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2004 SURVEY OF ENERGY RESOURCES

World Energy Council

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SURVEY OF ENERGY RESOURCES

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UK

ELSEVIER B.V.
Sara Burgerhartstraat 25
P.O. Box 211, 1000 AE Amsterdam
The Netherlands

ELSEVIER Inc.
525 B Street, Suite 1900
San Diego, CA 92101-4495
USA

ELSEVIER Ltd
The Boulevard, Langford Lane
Kidlington, Oxford OX5 1GB
UK

ELSEVIER Ltd
84 Theobalds Road
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UK

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Foreword

This 20th WEC *Survey of Energy Resources* contains a chapter for each energy resource, ranging from the conventional fossil fuels to the renewables, both new and traditional. Generally, the coverage of each resource comprises a commentary by a leading expert in the field, followed by definitions, data tables and country notes. The tables summarise the worldwide resources, reserves, production and consumption of fossil fuels and comparable data for non-fossil energy sources, as applicable. The country notes aim to highlight the main features of the resource and its utilisation.

- **Reserves/Resources** – where relevant, tables of fossil fuels provide reserve statistics (covered globally from WEC and non-WEC sources) and amounts in place (as reported by WEC Member Committees);
- **Tabulations** – data tables are arranged on a standard regional basis throughout;
- **Units** – where relevant, data have been provided in alternative units (cubic feet as well as cubic metres, barrels as well as tonnes) in order to facilitate use of survey data in an industry context;
- **References and Sources** – as far as possible, these have been consolidated in introductory notes to the data tables and country notes, or appended to the commentaries on each resource.

Any review of energy resources is critically dependent upon the availability of data, but reliable, comprehensive information does not always exist. While the basis of the compilation was input provided by WEC Member Committees, completion necessitated recourse to a multitude of national and international sources and in some cases estimation. Difficulties in obtaining information continue to be compounded by current trends in the energy sector. The availability of data has been reduced with the process of deregulation and privatisation, as data-reporting channels have been lost or specific items have become confidential. Moreover, problems in the quantification of energy resources persist, in particular for those universally-found resources: solar energy, wind power and bioenergy, owing to their evolutionary status and generally decentralised nature.

Although there will always be a problem with complete documentation of both solar and wind energy, the coverage of both has been much improved in this edition of the *Survey*. The utilisation of these two globally-available resources is expanding at both macro and micro levels but while the information regarding high-profile schemes (e.g. large offshore windfarms or solar roof programmes) is widely available, that for, say, isolated stand-alone wind turbines or PV installations for remote medical refrigeration is not and probably never will be.

Another problematical area is that of the definitions relating to resources and reserves: it is well recognised that each country tends to have its own notion of what constitutes resources and reserves. In this connection, we welcome a contribution from Dietmar Kelter, describing the work of the UN/ECE Ad Hoc Group of Experts which has been developing the UN Framework Classification for Reserves/Resources. In due course it is to be hoped that this work will provide the basis for a worldwide harmonisation of the relevant terminology. In the meantime, the resources and reserves specified in the present *Survey* conform as far as possible with the established definitions specified

by the WEC. It is a matter of judgement for each member country to determine which, among the available assessments of resources and reserves, best meet these definitions. A similar approach has been followed for non-reporting countries, for which the editors have selected the levels of reserves which, in their opinion, are most appropriate.

For this edition of the *Survey* it has been possible to greatly expand and improve the coverage of oil shale and natural bitumen and extra-heavy oil. Globally, whilst not being in today's front rank of developed energy reserves, huge resources of these minerals exist with, at the present time, limited exploitation. Nevertheless, inclusion is vitally important for the time when their large-scale development may become a reality.

With a wealth of R&D being undertaken in the marine energy sector, the focus is primarily on harnessing energy from tidal currents, rather than by means of barrages. For this reason, coverage of the two modes has been combined into one chapter (Tidal Energy).

As editors, we strive to develop and maintain contacts in the energy world and hope that in time the availability of data will not only improve but expand to cover those energy resources that presently go unrecorded (or under-recorded).

