part II

Basic Energy Facts

An energy system is made up of an energy supply sector and energy end-use technologies. The objective of an energy system is to deliver to consumers the benefits that energy use offers. The term energy services is used to describe these benefits, which for households include illumination, cooked food, comfortable indoor temperatures, refrigeration, telecommunications, education, and transportation. Energy services are also required for virtually every commercial and industrial activity. For instance, heating and cooling are needed for many industrial processes, motive power is needed for agriculture and industry, and electricity is needed for telecommunications and electronics. It is the availability of and access to energy services, not merely energy supply, that is crucial.

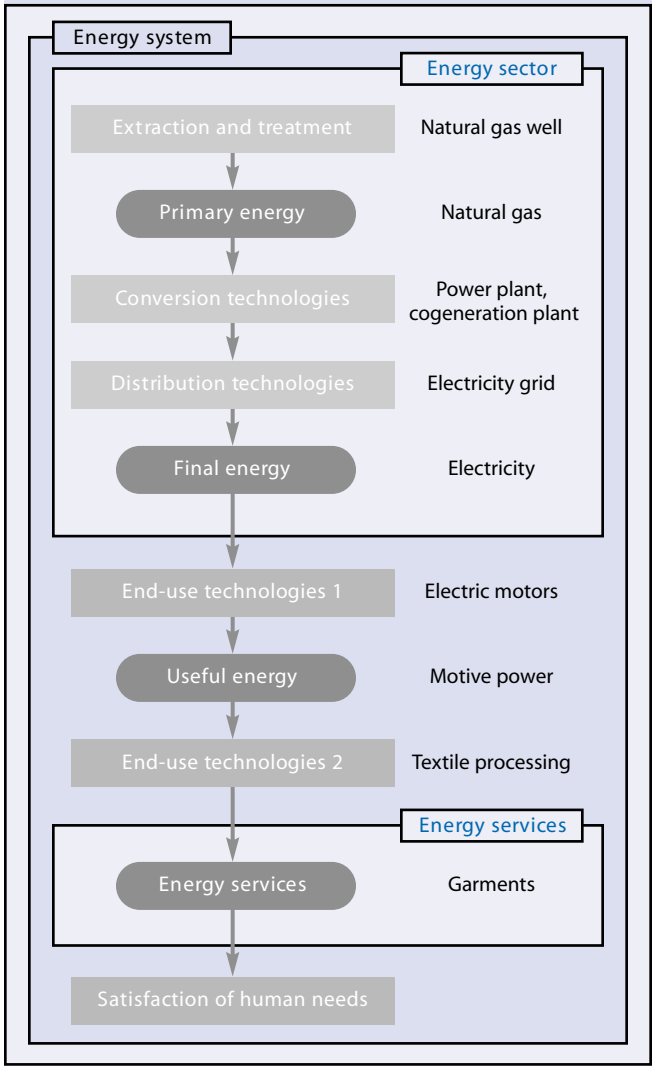
The energy chain that delivers these services begins with the collection or extraction of primary energy that, in one or several steps, may be converted into energy carriers, or final energy such as electricity or diesel oil that are suitable for end uses. Energy end-use equipment – stoves, light bulbs, vehicles, machinery, etc. – converts the final energy into useful energy, which (with the help of additional technologies) provides the desired benefits: the energy services. An example of an energy chain – beginning with natural gas extracted from a well (primary energy) and ending with produced garments as an energy service – is shown in Figure 2.

Energy services result from a combination of various technologies, infrastructure (capital), labour (know how), materials, and primary energy. Each of these inputs carries a price tag, and they are partly substitutable for one another. From the consumer's perspective, the important issues are the economic value or utility derived from the services. Consumers are often unaware of the upstream activities required to produce energy services.

