

## ENVIRONMENTAL EFFECTS OF FOSSIL FUEL COMBUSTION

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### Summary

Fossil fuels, which include coal, natural gas, petroleum, shale oil, and bitumen, are the main sources of heat and electrical energy. All these fuels contain—besides the major constituents (carbon, hydrogen, oxygen)—other materials including metal, sulfur, and nitrogen compounds. During the combustion process different pollutants like fly ash, sulfur oxides ( $\text{SO}_2$  and  $\text{SO}_3$ ), nitrogen oxides ( $\text{NO}_x = \text{NO}_2 + \text{NO}$ ), and volatile organic compounds are emitted. Fly ash contains different trace elements (heavy metals). Gross emission of pollutants is tremendous all over the world. These pollutants are present in the atmosphere in such conditions that they can affect man and his environment.

Air pollution caused by particulate matter and other pollutants not only acts directly on the environment but by contamination of water and soil leads to their degradation. Wet and dry deposition of inorganic pollutants leads to acidification of environment. These phenomena affect the health of the people, increase corrosion, and destroy cultivated soil and forests. Most of the plants, especially coniferous trees are not resistant oxides. Following longer exposure leaves wither and fall. Widespread forest damage has been reported in Europe and North America. Many cultivated plants are not resistant to these pollutants, especially in the early period of vegetation.

The mechanisms of pollutant transformation in the atmosphere are described by environmental chemistry. Photochemistry plays an important role in these

transformations.  $\text{SO}_2$  and  $\text{NO}_x$  are oxidized and sulfuric and nitric acids are formed in the presence of water vapors, fog, and droplets.

Other problems discussed, connected with human activities, are the emission of volatile organic compounds to the atmosphere. These emissions cause stratospheric zone depletion, ground level photochemical ozone formation, toxic or carcinogenic human health effects, and growth of the global greenhouse effect, accumulation and persistence in the environment.

Wet flue gas desulfurization (FGD) and selective catalytic reduction (SCR) can be applied for flue gas treatment, and  $\text{SO}_2$  and  $\text{NO}_x$  emission control.

## 1. Fossil Fuel Sources

Fossil fuel includes coal, natural gas, petroleum, shale oil, and bitumen. They all contain carbon and were formed as a result of geological processes from the remains of organic matter produced by photosynthesis hundreds of millions of years ago.

Man has used coal for a long time, first as a fuel to generate heat, and then to generate electrical energy. In the production of heat and energy its three variations are used: peat, lignite, and bituminous coal. Peat deposition is the first step in coal formation. Dried peat burns readily with a smoky flame and a characteristic odor. Vast peat beds occur in Europe, North America, and Northern Asia but are worked only where coal is deficient. In Ireland, millions of tons of peat are consumed annually. Russia, Sweden, Germany, and Denmark also produce and use considerable quantities. Peat is used locally in England and Scotland.

Lignite occupies a middle position between peat and bituminous coal. World production of lignite in 1992 was 308 million tons, of which Germany (mostly the eastern part) reached 135 million tons, Russia, 130 million tons. (CIS, 135 million), Czech Republic and Slovakia, 60 million tons, Poland, 67 million tons, Greece, 51 million tons, Romania 38 million tons, Turkey 45 million tons, and Bulgaria 28 million tons. One to two percent of the world lignite production comes from Spain, Hungary, India, Thailand, and North Korea. Lignite is largely extracted from open pits, where thermal-electric power stations are located. In countries that do not possess the supplies of bituminous coal there also exist underground mines of this coal. Lignite is characterized by its large content of ash, moisture, and often sulfur. Bituminous coal is a considerably more efficient fuel (combustible value in a moist and ash-free state is ca. 24 MJ/KG).

Deposits of bituminous coal and of anthracite exist mostly in Carboniferous and Permian formations. The area with the greatest accumulations of Carboniferous coal is the Euro-American province, stretching from eastern parts of South America across Europe to West Asia. This region contains over 22% of the world's supply of bituminous coal. The area of the land of Gondwana, which stretches across Central and Eastern Asia, Australia, South Africa and South America, is characterized by the occurrence of Permian carbons. This area contains roughly 17% of the world's supply of bituminous coal and lignite. The bituminous coal from the Mesozoic age (upper

Triassic period, Middle Jurassic period, Lower and Upper Cretaceous period) and the Tertiary period is of less economic significance.

Geological resources of bituminous coal together with anthracite are  $772.5 \cdot 10^9$  t and balance resources  $492.5 \cdot 10^9$  t. The largest quantity of geological supplies occurs in Asia (71%), and the largest supplies of balance resources are in Asia (44%) and America (26%).

Bituminous coal and anthracite are extracted in 40 to 45 countries by about 20 000 mines, mostly underground with different degrees of gas hazard. This hazard is greatest in mines of bituminous coal and of similar types. The hazard is due to the susceptibility of coals to self-ignition in underground excavations. In China the excavation is performed in little mines organized into cooperatives.