We are grateful to all those who have helped to produce this *Survey*: we extend our thanks to the WEC Member Committees, to the authors of the Commentaries and to Alessandro Clerici for his guidance and for contributing the Overview.

Judy Trinnaman and Alan Clarke
Editors

Overview

Any long-term strategic decision requires due diligence and hard data. This is particularly true in the energy sector, with its long project lead times, which can span decades. The World Energy Council has been producing the *Survey of Energy Resources*, a unique and authoritative reference publication on global energy resources, since 1934. This is the 20th edition of the this triennial *Survey*.

Access to energy is fundamental to our civilisation, and economic and social development is fuelling a growing demand for reliable, affordable and clean energy. Moreover, nearly 1.6 billion people, or roughly a quarter of the world's population, today lack access to modern energy services. On the other hand, global energy resources are abundant and energy production, conversion and transport technologies are improving rapidly. This makes it possible to transport energy ever more efficiently over long distances and creates logistical conditions which were unimaginable just a few years ago. At the same time, environmental factors are playing an increasingly important role in shaping the global energy sector and the entire energy supply and use chain.

Following a period of low oil prices and the ensuing complacency at the end of the 20th century, energy security is back on political and public agendas: geopolitics is a major factor shaping the world today. Recent events, including the increasing tensions in the oil-rich Middle East, highlight the fragility of the world's energy supply system and raise concerns over politically motivated supply disruptions and resulting price volatility. These concerns are not based on the overall availability of resources, but on the concentration of strategic energy resources in a few countries.

The ongoing privatisation and market liberalisation processes around the world, and the evolving energy regulation and environmental legislation, are creating even more uncertainties in the market. This calls for a balanced approach to the planning of the energy mix and for a maximum deployment of domestic energy resources when feasible. Local resources and renewable energies, together with improved efficiency throughout the whole production, supply and use chain will contribute to improving energy security.

The focus on short-term shareholder returns prevailing in the global capital markets today is detrimental to many energy projects, which offer long-term returns that are moderate but reliable.

Fossil Fuels

Global reserves of the main fossil fuels, particularly coal, are large enough to ensure their continuing dominance of energy supply for the foreseeable future.

Coal

Coal – the most abundant and widely distributed fossil fuel – can provide an affordable, reliable, and safe source of energy for hundreds of years, but today it faces serious environmental challenges. Although there are advanced clean coal technologies, which significantly reduce emissions from

coal-fired power generation plants, their costs are high. This will inevitably inhibit their wider deployment in the regions and countries where the use of coal is expected to grow most. Moreover, the issue of the high CO_2 emissions of coal-fired plants compared to gas-fired combined cycle technologies remains unresolved.

Oil

The past couple of years have clearly demonstrated the volatile nature of oil and the world's continuing dependence on this leading energy resource. The doubling of oil prices during the last few years has not, however, been caused by dwindling reserves. The *Survey* demonstrates that global reserves of oil are still large enough to meet the demand for the next few decades, and the continuous improvement in exploration, processing, conversion and end-use technologies may extend this period even further. Concentration of oil resources in a few regions and long supply routes to the main markets are at the heart of the issue.

Natural Gas

Global natural gas reserves are large and currently yield a reserve/production ratio of 50 to 60 years. It is widely expected that in the coming 2-3 decades natural gas will overtake oil as the most important energy resource in the world. Few, however, realise that this would be a huge challenge, not least due to the enormous investment requirement. Where will the necessary investment come from? The most prominent project in the gas industry so far, the development of the Troll gas field in the Norwegian part of the North Sea, has cost billions of euros to implement. Such investment would have hardly been possible on the basis of spot market prices.

It is also expected that LNG will be playing an increasingly important role, particularly in supplying remote markets. Its market penetration will continue to grow, spurred by technological developments in the liquefaction/re-gasification processes and a reduction in transport costs.

Uranium and Nuclear

As a result of growing international efforts in nuclear disarmament at the end of the last century, nuclear fuel from surplus military plutonium entered the commercial market and began to curtail demand for freshly mined uranium. Currently, freshly mined uranium accounts for just over half of the global annual reactor fuel demand, with the balance provided by secondary sources. Known uranium reserves are more than adequate to cover the requirements of existing reactors during their lifetimes and beyond.