One way to capture the importance of energy services (not merely energy use or supply as an end in itself) is to show its impact on the human development

index (HDI), a composite indicator developed by UNDP to show countries' relative well being in social as well as economic terms. Figure 3 displays the correlation between a country's human development index ranking and per capita energy use, with commercial energy used as a proxy for energy services. Because the efficiency of energy use in countries with the lowest per capita energy use is much lower than in countries with higher per capita energy use, the relative level of energy services is even lower in the low per capita energy use countries. Thus Figure 3 shows that an HDI of 0.8 or higher currently requires a minimum energy use of about 1 tonne of oil-equivalent per year per capita (or 42 GJ per capita). It is noteworthy that a higher than ten-fold increase in consumption of energy does not increase the HDI significantly.

FIGURE 2. AN EXAMPLE OF THE ENERGY CHAIN FROM EXTRACTION TO SATISFACTION OF NEEDS



In most low-income developing countries, a small, affluent minority uses various forms of commercial energy in much the same way as most people in the industrialised world do. However, most people in low-income developing countries rely on traditional, non-commercial sources of energy using inefficient technologies such as unventilated stoves or open fires. Traditional energy sources are generally not reflected in energy statistics. Analysis based on "per capita" consumption of commercially distributed energy resources is common because the data are much easier to collect. The resulting analysis, however, does not accurately reflect the world's energy situation. Though less well-documented, non-commercial energy is very significant globally, and is used far more widely than commercial energy in rural areas of many developing countries, particularly the least developed countries.

Per capita use of primary energy in North America was 280 gigajoules in 2000, more than eleven times as much as used by an average sub-Saharan African (who used 25 gigajoules that year when both commercial and non-commercial energy are included).[7] In OECD Europe and OECD Pacific – developed countries in those regions – per capita energy use was about 142 and 180 GJ, respectively. Figure 4 shows per capita commercial and non-commercial energy use in various regions.

Table 1 and Figure 5 show 2001 global primary energy use, including both commercial and non-commercial sources of energy. Fossil fuels (oil, natural gas, and coal) represent nearly 80 percent of the total. Nuclear power contributes approximately 7 percent; however, because nuclear power plants have only one third of thermal efficiency, the final electricity generated for consumption is basically the same as that generated by large hydropower. Large hydropower and "new" renewables (which includes modern uses of biomass and small hydropower, geothermal, wind, solar, and marine energy) each contribute slightly more than 2 percent; the percentage contribution of "new renewable energy sources" has changed little in recent years.

7. In this report, the term commercial energy refers to fossil fuels (oil, coal, and natural gas), nuclear energy, and large-scale hydropower. The term traditional energy is used to denote locally collected and often unprocessed biomass-based fuels, such as crop residues, wood, and animal dung. Most traditional energy is used non-commercially (i.e., non-commercial energy). Although traditional energy sources can be used renewably, the term new renewables refers to modern biofuels, wind, solar, small-scale hydropower, marine, and geothermal energy.

