Chapter 2
Summarizing Preview

2.1 Global Distribution of CO_2 Emissions

Comparing, worldwide for 2011, the CO_2 emissions caused by burning fossil fuels, in all regions of the world, in the G-20 countries as a whole and in some important members of the G-20 group, the results are shown in Fig. 2.1. In 2011, the G-20 countries were responsible for a total of 84 %, China and the OECD together for 67 %, China and the U.S. together for 44 % of global CO_2 emissions. Meeting the 2-degree climate target is therefore realistic only if these countries and groups of countries participate actively and purposefully.

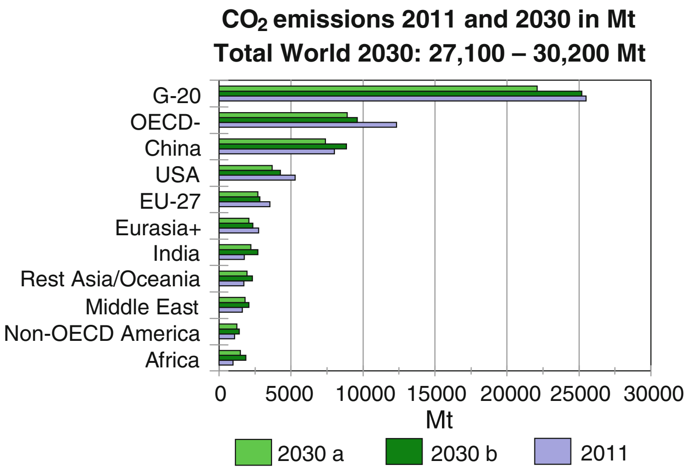

Fig. 2.1 Comparison of CO_2 emissions from the regions of the world and some countries in 2011 (excluding marine and aviation bunkers, see Appendix) and necessary reduction by 2030 (variants *a* and *b*) to achieve the 2 °C climate target

V. Crastan, *Global Energy Demand and 2-degree Target, Report 2014*,
DOI 10.1007/978-3-319-12310-3_2

The same graph shows for 2030 a scenario resulting from the present study, that includes the reduction in total emissions (variants a and b) required by Fig. 1.4. The main burden of the reduction must be carried by the industrialized countries (main actors: the U.S., Japan and EU-27). However, the success can only be guaranteed with a contribution from China in particular, but also of Eurasia (primarily Russia). More details in the following chapters.

Currently, the total emissions of CO_2 are still rising. The **trends** of the indicators already mentioned (energy intensity of GDP and CO_2 intensity of energy), which are defined and analyzed in more detail below, are very important.

2.2 Energy Intensity

Energy consumption is rising as a consequence of the world-wide increase in gross domestic product (GDP). This grows with the increase in world population and, above all, because of the legitimate increase in prosperity in the emerging and developing countries. The ratio energy/GDP is the ***energy intensity*** **ε**, that can be quantified, for example in **kWh/$**. To achieve the goals of climate protection requires the conversion and use of energy to be as efficient as possible, in order to have the lowest possible energy intensity. Hence, the concept of energy efficiency is also used: it is the reciprocal of energy intensity.

To compare the energy intensity of the economies of various countries, a measurement unit must be established that enables the economic capacity of a country to be defined in an objective and fair way. The absolute value of the GDP in $ at the currency's rate of exchange does not seem to be particularly suitable for that because the level of prices and therefore the buying power, that is the real indicator of capacity and competitiveness, can be very different. Therefore international organisations (World Bank, IMF [8, 13]) determine the GDP of all countries at purchasing power parity, the GDP (PPP). There have also been attempts to define other quantities. However, despite its shortcomings as a welfare indicator, the GDP (PPP) is the only statistically available characteristic that makes reasonable world-wide comparisons possible.

Extrapolation of the energy intensity to the year 2030 or 2050 requires scenarios that represent the development of world-wide energy demand corresponding to the growth of population and the GDP. Scenarios of this type have been developed for 2030 and 2035 by the International Energy Agency (IEA). They are shown in Fig. 2.2, together with the energy needs of the year 2009 [9]. The first two scenarios (*Reference and Alternative Scenario* for 2030) were presented in 2004. The *reference scenario* leads to an energy consumption of 22 TWa (1 TWa = 753 Mtoe), which would correspond to an average growth rate of primary energy demand of 1.8 %/year from 2009. The *alternative scenario* that meets the requirements of climate protection somewhat better, leads, for 2030, thanks to improved efficiency, to an energy consumption of 19.7 TWa (average growth rate 1.3 %/year). The *450 Scenario* of 2009 best meets the requirements of climate protection and for 2030 expects an energy demand of 18.5 TWa (corresponds to about 14,000 Mtoe). It requires a large decrease in both energy intensity and CO_2 intensity of energy.