In mid-2004 the nuclear power industry celebrates its 50th anniversary. The first nuclear power plant in the world was commissioned in Obninsk, Russia in 1954. Nuclear power's share of worldwide electricity supplies has been steady at 16–17% for many years, but it is expected to decline as old plants are de-commissioned and only a few new ones built. Reactor safety, waste disposal and plant decommissioning are still matters of concern.

Demand for new nuclear power is coming primarily from Asia, while in Western Europe, the only new nuclear reactor to be constructed is a 1 600 MW_e European Pressurised Water Reactor ordered by the Finnish utility TVO.

Renewable Resources

Although the worldwide production of renewable energy is expected to grow quickly, its share of the global energy mix will hardly increase.

Hydropower is the largest and most important renewable resource and generates about 17% of the world's electricity. It is estimated that only 33% of the technically and economically feasible global potential of hydropower has been developed to date, although there are significant regional variations. In Europe and North America, the majority of sites have been developed, while considerable potential for new development remains in Africa, Asia and South America. Large hydropower schemes, however, often face challenges due to their environmental impacts and long-term returns on investment.

Non-hydro renewables are expected to make a growing contribution to global power generation, even if their total share is likely to reach only about 5% in 2030.

Biomass has the potential to become the world's largest and most sustainable renewable energy source. To progress from this "potential" stage, both production and end-use technologies must be modernised.

Wind is often considered to be the most advanced of the renewables, after hydropower. Offshore projects spur the development of larger machines and wind turbines of up to 5 MW are about to enter the market. However, the electricity systems with an increasing share of wind power in their fuel mix will have to face new challenges. Experience in those countries with a high share of wind in their electricity production (i.e. ~20% and above), demonstrates the problems of integrating an intermittent energy source into the grid and the implications this can have for the global power system performance, including the need for new concepts for power plant operation scheduling and system control.

Geothermal is an important renewable resource and it can be utilised for base-load electricity production. The best geothermal fields are located within well-defined belts of geologic activity. Geothermal energy converting systems are able to provide electricity with an annual capacity factor of over 90%.

Solar radiation, the earth's prime source of energy, is being increasingly utilised. While photovoltaic (PV) power generation is still the most expensive solar technology, costs are falling and its versatility enables it to find many stand-alone applications.

Other Resources

The 2004 *Survey of Energy Resources* also presents the status of other energy resources, namely peat, oil shale, tidal, OTEC (ocean thermal energy conversion), natural bitumen and extra-heavy oil, wave and wood, all of which have a potential to help meet growing demand for energy around the world.

Environmental laws which penalise emissions from power plants or transportation and grant subsidies to selected renewables can create artificial local niches for certain energy sources. This may have an adverse impact on global energy prices and investment.

Conclusions

The overall conclusion drawn from this edition of the *Survey* is that there is no shortage of energy resources around the world. However, the physical concentration of the leading strategic resources in

only a few regions is a serious concern for many countries dependent on imported supplies. A diversified fuel mix is a prerequisite for energy security, stability of prices and supply, and should be taken into consideration when developing national energy plans or long-term business strategies, in particular against the background of the growing short term focus of the liberalised energy markets.

Alessandro Clerici
Chairman, Survey of Energy Resources Committee
Chairman, WEC Italian Member Committee

Contents

Chapter 1

Coal (including Lignite)

COMMENTARY

Three years have passed since the last *Survey of Energy Resources* was published, and in that time the coal industry has seen some significant changes. Total world production has increased, yet the number of companies involved in coal mining has reduced, and there has been a notable shift both in demand and production to the Asian market.

That coal can continue to supply the world's energy is not in doubt. The IEA has stated 'World reserves of coal are enormous and, compared with oil and natural gas, widely dispersed…. Proven coal reserves have increased by over 50% in the past 22 years. The correlation of strong growth of proven coal reserves with robust production growth suggests that additions to proven coal reserves will continue to occur in those regions with strong, competitive coal industries'.