FIGURE 3. RELATIONSHIP BETWEEN HDI AND PER CAPITA ENERGY USE, 1999/2000

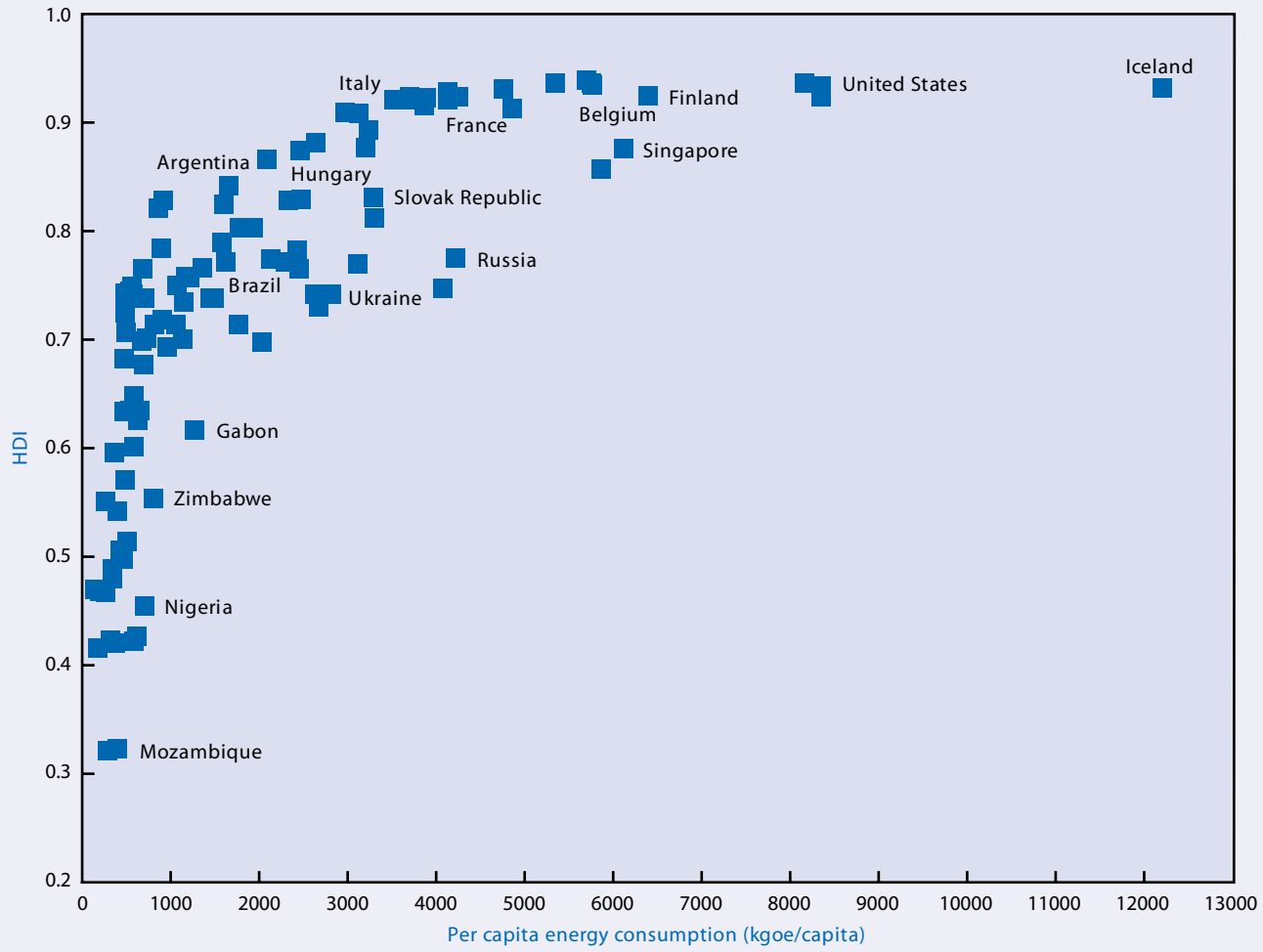
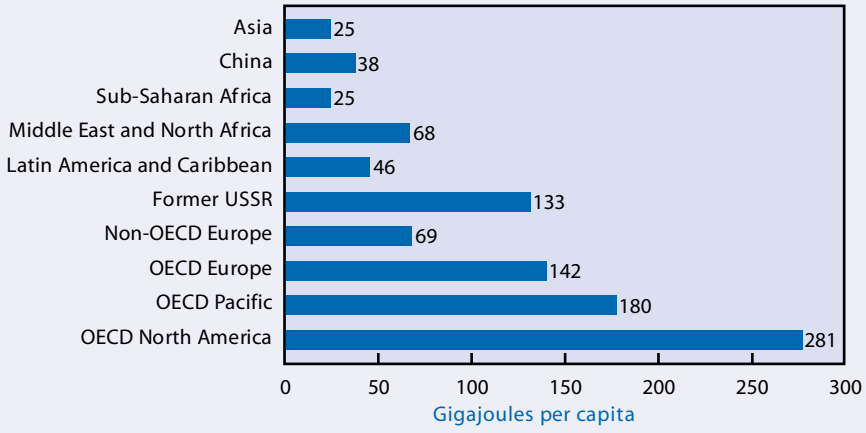