In 1992, world production of bituminous coal was 3179 million tons, of which China produced 1000 million tons, the USA produced 607 million tons, the CIS 489 million tons, India 213 million tons, South Africa 177 million tons, Australia 180 million tons, Poland 132 million tons, GB 83 million tons, and Germany 66 million tons. One to two percent of the world's production is reached by Canada, North Korea, below one percent is produced by Colombia, South Korea, Spain, Indonesia, Czech Republic, France, and so on.

## **2. Energy Demand and Air Pollution**

When coal was used to produce heat for warming flats and for cooking in greater municipal agglomerations, disadvantageous influences on the environment from its combustion were observed. Americans may think smog was invented in Los Angeles. Not so. In fact, and Londoner coined the term “smog” in 1905 to describe the city's insidious combination of natural fog and coal smoke. Smog in London predates Shakespeare by four centuries. Until the twelfth century, most Londoners burned wood for fuel. But as the city grew and the forests shrank, wood became scarce and increasingly expensive. Large deposits of “sea-coal” off the northeast coast provided a cheap alternative. Soon, Londoners were burning the soft, bituminous coal to heat their homes and fuel their factories. Sea-coal was plentiful but it didn't burn efficiently and much of its energy was spent making smoke, not heat. Coal smoke drifting through thousands of London chimneys combined with clean natural fog to make smog. If the weather conditions were right, it would last for days.

Early on, nobody had the scientific tools to connect smog with adverse health effects, but complaints about the smoky air as an annoyance date back to at least 1272, when King Edward I, on the urging of important noblemen and clerics, banned the burning of sea-coal. Anyone caught burning or selling the stuff was to be tortured or executed. The first offender caught was summarily put to death. This deterred nobody. Out of necessity, citizens continued to burn sea-coal in violation of the law, which required the burning of wood few could afford. Sadly, the problem of wood shortages exists today. The one important renewable resource, fuel wood, which supplies 20 or even 30 percent of energy in some rural economies, is running out and there is a world shortage. It is ironic that the first fuel resource to run into really short supply is a “renewable”

resource. The effect of this shortage on hundreds of millions of inhabitants of sub-Saharan Africa is to reduce even further their subsistence level lifestyle. The combustion of coal in household furnaces, so-called low emission, is still a nightmare for many municipal authorities. Such furnaces do not use modern technologies for combustion or the cleaning of fumes, practices possible in the case of large professional power stations.

The inventions of Edison, who also started the first power station using a direct current (1882), introduced mankind into the era of electricity. After the First World War people began building heat and power generating plants in the USA, Western Europe, and the Soviet Union. It should be mentioned, that the first water power station was established in Lauffen in 1891 and the first nuclear power station in Colder Hall, Great Britain in 1956. World demand for energy has increased over the course of the last two hundred years by an average 2.3% a year. Today, electrical energy constitutes about one-third of energy used on a global scale. Figure 1 presents the energy demand per person throughout the history.