Global Recoverable Reserves and Production

Based on figures (data to end-2002) given by WEC Member Committees and from a variety of other sources, total recoverable reserves (i.e. those deposits that are economically viable at today's prices and can be recovered using current technologies) have slightly reduced by 8% since 1999, to just under 910 billion tonnes. This is almost entirely due to economic re-appraisal of the German coal mining industry—worldwide the proven reserve base represents nearly 200 years of production at current rates.

However, production figures show an increase of 11% over 1999 levels. Of this, sub-bituminous coal production remained more or less at the same level, while bituminous coal production increased by 440 million tonnes and lignite by 35 million tonnes.

Africa

The bulk of Africa's 220 mt total coal production in 2002 was bituminous coal, dominated by South Africa. 45 thousand tonnes of sub-bituminous coal was produced, from just two countries—Malawi and Nigeria. Although overall production in Congo and Tanzania is low, there have been significant relative gains since 1999. Egypt has experienced a major decline in coal production, from 200 000 tonnes in 1999 to only 37 000 tonnes in 2002.

The proved recoverable reserves figure for Africa has been downgraded by 9%, owing to a significant reappraisal of the reserves reported for Botswana.

2004 Survey of Energy Resources

North America

The amount of proved recoverable coal reserves in Canada, Mexico and Greenland has remained static, with a slight decrease reported for the USA. Total reserves for North America amount to about 250 billion tonnes. Overall production figures show a similar story—a decrease for the region of around 1%, to just over 1 billion tonnes. The USA accounts for the bulk of this production, with 990 mt. It reports increased production of sub-bituminous coal, with a decrease in bituminous coal production in the order of 50 mt.

South America

Production in South America has increased by roughly 16% over the period—notably due to increased production of bituminous coal in Colombia and Venezuela for the export market. There has been a halving of the already low levels of production in both Argentina and Chile.

In regional terms, South America has the second lowest proved recoverable reserves figure, at just under 20 mt, an 8.5% decrease from the 1999 figures.

Asia

The overall production figures for the Asian region have increased by 26%, reflecting the increasing importance of the region as both a supplier and consumer of coal. The major producers are China (1.4 billion tonnes), India (360 mt) and Indonesia (103 mt). Both Japan and Korea have significantly reduced their coal production, due to the high cost of domestic production compared to the price of imported coal on the Asian market.

Reserve figures for the region have remained stable at nearly 260 billion tonnes, a slight increase of 2% over 1999.

Over recent years there have been some concerns raised over the accuracy of Chinese coal statistics, which as such a large supplier can have significant impacts on global demand and production figures, and affect global environmental issues such as CO_2 emissions. It is interesting to note that the end-2002 reserves figures reported for China are the same as at end-1999.

Europe

Coal production in Europe has slightly increased over the 1999 figures, mainly through higher levels of lignite production. Bituminous coal production has decreased, notably in Germany, Spain, France, Poland and the UK.

Proven reserves are significantly lower than in 1999, with a reduction of over 20% during the period. The bulk of this is due to the very significant decrease in the size of German reserves, which due to the economic reappraisal of the mining industry have reduced by almost 90%, from 66 billion tonnes in 1999 to just under 7 billion by the end of 2002.

Middle East

Iran is the only coal producer in the Middle East region, producing 1.8 mt in 2002, an increase of 17% over 1999. Proved recoverable reserves have fallen by 75%, from 1 710 mt in 1999 to just 419 mt in 2002.

Oceania

Australia is the world's leading exporter of coal, and is ranked 4th worldwide in terms of annual production, with 340 mt in 2002. The majority of the coal produced is bituminous coal for export, although it does have a sizeable lignite industry supplying the domestic power generation market. New Zealand is a small producer for a mainly domestic market, although it does export some specialist coals, e.g. for carbon steel. Reserves in New Zealand have remained static, although a 4% drop in bituminous coal reserves in Australia is reported.