FIGURE 4. PER CAPITA ENERGY USE (COMMERCIAL AND NON-COMMERCIAL), BY REGION, 2000



Notes: Asia excludes Middle East, China, and OECD countries; Middle East and North Africa comprises Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates and Yemen; Latin America and Caribbean excludes Mexico; OECD Pacific comprises Australia, Japan, Korea, and New Zealand; Former USSR comprises Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan; Non-OECD Europe consists of Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Gibraltar, Macedonia, Malta, Romania, and Slovenia; OECD North America includes Mexico.

Sources: IEA, 2002a and 2002b.

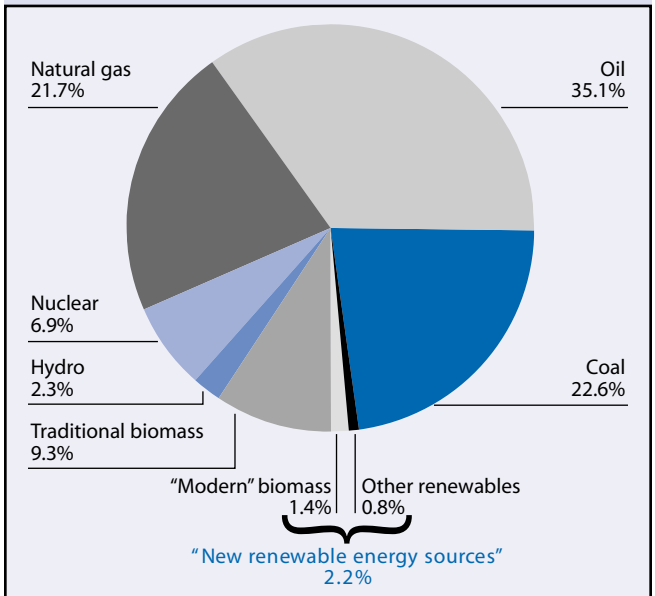
TABLE 1. WORLD PRIMARY ENERGY USE AND RESERVES, 2001

Source	Primary energy (exajoules, EJ)	Primary energy (10^9 tonnes of oil equivalent, Gtoe*)	Percentage of total (%)	Proved reserves (10^9 tonnes of oil equivalent, Gtoe*)	Static reserve-production ratio (years)[a]	Static resource base–production ratio (years)[b]	Dynamic resource base–production ratio (years)[c]
Fossil fuels	332	7.93	79.4	778			
Oil	147	3.51	35.1	143	41	~ 200	125
Natural gas	91	2.16	21.7	138	64	~ 400	210
Coal	94	2.26	22.6	566	251	~ 700	360
Renewables	57	1.37	13.7				
Large hydro	9	0.23	2.3		Renewable		
Traditional biomass	39	0.93	9.3		Renewable		
'New' renewables[d]	9	0.21	2.2		Renewable		
Nuclear	29	0.69	6.9	55			
Nuclear[e]	29	0.69	6.9	55	82[f]	~300 to >10,000[f]	
Total[f]	418	9.99	100.0				

* 1 toe = 42GJ. a. Based on constant production and static reserves. b. Includes both conventional and unconventional reserves and resources. c. Data refer to the energy use of a business-as-usual scenario—that is, production is dynamic and a function of demand. Thus these ratios are subject to change under different scenarios. Dynamic resource base – production was calculated based on a 2 percent growth rate per year from 2000 to peak production (oil 6.1 Gtoe, gas 6.3 Gtoe, and coal 8.9 Gtoe), followed by a 2 percent decline per year until the resource base is exhausted. d. Includes modern biomass, small hydropower, geothermal energy, wind energy, solar energy, and marine energy. Modern biomass accounts for 6.0 exajoules; 2.9 exajoules comes from all other renewables. "Modern biomass" refers to biomass produced in a sustainable way and used for electricity generation, heat production, and transportation (liquid fuels). It includes wood/forest residues from reforestation and/or sustainable management, rural (animal and agricultural) and urban residues (including solid waste and liquid effluents); it does not include traditional uses of fuelwood in inefficient and pollutant conversion systems. e. Converted from electricity produced to fuels consumed assuming a 33 percent thermal efficiency of power plants. f. Based on once-through uranium fuel cycles excluding thorium and low-concentration uranium from seawater. The uranium resource base is theoretically 60 times larger if fast breeder reactors are used.