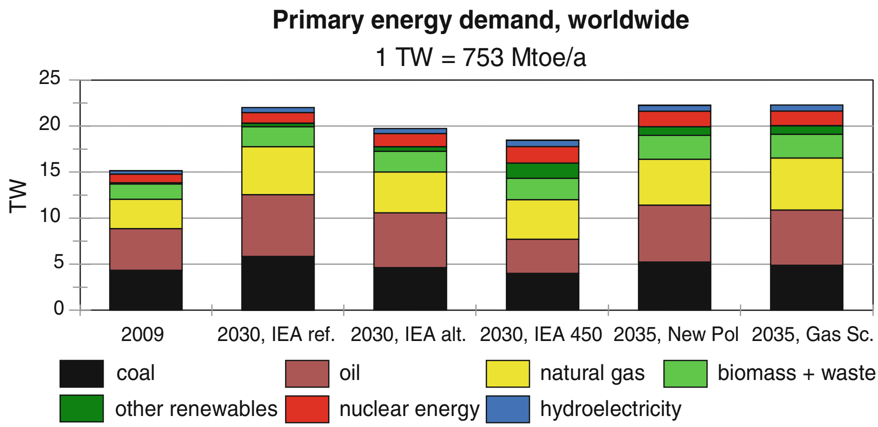

Fig. 2.2 IEA global demand scenarios for primary energy (2030, 2035)

With an energy demand of 19.3 TWa, slightly more than in the 450 Scenario, and a GDP (PPP) of $125,000 billion in 2030, the energy intensity (for variant *a*) would amount to 1.35 kWh/$, as already noted in the introduction (see also Fig. 2.3), i.e. a reduction of 31 % compared to 2011 (reduction rate 1.94 %/year).

The scenarios presented in 2011 for 2035 (New Policies Scenario and Gas Scenario, with about 22.5 TWa (growth rate of about 1.5 %/a), allow a greater share of fossil fuels and thus a slightly greater energy intensity. To achieve the 2-degree target, this would have to be compensated by a greater reduction in the CO_2 intensity of energy. These scenarios take account of the needs of climate protection only if it is assumed that a significant portion of the consumption of fossil fuels, thanks to CCS, does not contribute to CO_2 enrichment of the atmosphere.

The global comparison of the energy intensity (gross energy per $) is given in Fig. 2.3 for 2000 and 2011. Progress from 2000 to 2011 is considerable, but more effort is essential, especially in regions of the world with poor energy efficiency (Eurasia, China, Africa, Middle East).

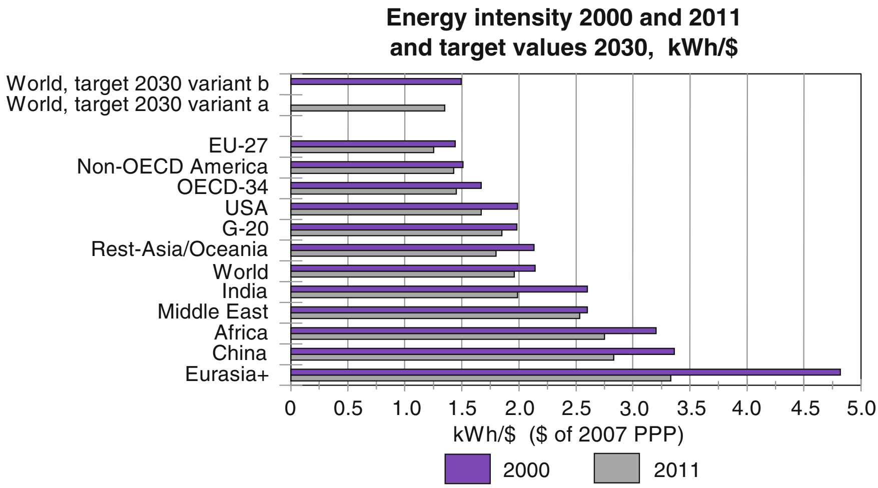

Fig. 2.3 Comparison of the energy intensity of the years 2000 and 2011 for world regions and countries. The target value 2030 (variant *a* of Fig. 1.2) requires 4 % more energy than the IEA 450 Scenario, that of variant *b*, about 4 % more than the New Policies Scenario

