Département de
Génie Energétique et Environnement
INSA
Lyon, France

Department of Civil and Environmental
Engineering
Luleå University of Technology
Luleå, Sweden

Coal Fire Emission Contributes to Global Warming

Bruno GERVET

Supervisor: Prof. Bo Nordell

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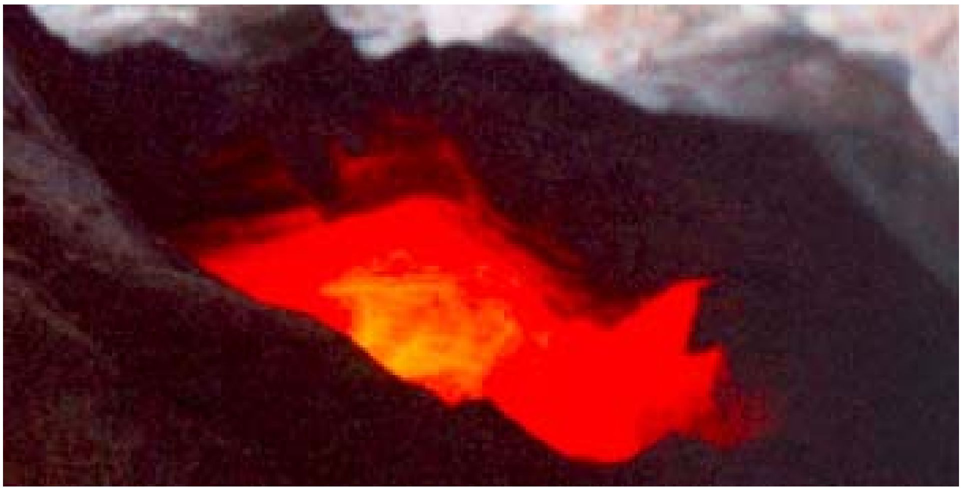


Renewable Energy Research Group
Division of Architecture and Infrastructure
Luleå University of Technology
SE-97187 Luleå, Sweden

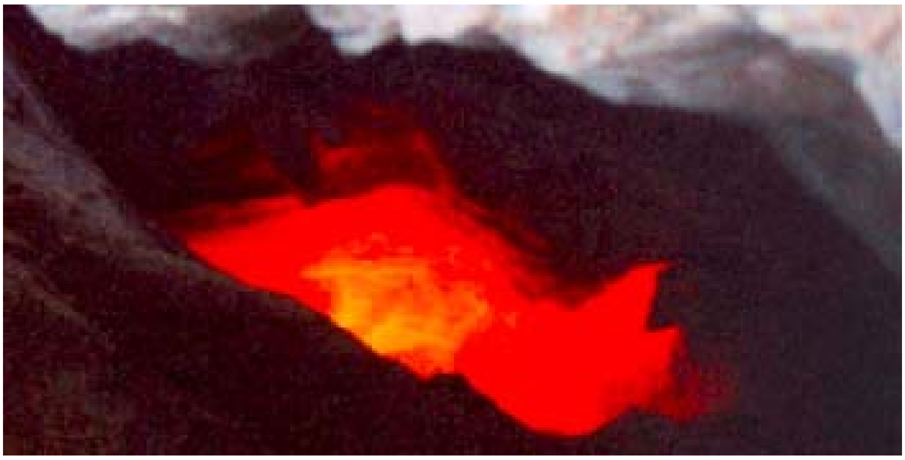
1. Net Heat Generation from Coal Fire

1.1. Background

Although global warming is scientifically accepted, its cause is still disputed. Nordell (2003) suggested a most natural explanation; that this warming is a result of heat emissions from the global consumption of non-renewable energy. Global warming means that heat has been accumulating in air, ground, and water since 1880. During the same period heat was released into the atmosphere by heat dissipation from the global use of fossil fuel and nuclear power. Any such thermal pollution must contribute to the warming. A comparison of accumulated and emitted heat show that heat emissions explains 55% of the global warming. Moreover, the amount of emitted heat is underestimated, since the non-commercial use of fossil fuel is not included, e.g. gas flares, underground coal fires, oil used in production of plastics, and also biofuel (wood) consumed at a greater rate than the growth. Here, the task was to estimate the heating caused by one of the non-commercial energy sources, the coal fire.