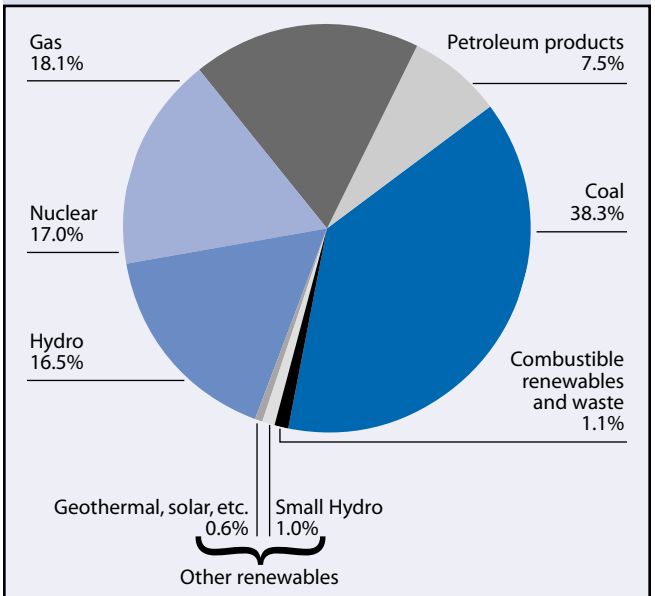
Source: Updated from WEA, 2000, and Table 7.

FIGURE 5. WORLD PRIMARY ENERGY USE, BY ENERGY SOURCE, 2001 (SHARES OF 10.2 GTOE)



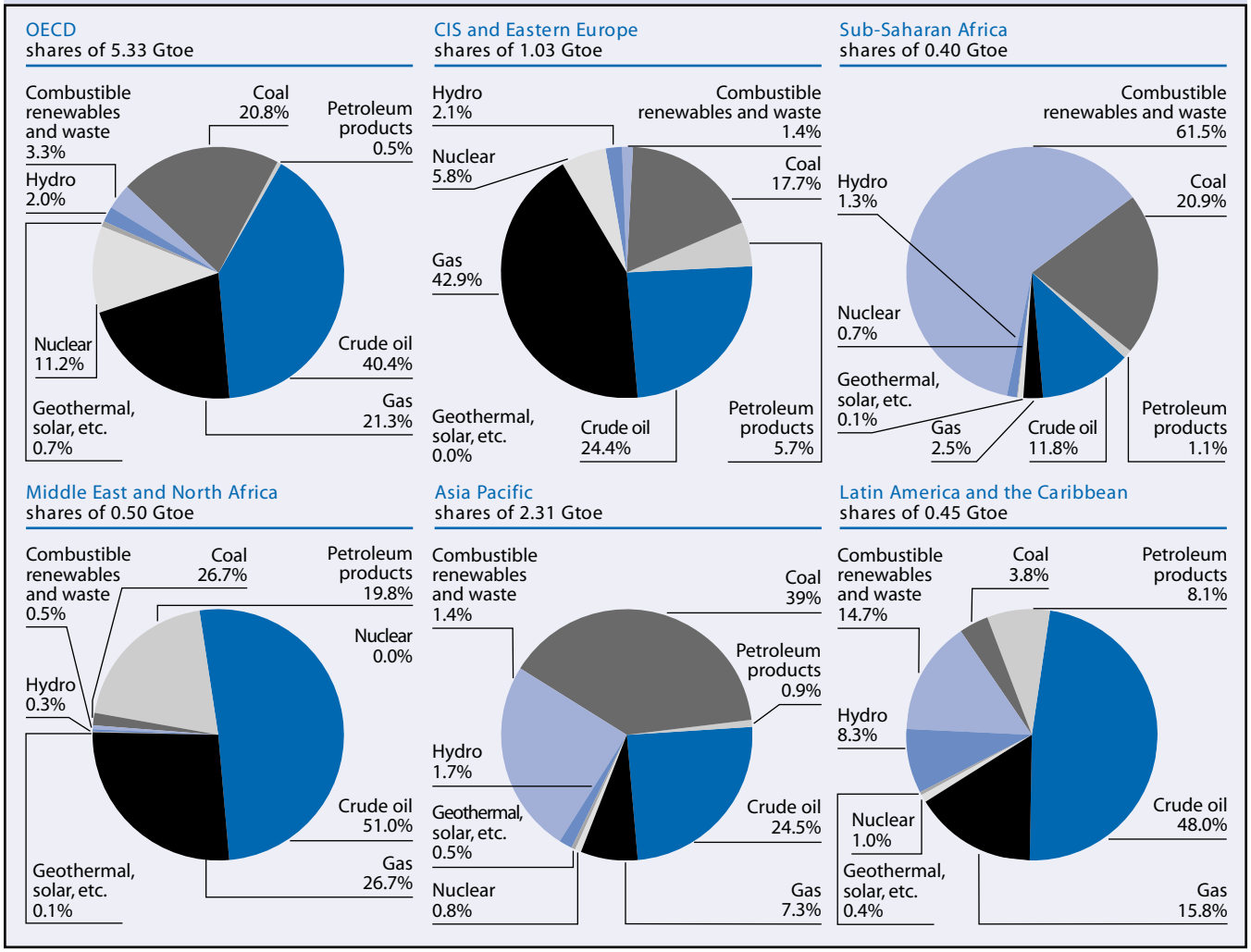
Source: Tables 1 and 6.