Fig. 1.1 shows proven coal reserves by geographical distribution, highlighting the dominance of three key regions—Europe, North America and Asia. Coal resources are more geographically widespread, while reserves are governed by economic viability—and thus are more likely to be concentrated in countries where coal is a commodity, either for domestic

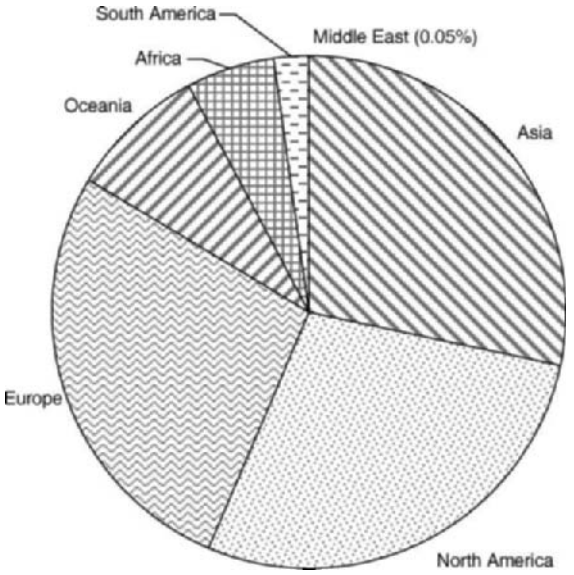

FIGURE 1.1 Proved coal reserves at end-2002—regional distribution.

energy use or as an export product. The top 10 producing countries together make up 85% of total global coal production (Fig. 1.2).

Coal reserves can change significantly and rapidly, as policies change and resources lose

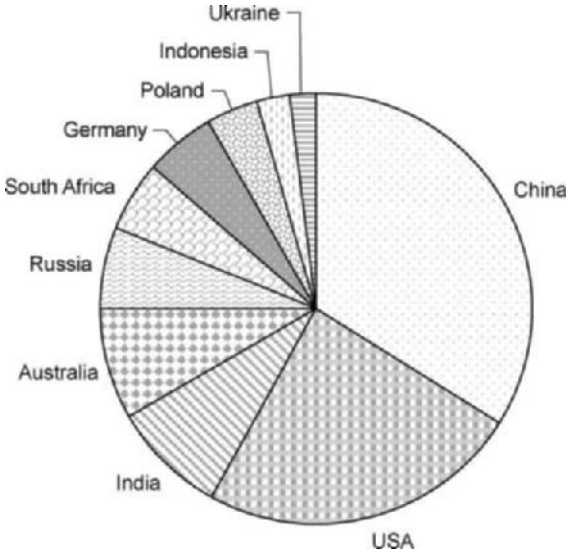

FIGURE 1.2 The top ten coal producing countries in 2002.

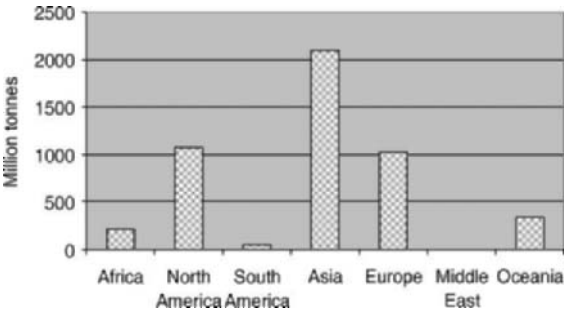

FIGURE 1.3 Coal production, 2002—by region.

or gain viability. This is clearly shown in the European data, where despite maintaining overall production figures (due to increased lignite production in Germany and Greece), European reserves have shifted downwards since 1999, reflecting the decline in the hard coal industry in Western Europe and restructuring in the transitional economies, particularly in Poland.

That Asia is now the focus of global production can clearly be seen in Fig. 1.3. With over 2 billion tonnes of coal produced, an increase of over 25% between 1999 and 2002, the Asian region coal production is double that of the next largest, North America. With global proved recoverable reserves remaining high it would seem there is no practical restraint on the continuing use of coal.

Coal Demand

Significant changes in the location of coal demand have taken place over the last 20 years. In 1980 Europe, the former Soviet Union and North America consumed roughly the same quantities of hard coal for their power generation and steelmaking needs. North America's demand has stayed roughly static, as a percentage of total global consumption (in real terms, an increase of 300 mt over the period). However, by 1990 the trends were of decreasing demand in Europe and the FSU. Demand in the Asia–Pacific region for hard coal, in contrast, has increased

dramatically from 34 to 52% over the same period—equivalent to almost 1 billion tonnes.