2.3 CO_2 Intensity of Energy

CO_2 emissions from the use of energy are rising because, particularly (but not only) in the emerging nations, there is increasing use of energy sources (oil, coal, gas) that emit large amounts of CO_2. This is expressed in the ***CO_2 intensity k*** of the consumed energy in units of **g CO_2/kWh**. It is dependent on the type of energy used. The CO_2 released in burning coal gives a value of around k = 350 g CO_2/kWh, burning oil gives about 260 g CO_2/kWh and burning natural gas is about 200 g CO_2/kWh. The use of low-CO_2 energy sources (water power, solar radiation, wind energy, solar heating, geothermal energy, biomass energy, sea currents and wave power and also nuclear energy) reduces the resulting value of CO_2 intensity.

Figure 2.4 compares the CO_2 intensity of energy for 2000 and 2011 worldwide. The progress in this decade is not only inadequate, but CO_2 intensity has actually increased slightly worldwide. Slight but not sufficient progress is only recorded in Europe and America (North and South America). Eurasia is almost stationary and Asia and the Middle East generally have a clear deterioration of the specific emissions. The target value for 2030 can only be achieved if not only the replacement of coal by gas but also the use of renewable energy, nuclear energy and CCS quickly receives a higher priority in emerging markets.

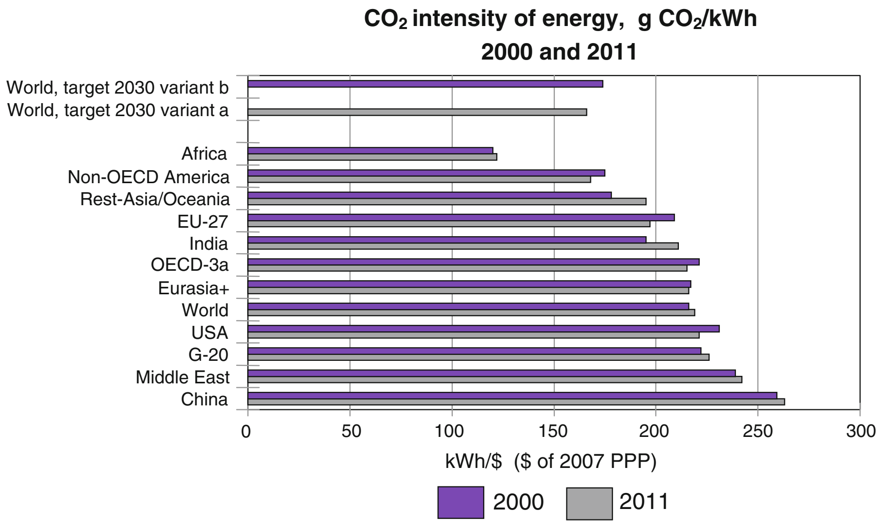

Fig. 2.4 Worldwide comparison 2000 and 2011 of the CO_2 intensity of energy and target values 2030 (variant *a* and *b*)

2.4 Energy Sector

The representation of the energy flows in the appendix shows clearly that worldwide more than half of the CO_2 emissions (only fossil fuels) come from the energy sector that serves mainly for the production of electricity. The worldwide level of electrification corresponds to a large extent to the level of economic development. In addition, CO_2-reducing actions in the area of heating and mobility have the effect of increasing the demand for electricity (heat pumps, hybrid and electric cars).

Figure 2.5 shows the share of CO_2 emissions coming from the energy sector (electricity + district heating + losses in the energy sector; see also the appendix for exact definition). The type of electricity production and efficiency of the energy sector play the leading role. The need to catch up is greatest in China, India and Eurasia. The low share of Central and South America (non-OECD America) can be explained with the prominence of water power in this continent.