1.2. Definition

A coal fire is the underground smouldering of a coal mine (See picture 1.1). Such fires have economic, social and ecological impact. Mine fires can burn for very long periods of time (from months to centuries), until the seam in which they smoulder is exhausted. Because they are underground, they are extremely difficult and costly to reach and extinguish.



Pict. 1.1*, Coal Fire in northern China.*

Ironically, till recently, such a major environmental hazard was overlooked by the international community. Some reasons that can be attributed to the rather low levels of concern are:

- Ignorance of the magnitude of the problem;
- Scattered nature of the information/data on coal fires;
- Secrecy and reluctance on the part of related organisations to even acknowledge the occurrence/magnitude of the problem;
- Side-tracking the issue by the funding agencies/policy makers in preference to other issues which have already gained international attention;
- Limited research groups focussing on the problem (also related to limited funds available for such research).

1.3. Origin of Coal Fire

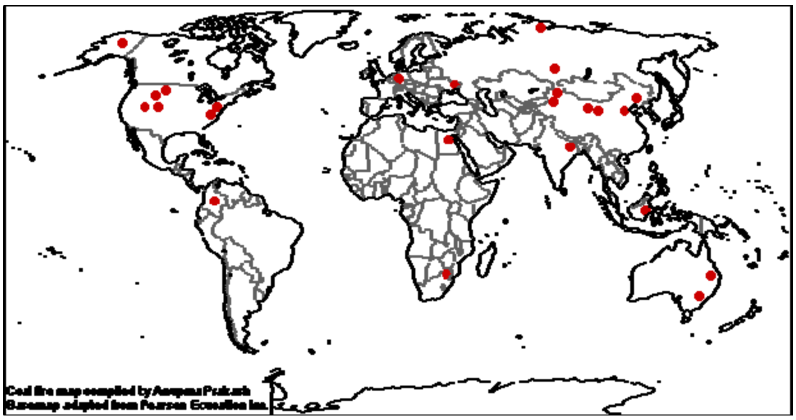
Mine fires may begin as a result of an industrial accident, generally involving a gas explosion. Historically, some mine fires were started when bootleg mining was stopped by authorities, usually by blowing the mine up [1]. Many recent mine fires have started from people burning trash in a landfill that was in proximity to abandoned coal mines.

Some fires along coal seams (See picture 1.2) are natural occurrences. Some coals may self-ignite at temperatures as low as 40 °C, as spontaneous combustion; because it is the most important process that can spark off a coal fire, it will be developed in section 1.5. It is also highly possible that fires can occur when a forest wildfire above the ground conducts its heat through the rock. Additionally, frictional energy from mining machines and negligent acts of mine workers can also trigger coal fires. According to Anupma PRAKASH some of the coal fires in the Jaharia Coalfield in India started due to illegal distillation of alcohol in abandoned deep mines [2].
The most important thing is that once the coal seam catches fire, the problem gets more and more difficult to tackle.

Pict. 1.2, *Coal Seam, Wuda, China [7].*

1.4. Distribution

The problem of coal fires is as widespread as the geographic occurrence of coal. The nature and magnitude of the problem differs from country to country. The Map 1.3 showing the distribution of coal fires around the world is far from complete. It only depicts the better known and documented coal fire occurrences.



Map 1.3, *Distribution of coal fires around the world [2].*

Globally, thousands of inextinguishable mine fires are burning, especially in China and India, where poverty, lack of government regulations and runaway development combine to create an environmental disaster [3].

"It's a worldwide catastrophe",
says geologist Anupma Prakash of the University of Alaska at Fairbanks.

The problem of spontaneous combustion and uncontrolled burning of coal seams is not limited to the Chinese and Indian coal fields. It can be encountered throughout the world in most coal-producing countries.
With the world's largest coal reserves, coal fire in the United States mainly occurs in Pennsylvania. According to data from the National Abandoned Land Inventory System of the Pennsylvania Department of Environmental Protection, there are currently 140 underground coal mine fires and 58 burning refuse piles in Pennsylvania [4] (See picture 1.4).

Pict. 4.4, *A coal fire in the mountains of Colorado*

Scientists estimate that Australia's Burning Mountain, the oldest known coal fire, has burned for 6,000 years [3].