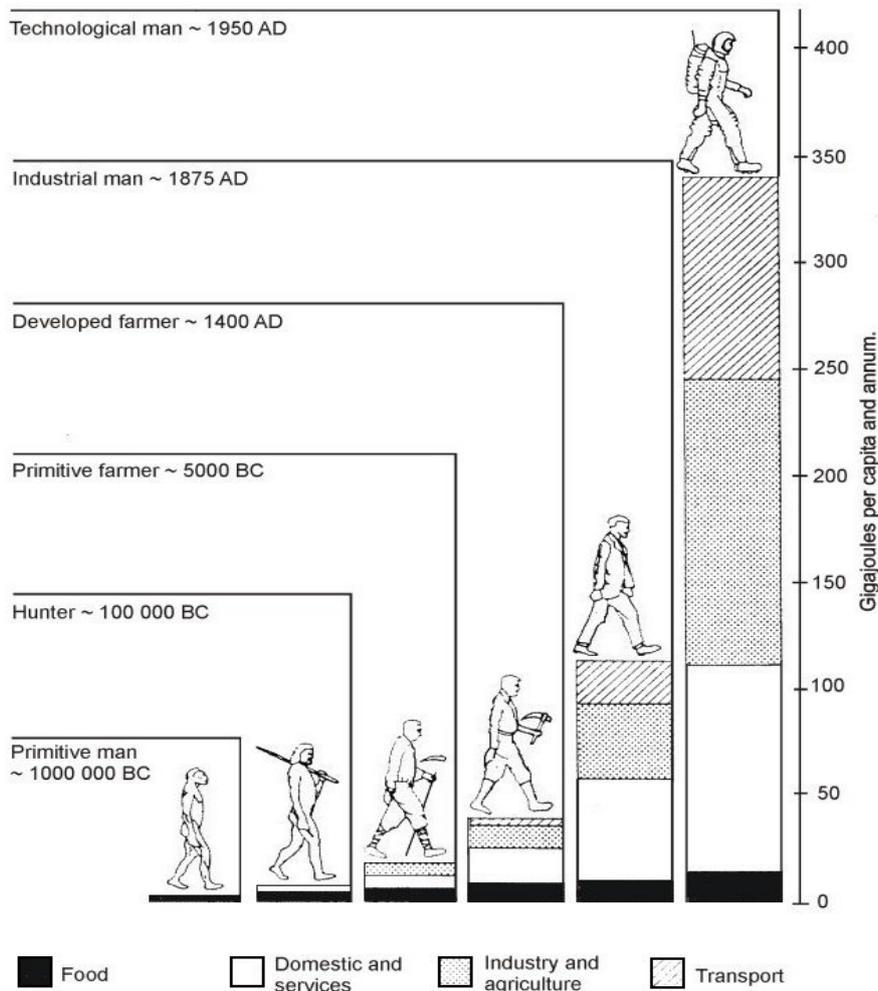


Figure 1. Individual energy consumption. The Services sector includes teaching, trade, office work, etc

If the whole world could be brought up to Western Europe's living standard, which requires for its maintenance about six tones of coal equivalent per person per year (that is 61 kW electric fires burning day and night for each of us, then the world's proved discovered fossil fuel resources, coal, oil, and gas, would last for just 17 short years. As it is, there are  $31.4 \times 10^{21}$  Joules of proven fossil fuel's reserves (coal 20.3, oil and gas 11.1); at current rates of demand of  $400 \times 10^{18}$  Joules per annum the resources will last for 80 years. Nuclear energy could transform the situation if we choose to use it. As it is, every year we burn fossil fuel that took a million years to form. Therefore, in some 200 years, starting from the middle of the last century, we will have burnt all the fossil fuel formed during the history of the world. There is currently a glut of fossil fuels but as the developing world industrializes and its economies expand, that glut could quickly become a famine 25 years from now.

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### Bibliography

- Baumbach G. (1996). *Air quality control*, 490 pp. Berlin, Heidelberg: Springer.
- Bocleris J. O'M., ed. (1978). *Environmental Chemistry*. New York and London: Plenum Press.
- Connel D.W. (1997). *Basic concepts of environmental chemistry*, 506 pp. New York: Lewis Publishers.
- Dtanners D. and Bourdean P. (1995). *Europe's Environment*. Copenhagen: European Environment Agency.
- Dunderdale J., ed. (1990). *Energy and the Environment*. Cambridge: Royal Society of Chemistry.
- IAEA (1991). *Electricity and the Environment*. Vienna: IAEA.
- Markovic V., Chmielewski A. G., and Zimek Z., eds. (1995). Radiation processing of combustion flue gases. *Radiation Physics and Chemistry*, 45(6), 939–1038.
- Sawyer C. N., McCarly P. L., and Parkin G. F. (1994). *Chemistry for Environmental Engineering*, 658 pp. New York: McGraw-Hill, Inc.

### Biographical Sketch

**Andrzej Grzegorz Chmielewski** was born in Warsaw in 1943. In 1967 he graduated from the Warsaw University of Technology where he obtained his Ph.D. (1974) and D.Sc. (1984) in chemical engineering. He was appointed Professor in 1992. Six Ph.D. theses and 15 M.Sc. diploma theses were performed under his supervision. In 1967-1983 he was employed at the Warsaw University of Technology (Institute of Process and Chemical Engineering). In 1976-1977 he worked as Postdoc. Res. Assoc. at the Chemistry Department, University of Tennessee, Knoxville, USA.

Since 1983 he has been working at the Institute of Nuclear Chemistry and Technology, at the beginning as Head of the Department and since 1986 till 2001 as Scientific Director of the Institute. Recently he is a Head of the Department at the Institute and holds position of the Professor at the Warsaw University of Technology (Department of Chemical and Process Engineering). He has lectured in Japan, Brazil, Syria and Saudi Arabia and served as UN expert to China, the Philippines, Iran, Brazil, Ukraine, Chile, Malaysia and South Korea. He is author and co-author of over 100 papers, two textbooks and over 45

patents (including patents in the USA(3), Germany(2), Canada, Japan, China, Russia, Ukraine). Many of invented solutions were implemented in industry. Among them new type wastewater equalizer-clarifier constructed at the biggest Polish refinery Orlen, Plock and the installation for electron beam flue gas purification from SO<sub>2</sub> and NO<sub>x</sub> for 100 MW<sub>e</sub> block at EPS Pomorzany, Szczecin (second plant in the world using this process). In 1999 he was awarded with the title “Engineer of the Year” by prestigious Polish professional journal “Technical Review”.

Professor Chmielewski is the Editor-in Chief of the scientific journal “Nukleonika.” Vice-chairman of the Atomic Energy Council, a member of the Board and in the years 1999-2001 President of the Polish Nuclear Society, vice-president of the Council of the Radiation Research Foundation, member of the Advisory Board of the “Europe Nuclear Worldscan” (ENS, Switzerland), a member of the Scientific Council of many Institutes.