FIGURE 6. WORLD ELECTRICITY PRODUCTION, BY ENERGY SOURCE, 2001 (SHARES OF 15,476 TWH)



Sources: IEA, 2003c. Small hydro data from International Association for Small Hydro (IASH), www.iash.info/worldpotential.htm.

FIGURE 7. PRIMARY ENERGY USE IN VARIOUS REGIONS, BY ENERGY SOURCE, 2001



Source: IEA, 2003c.

Figure 6 shows global electricity production, numbers obtained in terawatt hours, i.e., final outputs that reflect the net energy service provided by all sources.

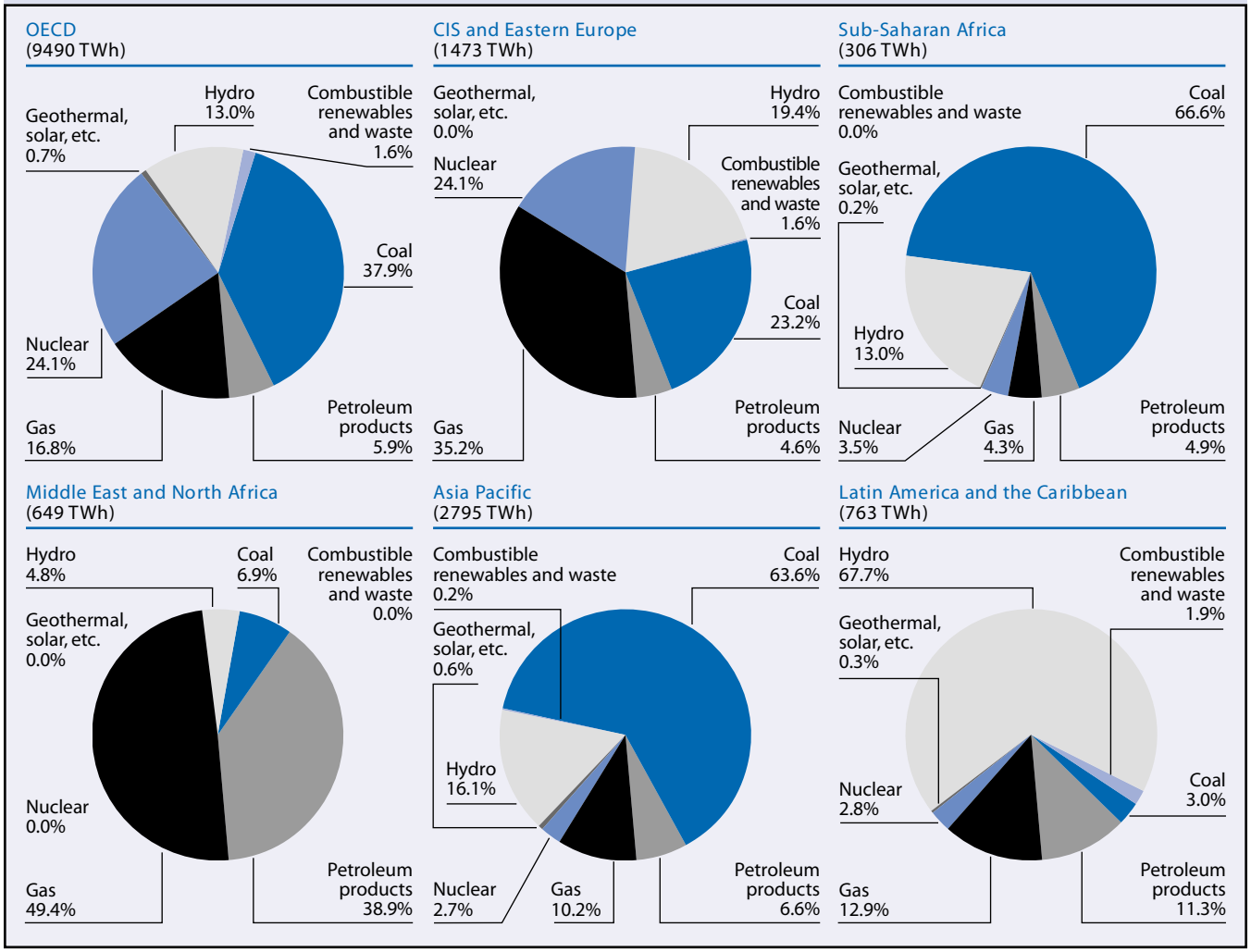
Total sales of energy carriers world-wide in 2001 amounted to on the order of US$2 trillion, about 6 percent of the world's gross domestic product.[8] Small shares of these amounts could make an enormous difference in terms of sustainable development if directed to cleaner energy forms. However, this is still not the case: at present, subsidies to conventional energy are on the order of $250 billion per year, while sales of "new" renewables are on the order of $20 billion per year.

There are great disparities in the way energy is consumed. Average "per capita" primary energy use in the world has reached 1.65 toe per year, which is approximately twenty times greater than minimum human energy requirements for survival, i.e., the daily energy use of primitive man (2000 kcal).