1.5. Spontaneous Combustion

The last but most important process that can spark off a coal fire is called spontaneous combustion (See picture 1.5). Coal reacts with atmospheric oxygen even at ambient temperatures and this reaction is exothermic. If the heat liberated during the process is allowed to accumulate, the rate of the above reaction increases exponentially and there is a further rise in temperature. When this temperature reaches the ignition temperature of coal, the coal starts to burn and the phenomena is described as spontaneous combustion. The temperature at which the coal oxidation reaction becomes self-sustaining, and at which spontaneous combustion occurs, generally depends on the type of coal and surrounding conditions of heat dissipation. In poor quality coal, the fire may start burning at temperatures as low as 30-40° C. The three components for starting combustion are carbonaceous material, oxygen and heat. All fire fighting and prevention plans are based on the elimination of one of more of these components. These reactions worsen with the sun and the oxidation of the coal.

The north of China is predestined for spontaneous combustion of coal due to its arid climate, but also because of the structure of the Chinese coal mining economy. About 25 % of the Chinese coal output is produced by township-owned or private Coal mines. These mines tend to be rather small in size, so that in order to mine that such big amount of coal, a large quantity of these small mines are in operation and each of them produces a fresh outcrop of coal vulnerable to spontaneous combustion [5]. In coal-bearing regions in rural China people often dig coal for household use, abandoning the pits when they become unworkably deep, leaving highly combustible coal dust exposed to the air [1].

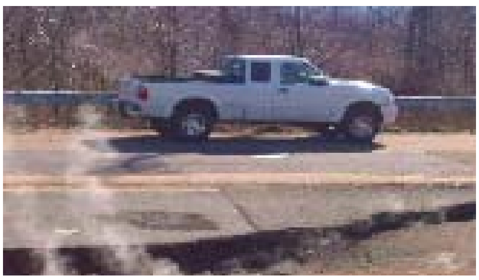
1.6. Impact

Across the globe, thousands of coal fires are burning. These are almost impossible to reach and extinguish once they get started. Such underground blazes threaten towns and roads, poison the air and soil, and worsen global warming. The menace is growing since the global coal demand increases.

The task of extinguishing underground coal fires, sometimes exceeding temperatures of 540°C, is highly dangerous and very expensive.

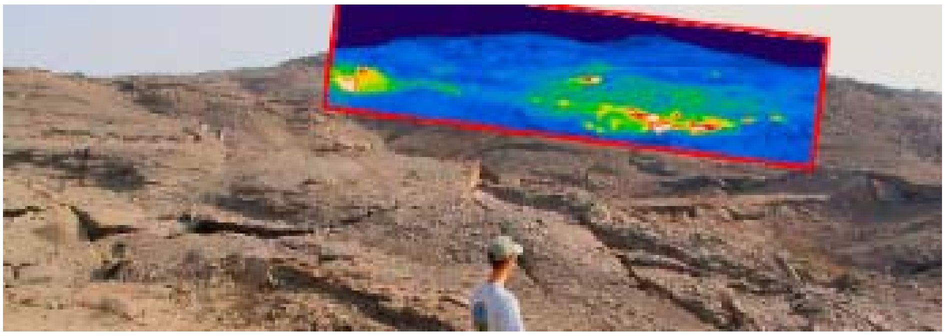
The coal fires' main impact is on the health of the people living in the vicinity of the coal field and on the economy of the region, which is often based on coal mining. The most obvious danger to the inhabitants and especially for the miners is the firsthand contact with the fire in or above the coal mine. Furthermore the chemical products of the combustion process can pose a threat to the communities living near the coal fires. The possible paths of contamination in this case are mainly the ingestion of toxic fallout via agricultural crop or through the groundwater or the inhalation of gaseous components, e.g. the heavy smoke is implicated in an epidemic of asthma [6]. The chemical products of the combustion process cause also a severe pollution of the air, water and soil in the vicinity of the burning coal field; this is a hazard to the ecosystem of the region. The emissions from coal fires not only pollute the local atmosphere, but add substantial amounts of the greenhouse gases (CO2, CH4) along with the SOx, NOx and CO.

Another associated problem is widespread cracking and subsidence of land surface. As the burned coal turns into ash, voids are created and often the rock overburden can no longer be supported and deep cracks open up. Eventually the surface collapses, which can cause extensive damage to agricultural land, buildings and transport networks. Most of the time these lands are useless for any further economic activities [6] (See picture 1.2 and 1.5).



