages given.

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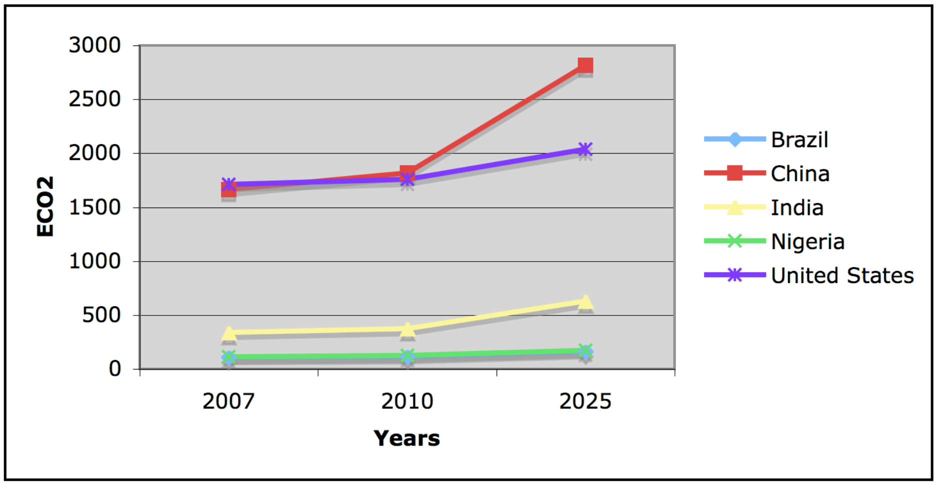
Country	2007: E_{CO2} (Tg/yr)	2010: E_{CO2} (Tg/yr)	2025: E_{CO2} (Tg/yr)
Brazil	106	114	160
China	1665	1818	2816
India	338	375	628
Nigeria	114	122	171
United States	1709	1756	2036



As shown in the chart, although China has the largest rate of decrease in ECO_2/dollar GDP, it also has the largest rate of growth for GDP, so it will overtake the US as the largest emitter before 2010.

CHAPTER 2

2.1 Section 2.2 proposes that 25-50 years is the best choice for a sustainability planning time scale. Do you agree? Explain.

The response could involve discussion of human adult lifetime, scales of carbon and climate cycles, the multifaceted nature of the transition, monitoring of change, or development of technology. It may also address differences in time scale between planning for "weak" or "strong" sustainability.

2.2 Use the information in Table 2.1 to estimate how much zinc could be used in a "sustainable" automobile. Clearly show your reasoning.

Solution Notes: The key here is obviously to use the Sustainable Rate of Use of 1.5 kg/(person-year) from Table 2.1. The answer should consider the replacement rate of cars and consumption of zinc in other forms (doorknobs, etc). The final calculation should be something similar to:

(1.5–[other uses])*[number of years car is expected to last]=[zinc estimate in kg]

2.3 Consider the quantitative sustainability example of greenhouse gases in Section 2.3.3. Discuss the options for allocating the allowable CO_2 emissions, together with the benefits and problems of the options.

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