It is therefore of primary importance to generate electricity with the least possible production of CO_2. The following are possible ways, ***which should all be used*** (weighted differently depending on the country), to achieve this [10]:

(a) Large reduction of losses in the energy sector by significantly increasing the **efficiency of thermal power plants** (cogeneration, combined-cycle generation).

(b) **CO_2 capture and storage** (**CCS**) in coal, oil and gas-fired power plants; with a significant limitation: the technology is not yet mature, is probably expensive and is not yet fully tested for environmental sustainability. But without CCS the aforementioned objectives are unlikely to be reached.

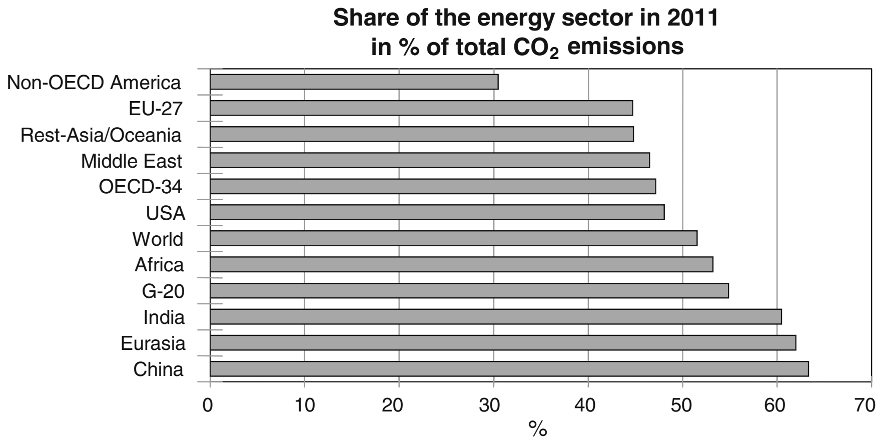

Fig. 2.5 Share of the energy sector in % of total CO_2 emissions in 2011

(c) Use of **natural gas** instead of coal and oil: CO_2 emissions, compared to coal, are reduced to about 55 % (compared to oil, to about 75 %), with limitations: world-wide gas reserves are not unlimited and political dependencies. Fracking significantly increase the reserves, but environmental risks have not yet been sufficiently clarified.

(d) Use of **nuclear energy**: the power stations are nearly free of CO_2 emissions; restrictions: reserves of uranium, used in 3rd-generation reactors, are also limited. Use of reactors of the 4th generation is possible, but requires careful technical and political consideration. Nuclear fission has met increasing resistance after Fukushima. Nuclear fusion will only be available in the second half of the century.

(e) Use of all opportunities to generate electricity from **water power**: Restrictions: the potential for this is limited, resistances from nature conservation and ecology.

(f) Use of **wind energy**: the technology is mature and, where the wind conditions are favourable, cost-efficient. With the use of off-shore installations, the potential is considerable. Limitations: power grids and energy storage require significant adjustment.

(g) Use of **geothermal energy**: Limitations: geothermal power stations are especially suitable for sites with geothermal anomalies, but there they have a large potential.

(h) Use of **biomass and waste**: Restrictions: the capability of biomass is limited. Biomass should therefore be used primarily, and provided its use is ecologically acceptable, for heat, combined heat and power and motor fuels. But the production of bio-fuels is often far from CO_2-neutral.

(i) Use of solar thermal energy and photovoltaic: **Solar thermal power stations** are suitable for countries with a low proportion of diffuse light, and there they have a large potential. **Photovoltaic** generation is currently hindered by its high cost, but as its potential is practically unlimited and has widespread availability, its further development must be pursued with determination, and as long as economically worthwhile including reasonable feed-in tariffs. Here too, adjustments in the transmission and distribution grid as well as in energy storage (partly through load control) are necessary.