Pict. 1.5, *Coal Fire in U.S. Source: John Griggs.*

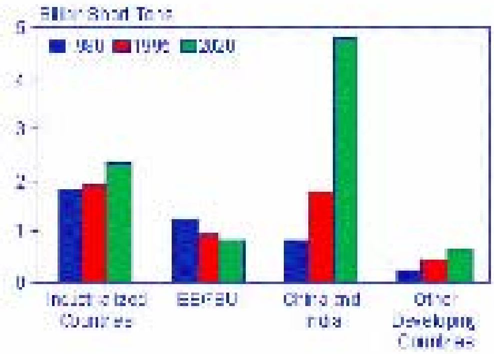
Impacts of coal fires on climate change, and their contributions to global warming, are increasingly receiving expert attention. Due to the risks of coal fires, satellite pictures or thermal images have been used to map China's coal fires, which resulted in the discovery of many previously unknown fires. Such images will be used to prevent the scattering coal fires, and thus to treat them on time. The thermal image clearly depicts the very hot areas [7] (See picture 1.6).



Pict. 1.6, *In-situ thermal camera image superimposed on a panoramic picture in a coal fire area [7].*

1.7. Coal fire in China

China is the largest coal producer and consumer worldwide (See Graph 1.7), even if it accounts for only 11% of the world's total recoverable coal reserves; China supplies 75% of its energy with coal. The country presently accounts for 28% of the world’s coal use. Due to mining of its vast coal fields, fires are spreading.



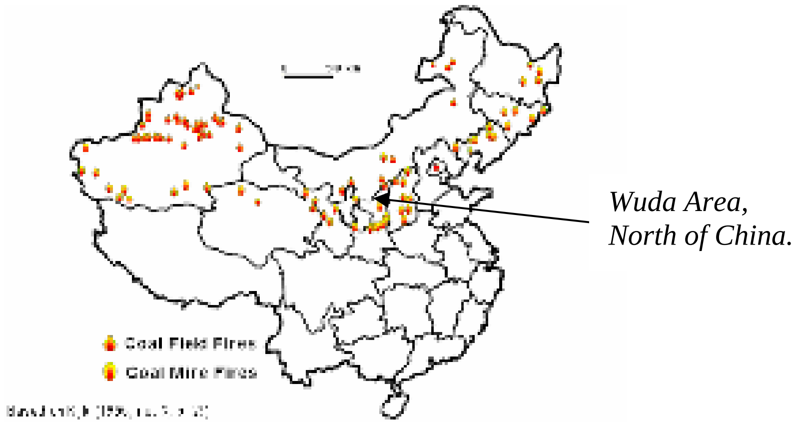
Source: Energy Information Administration (EIA)

Graph 1.7, *World coal consumption by region.*

It is only within the last years that the topic of coal fires growing popularity also within the daily media. This is the result of several bilateral and multi-lateral research initiatives, e.g. the geoscientific Sino-German Research Initiative on Coal Fire Research. The overall goal of these projects is firstly to get a better understanding of the physical-chemical as well as mechanic processes of the fires; secondly, projects aim at the set up of coal fire monitoring and also warning systems; thirdly, projects aim at the support of Chinese extinction strategies to save the valuable resource coal. The overall goal is to reduce the greenhouse gas emissions released [8].

‘We don’t need more science. We need more bulldozers.’ (Chinese, [3]).

Coal reserves of China are concentrated mainly in the northern part of the country. The coal mining belt stretches 5000 km from east to west and about 750 km in the north-south direction. Coal fires are spread in this entire belt. The Map 1.8 showing the distribution of coal fires in North China gives an idea of the extent of the problem of coal fires in China. However, the scientific efforts of coal fire mapping, monitoring, prevention and fighting have been restricted to a few sites only. The most important of these locations are Ningxia area, Xinjiang area and **Wuda area**.



Map 1.8, *Distribution of Coal Fire in North China 29].*

1.7.1. Coal Fire in Wuda

Wuda is a coal mining city located in Inner Mongolia; this mean area covers about 200 km from North to South and 220 km from East to West (See Map 1.8). Nowadays, it is accounted over 20 coal fire areas in Wuda [7].