According to the BP Statistical Review of World Energy, world coal consumption increased by 6.9% in 2002. However, this was almost entirely a Chinese phenomenon: reported consumption in China rose by an extraordinary 27.9%. Excluding China, world coal consumption grew by just 0.6%.

One reason for this is the huge increase in demand for electricity in Asian countries. China's electrification programme, for example, has connected 700 million people over the last 15 years. As a result of the programme, annual electricity production in China has increased by nearly 1 000 TWh: 84% of this is coal-fired. Forecasts indicate that this regional trend will continue, with the bulk of the projected increase in global coal demand coming from the region. According to IEA reports, China has experienced an ongoing decline in coal demand since 1996, but demand increased strongly in 2002, largely owing to continued strong economic growth.

Japan continues to be the largest importer of hard coal—both steam coal and coking coals—and is projected to account for 24% of total world imports by 2020. Other Asia–Pacific countries, such as Malaysia, the Philippines and Thailand, are looking to coal to diversify their energy mix and provide a secure supply of affordable energy to meet their growing electricity needs.

The decline of coal consumption in the EU can be attributed to a number of factors, including more stringent environmental legislation, the availability of gas from the North Sea and Russia, as well as increasingly from North Africa and the Middle East. As older coal-fired plant faced retirement, the capital costs of building combined-cycle gas plant were considerably lower than building a new coal-fired plant with the required environmental controls, and at a time when gas prices were relatively low, were the economic option. However, such long-term decisions can be affected by the vagaries of the gas market—as happened in the UK in 2001 when coal-fired plants were brought back on-line owing to sudden increases in gas prices.

Coal Trade

In 2002, hard coal trade continued to expand, growing to 623 mt (435 mt steam coal, 188 mt coking coal). Worldwide hard coal trade is divided into seaborne trade of 579 mt and internal trade of 44 mt. Steam coal exports from Russia increased by 33% over 2001 levels and from Australia by 6%. Significant reductions in exports were seen from Kazakhstan, China, the USA and Colombia. Coking coal exports generally decreased in 2002, with the exception of China, which achieved a 20% increase in shipments.

In 2002, international hard coal trade in maritime traffic totalled about 16% of the worldwide hard coal output. Almost 85% of hard coal output is thus consumed in the producing country itself—in particular for power generation and by some key industries, such as iron and steel, cement and chemicals. This is especially true for the three biggest hard coal producers—China, the USA and India.

However, between 1998 and 2001 coal exports from China grew from 32 to 90 mt—an increase of 179%, making it the world's second largest coal exporter. Preliminary Chinese data suggest that 2002 exports of 84 mt would maintain China's position in the world export league.

Environmental Issues

Environmental policies are the key factor in determining the *future* role of coal around the world. While coal can and does provide an affordable, reliable, secure and safe source of energy it, along with other fossil fuels, continues to face environmental challenges. The introduction of carbon taxes, emissions trading and other policies to restrict emissions of greenhouse gases to the atmosphere will have an adverse effect on