Figure 7 gives a breakdown of primary energy use for various regions (OECD, Commonwealth of Independent States and Eastern Europe, Sub-Saharan Africa, Middle East and North Africa, Asia-Pacific, Latin America and the Caribbean). The regions show large differences in their primary energy mix, reflecting both the availability of primary energy sources and consumption patterns.[9] Figure 8 shows electricity production for the

8. As estimated by converting 10 Gtoe to barrels of oil at a value of US$30 per barrel.
9. According to the International Energy Agency (2003, p. I.9), "Combustible renewables and waste comprises solid biomass, liquid biomass, biogas, industrial waste and municipal waste. Biomass is defined as any plant matter used directly as fuel or converted into fuels (e.g., charcoal) or electricity and/or heat. Included here are wood, vegetal waste (including wood waste and crops used for energy production), ethanol, animal materials/wastes and sulphite lyes (...) also known as "black liquor (...). Municipal wastes comprises wastes produced by residential, commercial and public service sectors that are collected by local authorities for disposal in a central location for the production of heat and/or power. Hospital waste is included in this category". The Agency also

FIGURE 8. SHARES OF ELECTRICITY PRODUCTION IN VARIOUS REGIONS, BY ENERGY SOURCE, 2001



Source: IEA, 2003c.

same regions, again with large variations.