It is the most studied mine worldwide. Lots of investigation like *Multitemporal In-Situ Mapping of the Wuda Coal fire* (C. KUENZER*), Detailed Mapping of Coal Fire – Wuda Coal field* (T. LITSCHKE, 2005), *Uncontrolled coal fires and environmental Impact in Wuda* (C. KUENZER, 2007), *Detection of underground coal fire in Wuda* (X.M. ZHANG, 1999), *Coal Fire Detection and Monitoring in Wuda* (P. KUMAR, 2003) were taken place. For this reason, in order to evaluate the world fired coal since 1880, the research will focus on this area.

The fire in Wuda is mainly ignited by abandoned private mines due to the low quality of the coal. Coal in the Wuda area is highly prone to spontaneous combustion. The climate of Wuda, and the surrounding area is a middle latitude strong continental semi-arid to fully arid climate, with large daily and seasonal temperature amplitudes influenced mainly by the East Asian Monsoon (Weischet, 1988; Xie, 2001). Moreover, vegetation cover is very sparse.

Since commercial mining in the Wuda syncline started in **1958**, **120 megatons** have been mined by the year **2000**. The first coal fires in the area were discovered in 1961. Before 1989 most coal fires in Wuda were isolated and scattered in different locations. The isolated fires started to connect gradually between 1989 and 1995. An **acceleration** of the process from **year to year** is observed. The recent annual amount of coal being burned is estimated to be **200,000 tons** [14-15]. It is assumed that so far, **two millions tons of coal** were destroyed due to coal fires [8]. In 2002 8.8% of the three coal mining areas in the syncline are affected by coal fires and the coal fire area has an extent of 3.07 km^2 (Jia, 2002).

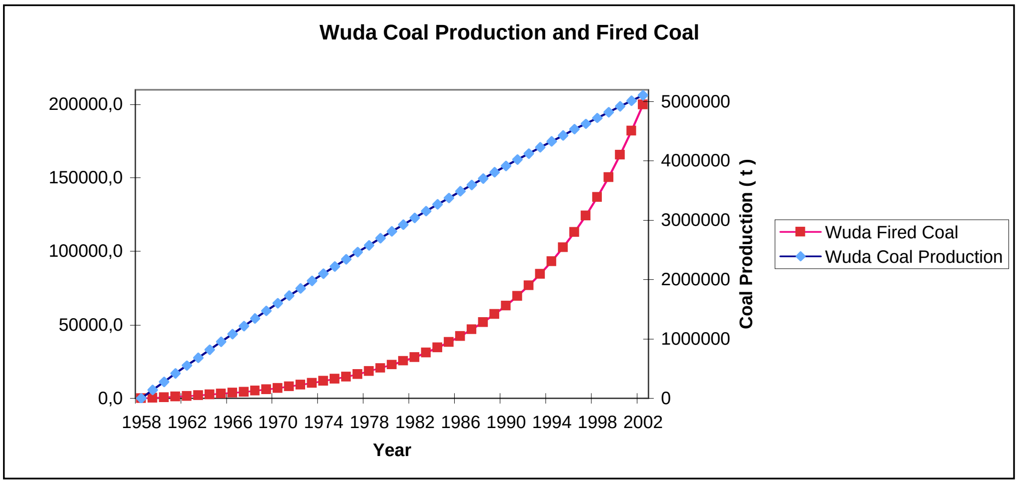
1.7.2. Estimation of Fired Coal in Wuda

The difficulty to evaluate the fired coal is to find out the most reliable data. Actually, it is impossible to reach an exact estimation since the coal fire has never been recorded and is not well detected. The work is based on C. KUENZER 's estimation in Wuda and in China;

according to her, most of available data on different website are upper-estimated in order to sit people up.

From the available estimation of Wuda coal mine, the Wuda fired coal and the Wuda coal production were interpolated since 1958, as shown on Graph 1.9; Wuda fired coal was interpolated considering "an acceleration of the process year to year", considering the total amount of fired coal since 1958, and considering a fired coal peak in 2002 of 200000 tons. Wuda coal production was interpolated considering that its production follows the China production increase, and considering the amount of coal extracted since 1958.