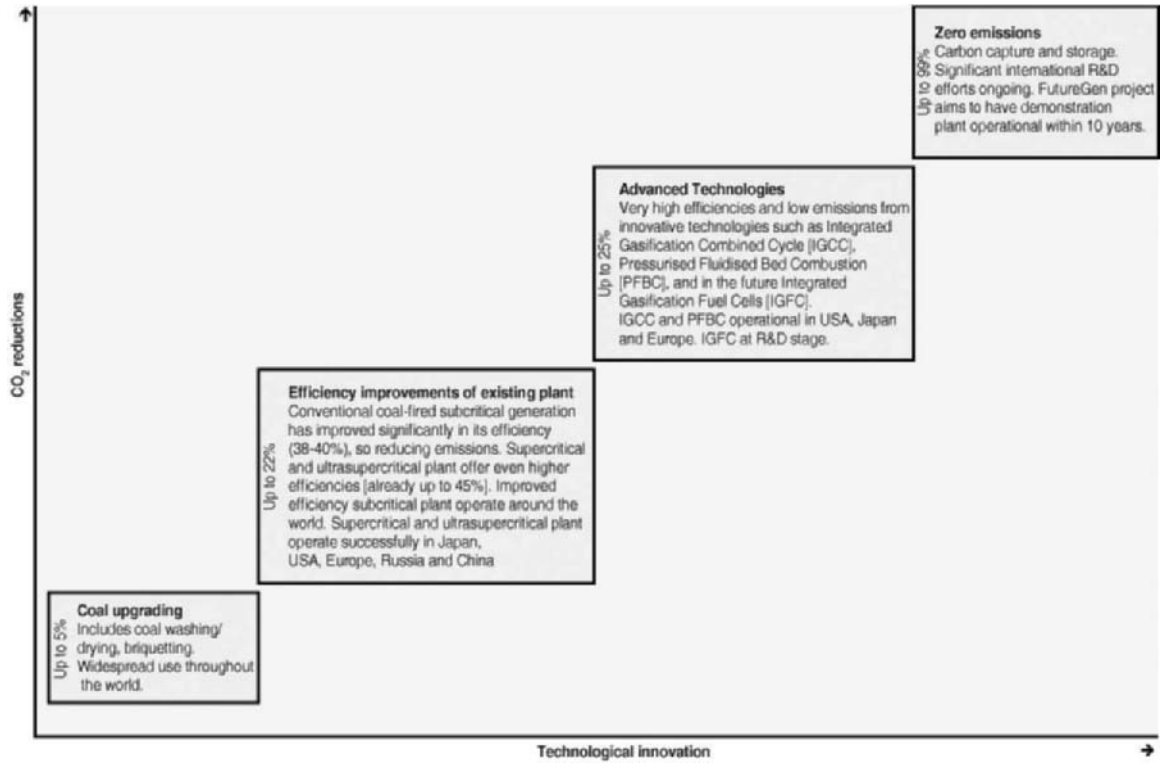

FIGURE 1.4 The coal-fired route to CO_2 reduction (Source: WCI, 2003).

the global coal market. Yet the crucial issue is how coal is used, not the fuel itself (Fig. 1.4).

Technologies have already been developed that are capable of almost entirely eliminating local and regional pollutants from coal-fired power generation, and efficiency gains can significantly reduce carbon dioxide emissions—the thermal efficiency of coal-fired electricity generation underwent an eight-fold improvement during the 20th Century. However, if coal is to maintain its place in the energy mix of the future, the development and deployment of improved coal technologies has to continue.

Ongoing developments in supercritical conventional coal combustion are likely to bring the thermal efficiency of coal burning to over 50%. The gasification of coal in integrated combined cycle (IGCC) systems is becoming increasingly well understood and commercially practical. Near-zero emissions can be realised if such IGCC systems are combined with emerging carbon-capture and storage technology.

Indeed coal, via gasification technology, has the potential to become a mainstay of a future 'hydrogen economy'. It is an abundant potential source of the huge quantities of manufactured hydrogen that would be required for the widespread application of emissions-free hydrogen-based energy systems.

Christine Copley
World Coal Institute

DEFINITIONS

Proved amount in place is the resource remaining in known deposits that has been carefully measured and assessed as exploitable under present and expected local economic conditions with existing available technology.

Maximum depth of deposits and **minimum seam thickness** relate to the proved amount in place.

Proved recoverable reserves are the tonnage *within* the proved amount in place that can be recovered in the future under present and expected local economic conditions with existing available technology.

Estimated additional amount in place is the indicated and inferred tonnage *additional to* the proved amount in place that is of foreseeable economic interest. It includes estimates of amounts that could exist in unexplored extensions of known deposits or in undiscovered deposits in known coal-bearing areas, as well as amounts inferred through knowledge of favourable geological conditions. Speculative amounts are not included.

Estimated additional reserves recoverable is the tonnage *within* the estimated additional amount in place that geological and engineering information indicates with reasonable certainty might be recovered in the future.