Fossil fuels use accounts for 83 percent of the energy consumed in industrialised countries, 89 percent in transition-economy countries, and appreciably less in some other regions. In contrast, traditional and modern biomass account for 16 percent of the energy consumed in the developing countries of the Latin America and Caribbean, for 25 percent in developing Asia, and almost 60 percent in Sub-Saharan Africa. Yet it represents only 3 percent of primary energy used in industrialised countries, and is negligible in the transition economy countries of Eastern Europe and the former Soviet Union. Nuclear energy is also significant in industrialised countries (where it is the source of 11 percent of primary energy) and transition economy countries (7 percent); however, it makes only a minor contribution in developing countries (0.4 percent, or even less). Hydropower is unevenly used, providing 72 percent of electricity in Latin America and the Caribbean, and 9 percent in Middle East and North Africa, regions with scarce resources. Non-hydro renewable energy in electricity production is low in all regions.

World-wide, traditional energy accounts for nearly 10 percent of total primary energy used (Figure 5). However, the distribution is uneven: traditional energy accounts for less than 3.4 percent of energy use in industrialised countries but an average of 17.9 percent in developing countries In some low-income developing

recognises that "Data under this heading are often based on small sample surveys or other incomplete information". The available statistics, do not separate unsustainable sources of biomass (e.g., fuelwood from deforestation) from the sustainable (e.g., biodiesel). Until more comprehensive data are published for all countries, it could be assumed that all Combustible Renewables and Waste (CRW) from developed countries are renewable; for developing countries, at least, the CRW applied into electricity production (thus a modern process) can also be considered renewable.

TABLE 2. PRIMARY ENERGY USE, BY REGION, 2001

Region	TPES* (Gtoe)	Population (billions)	toe/capita	Growth rate 1990-2001 %/year
1. OECD (all industrialised countries)	5.33	1.14	4.68	1.52%
2. Commonwealth of Independent States and Eastern Europe	1.03	0.35	2.98	-3.26%
3. Sub-Saharan Africa	0.40	0.67	0.60	2.23%
4. Middle East and North Africa	0.50	0.31	1.62	4.65%
5. Asia Pacific (non-OECD) with China	2.31	3.21	0.72	3.18%
6. Latin America and the Caribbean (without Mexico)	0.45	0.42	1.07	2.64%
World	10.03	6.10	1.64	1.41%
Developing countries (3+4+5+6)	3.66	4.62	0.79	3.19%

* TPES (total primary energy supply) is the indigenous production of energy, plus imports and positive stock changes, minus exports and international marine bunkers.

Source: IEA, 2003c.

countries, traditional biomass accounts for 80 percent or more of total energy use.

There are significant inequities in annual per capita energy use among groups of countries. In 2001, industrialised countries used 4.7 tonnes of oil equivalent (toe) per capita, in contrast to developing countries, which used only 0.8 toe per capita; the world average was 1.7 toe per capita. The per capita energy use in the sub-Saharan region was only 0.6 toe. The rate of growth in energy use also varies across country groups. Between 1990 and 2001, the average annual growth rate in primary energy use in industrialised countries was 1.5 percent; in developing countries, it was more than twice that amount (3.2 percent, with important variations among different regions of developing countries). Population growth and rising levels of economic activity drive this rapid increase (Table 2).

From this overview, it is clear that the availability and use of energy around the world is extremely heterogeneous. The varying growth rates in energy use have helped to reduce the gap in energy services between industrialised and developing countries and are the result of energy efficiency measures in OECD countries, the export of energy-intensive activities to developing countries, and increased access to energy services throughout the world. Nevertheless, the situation remains far from equitable. ■