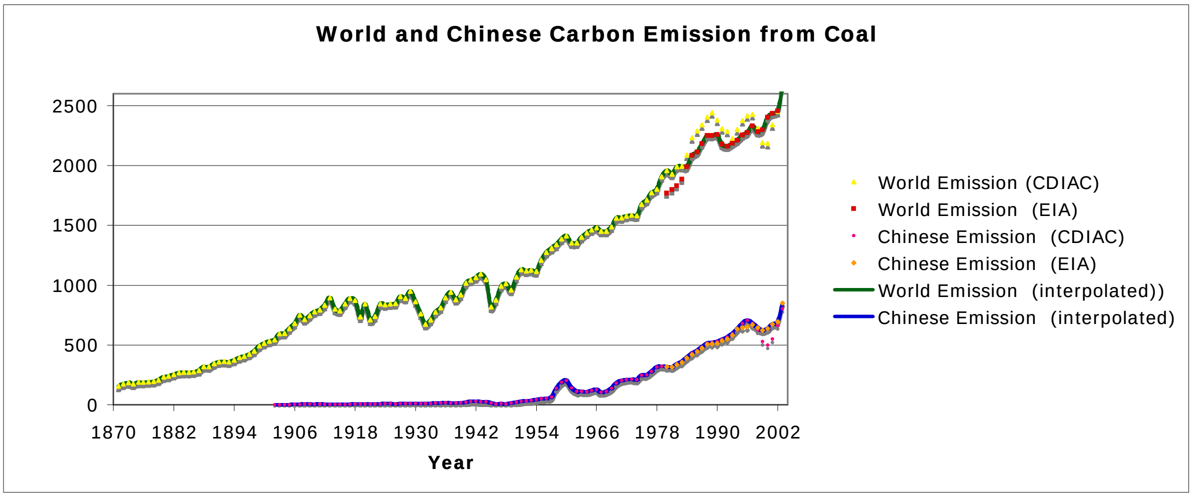
The Graph shows that even though the coal production increases linearly, the coal fire need time to scatter; it confirms the coal fire evolution description mentioned in *section 1.7.1.*



Graph 1.9, *Interpolation of Wuda Fired Coal and Coal Production since 1958.*

1.7.3. Coal fire in China

The coal fire through China was interpolated from the coal production emission in China. Like the investigation for gas flaring, the data from EIA (Appendix 1) and CDIAC (Appendix 2) have to be compared (Graph 1.10).

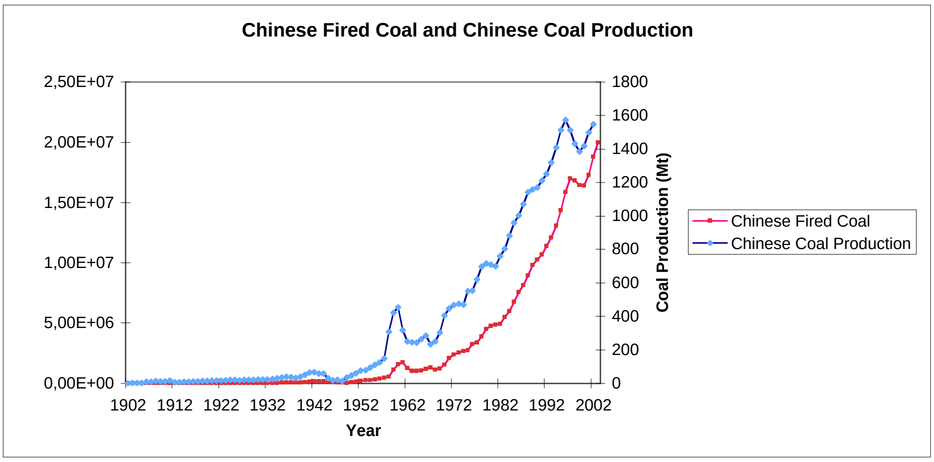


Graph 1.10, *World and China Carbon Emission from Coal.*

The curves from EIA and CDIAC are quite similar; by the way, we will consider as World carbon emission and Chinese carbon emission from coal versus year, a linear curve, which takes into account the both database (Graph 1.10).

The World coal production and the Chinese coal production are obtained from the World and Chinese carbon emission, by evaluating the ratio between production and carbon emission provided by EIA's database (0.45 kg of Carbon/kg of Coal).