2.5 Indicator of CO_2 Sustainability

The upward trend in CO_2 emissions can only be broken by influencing both of its causes. The important number is the product of the two factors ***energy intensity ε*** and ***CO_2 intensity of energy k****, used as* ***indicator η of CO_2 sustainability.***

The absolute values and the yearly changes are given by [10]:

$$\eta\left[\frac{\text{gCO}_2}{\$}\right] = k\left[\frac{g\,\text{CO}_2}{\text{kWh}}\right] \times \varepsilon\left[\frac{\text{kWh}}{\$}\right]$$

$$\Delta\eta\ [\%/\text{a}] = \Delta k\ [\%/\text{a}] + \Delta\varepsilon\ [\%/\text{a}]$$

With a reasonable estimate of their gross domestic products for 2030 (GDP PPP), taking into account the estimate for 2018 of the International Monetary Fund, the result is, with the assumptions of Fig. 2.1 (variants *a* and *b*), the scenarios for the decrease of the indicator shown in Fig. 2.6. All of them, but especially China, Eurasia (crucially influenced by Russia) and the Middle East have a very strong need to catch up. The 2-degree target can only be achieved if in these regions of the world also, both the energy intensity and CO_2 intensity of energy are reduced in accordance with the following chapters (see Sect. 12.1 for China, Chap. 7 + Sect. 12.4 for Eurasia/Russia and Chap. 6 for the Middle East).

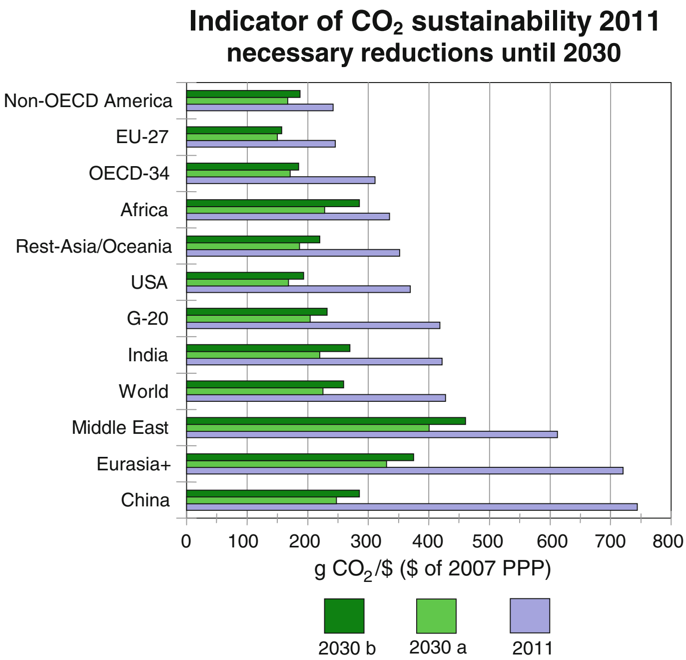

Fig. 2.6 Sustainability indicator of world regions and important countries for 2011 and necessary development to 2030 for the 2 °C target, variants *a* and *b*

The resulting per-head indicators: **e** for energy (from **ε**), and **α** for CO_2 emissions (from **η**) are also of interest:

$$e\left[\frac{\text{kW}}{\text{capita}}\right] = \varepsilon\left[\frac{\text{kWa}}{10{,}000\ \$}\right] \times y\left[\frac{10{,}000\ \$}{\text{a, capita}}\right]$$

$$\alpha\left[\frac{\text{t}\,\text{CO}_2}{\text{a, capita}}\right] = \eta\left[\frac{\text{t}\,\text{CO}_2}{10{,}000\ \$}\right] \times y\left[\frac{10{,}000\ \$}{\text{a, capita}}\right]$$

where y is the PPP-corrected GDP (PPP = purchasing power parity) per capita.

(1 kWa/10,000 $ = 0.876 kWh $, 1 t CO_2/10,000 $ = 100 g CO_2/$).

The indicator **α** (t CO_2 per capita per year, with a worldwide value in 2011 of about 4.5 t/capita, and target 2030 just 3.4 t/capita) makes sense in the long term as a global target, as the population growth is most likely to be predictable. It is, however, less suitable for current comparisons between countries, and therefore as short-term basis for negotiation, because of the greatly differing levels of development of the regions of the world.

The indicator **e** (kW per capita, with a worldwide value in 2011 and target for 2030 both, about 2.3 kW/capita) is also not suitable as a comparison value for the same reason. It can be determined from energy intensity and GDP per capita. It is primarily of interest in connection with studies on the feasibility of a 2,000-W society.

http://www.springer.com/978-3-319-12309-7

Global Energy Demand and 2-degree Target, Report 2014
Crastan, V.
2014, XIV, 263 p. 408 illus., 398 illus. in color., Hardcover
ISBN: 978-3-319-12309-7