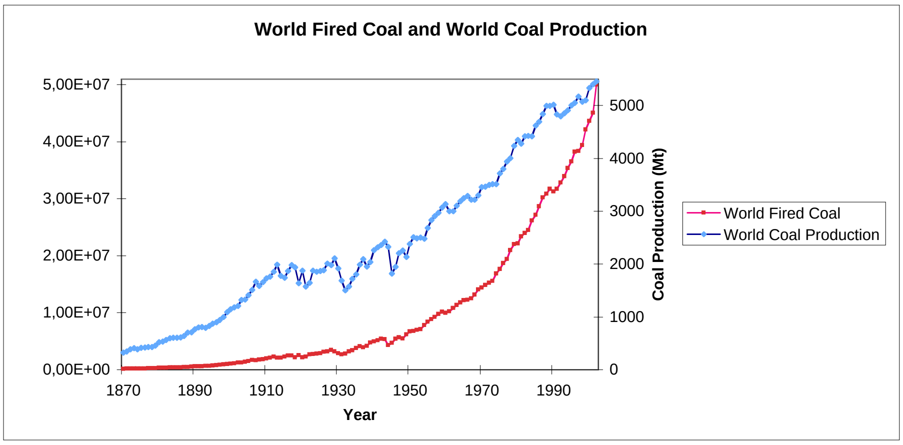
The Chinese fired coal is interpolated considering the worst case, i.e. all Chinese coal mines behave like Wuda coal mine. Hence, first, the Wuda's curves have to be reduced from the Wuda's coal mining scale to the Chinese coal mining scale, and then, a curve that describes the Wuda annual coal fire increase versus the Wuda annual coal production increase has to be extrapolated. Thus, the Chinese fired coal can be obtained considering its amount of 20 millions tons in 2002 (C. KUENZER) (Graph 1.11).



Graph 1.11, *Chinese Fired Coal and Chinese Coal Production since 1902.*

1.8. Coal Fire in the World

The fired coal through the world is obtained by the same way than for the Chinese fired coal (Graph 1.12), with the exception of the World coal mining production scale consideration. Moreover, the World fired coal is interpolated considering that the Chinese coal fire account for 40% of the World coal fire, in 2002 (C. KUENZER).



Graph 1.12, *World Fired Coal and World Coal Production since 1870.*

The results got in the precedent sections can be summarised in the Tab. 1.13.

Tab 1.13. Fired Coal, 1880 – 2002

1880 - 2002	Wuda	China	World
Fired Coal (Mt)	2	324.82	1307.899
Fired Coal (kJ)	$5.0437\ 10^{13}$	$7.796\ 10^{15}$	$3.139\ 10^{16}$
Fired Coal (kWh)	$1.401\ 10^{10}$	$2.165\ 10^{12}$	$8.719\ 10^{12}$

According to the Tab 4.13, the fired coal worldwide since 1880, is about $8.719\ 10^{12}$ kWh. However, lots of uncertainties have to be considered.

1.9. Reviews and Uncertainties

These results have to be considered warily. Actually, it is impossible to evaluate a right amount of fired coal since the coal fire has never been recorded and cannot be well detected.

The evaluation of World fired coal was interpolated from the worst coal mine worldwide, i.e. Wuda syncline. It should mean that the estimation got is upper-estimated, but it is impossible to claim it. We cannot say whether it is an under or an upper-estimation, because on one hand, we only considered the coal fire lighted by spontaneous combustion, and on the other hand the worst case was considered. Moreover, there is a large uncertainty to the value of Wuda syncline, like total amount of fired coal or fired coal in 2002, to the percentage of Chinese fired coal versus world fired coal, and to the Chinese fired Coal in 2002.

There is different type of coal fire; several happen underground and thus cannot be reached and will never be able to be recorded. However, some of these underground coal fires last for many centuries, without the earth’s temperature never increasing. This kind of coal fire can be then neglected whether the amount of coal fire is responsible of a weighty part in the earth’s temperature increase.

1.10. Conclusion

The coal fires worldwide emit $8.719 \cdot 10^{12}$ kWh of heat; they account for 1307 million tons of coal and are in charge of 0.3 % of Missing Net Heat Generation and of 0.1 % of Total Net Heat Generation since 1880. The coal fire spontaneous combustion contribution is thus quite low; its contribution to the earth’s temperature increase is then negligible, like the underground coal fire contribution. Therefore, it should be important to consider the underground coal fire in the estimation (they could together play such a part); unfortunately it is absolutely impossible to evaluate it.

The Chinese coal fires account for 0.12% of World CO_2 emission in 2002 and the coal fires worldwide account for 0.31% of World CO_2 emission in 2002.

So far only coal fire-fighting activities at individual fires have taken place to hinder existing coal fires from extending into the present active coal-mining areas. The Wuda syncline

(Graph 1.14) is one of the coal fire areas that have received the most of public attention through a Sino-German coal fire research initiative, coordinated by the German Aerospace Centre, DLR, which started in 2003 and will last until the end of 2009.

Graph 1.14, *Coal Fire in China.*

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Appendix 1: EIA – Energy Information Administration.

[1] http://www.eia.doe.gov/
[2] Highlights of GAO-04-809, a report to the Honorable Jeff Bingaman, Ranking Minority Member, Committee on Energy and Natural Resources, U.S. Senate Reduce Emissions.

The Energy Information Administration (EIA), created by Congress in 1977, is a statistical agency of the U.S. Department of Energy. Their mission is to provide policy-independent data, forecasts, and analyses to promote sound policy making, efficient markets, and public understanding regarding energy and its interaction with the economy and the environment. EIA is the Nation's premier source of unbiased energy data, analysis and forecasting. By law, EIA's products are prepared independently of Administration policy considerations. EIA neither formulates nor advocates any policy conclusions. EIA issues a wide range of weekly, monthly and annual reports on energy production, stocks, demand, imports, exports, and prices, and prepares analyses and special reports on topics of current interest [1].

Who uses EIA's products?

EIA's data and analyses are widely used by Federal and state agencies, industry, media, researchers, consumers, and educators. All of EIA's products can be accessed through its Web site, http://www.eia.doe.gov, which logs more than 2 million user sessions a month [1].

Review

> *" First, the Department of Energy's Energy Information Administration (EIA) collects and reports data voluntarily provided by oil- and gas-producing states. Because EIA has* ***no authority to require states to report****, some do not, leading to incomplete data. Second, EIA has provided limited guidance to states to promote consistent reporting. As a result, only about one-fourth of the states reporting provide data that EIA considers consistent. Third, the data EIA collects* ***do not distinguish between flared gas and vented gas****—an important distinction since they have dramatically different environmental impacts.* ***Data on flaring and venting outside the United States are also limited, since many countries report unreliable data or none at all.*** *To improve data on flaring and venting, EIA could use its authority to collect data directly from oil and gas producers; to obtain more consistent data, EIA could improve its guidelines for reporting. From an environmental perspective, EIA, the Minerals Management Service, and the Bureau of Land Management could require flaring and venting data to be reported separately from each other. Globally, the federal government could set an example by continuing to improve U.S. data, continuing to support global efforts, and using U.S. satellite data to detect unreported flaring"* [2].

Appendix 2: CDIAC

http://cdiac.ornl.gov/
Contact : Dale Kaiser <kaiserdp@ornl.gov>

The Carbon Dioxide Information Analysis Center (CDIAC) is the primary climate-change data and information analysis centre of the U.S. Department of Energy (DOE) since 1982. CDIAC is located at DOE's Oak Ridge National Laboratory (ORNL) and includes the World Data Centre for Atmospheric Trace Gases.

CDIAC's data holdings include records of the concentrations of carbon dioxide and other radiatively active gases in the atmosphere; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of carbon dioxide to the atmosphere; long-term climate trends; the effects of elevated carbon dioxide on vegetation; and the vulnerability of coastal areas to rising sea level.

CDIAC provides data management support for major projects, including the AmeriFlux Network, continuous observations of ecosystem level exchanges of CO2, water, energy and momentum at different time scales for sites in the Americas.

CDIAC is supported by DOE's Climate Change Research Division of the Office of Biological and Environmental Research.

CDIAC responds to data and information requests from users worldwide investigating the greenhouse effect and global climate change.

The CO_2-emissions database is derived from a variety of sources and requires considerable data processing, selection, and integration. Each of the data sets used for calculating the CO_2-emission estimates is checked carefully. CDIAC works with the UN Statistical Division annually to quality assure each new version of the UNSTAT Database. Although the review process is unable to detect some kinds of data problems, it does confirm that the UNSTAT Database meets high standards of data management and internal consistency.