Environmental Impacts and Benefits of Regional Power Grid Interconnections for China

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1. Current Status of and Prospects for China's Power Grid

1.1 The current status of the China's power grid

China's power industry has entered into the era of large power networks, and power transmission technologies have also upgraded greatly with the recent rapid development and construction of these power networks. At present, there are seven inter-provincial power grids (East China, Northeast, Central China, North China, Northwest, Sichuan-Chongqing and South China—which covers Yunnan, Guizhou, Guangxi, Hainan and Guangdong) and four independent provincial power networks (Shandong, Fujian, Xinjiang and Xizang (Tibet) operating in mainland China. Large power grids now serve all cities and most villages throughout China[1], as can be seen in Figure 1.

By the end of 2001, the total generating capacity in China was 338 GW (gigawatts), of which hydroelectric capacity (totaling 83 GW) accounted for 24.5%, thermal power (253 GW) accounted for 74.9%, and nuclear and other types of generation (at 2 GW or so) accounted for 0.6%. This division of capacity is shown in Figure 2. The total electricity generated in 2001 was 1,483,856 GWh (gigawatt-hours), of which thermal power supplied 1,204,478 GWh, accounting for 81.2% of total generation. Of thermal generation, 95% was from coal-fired power plants (as shown in Figure 3)[3]. China's reliance on coal-fired power has caused serious environmental problems, as will be described later in this paper.

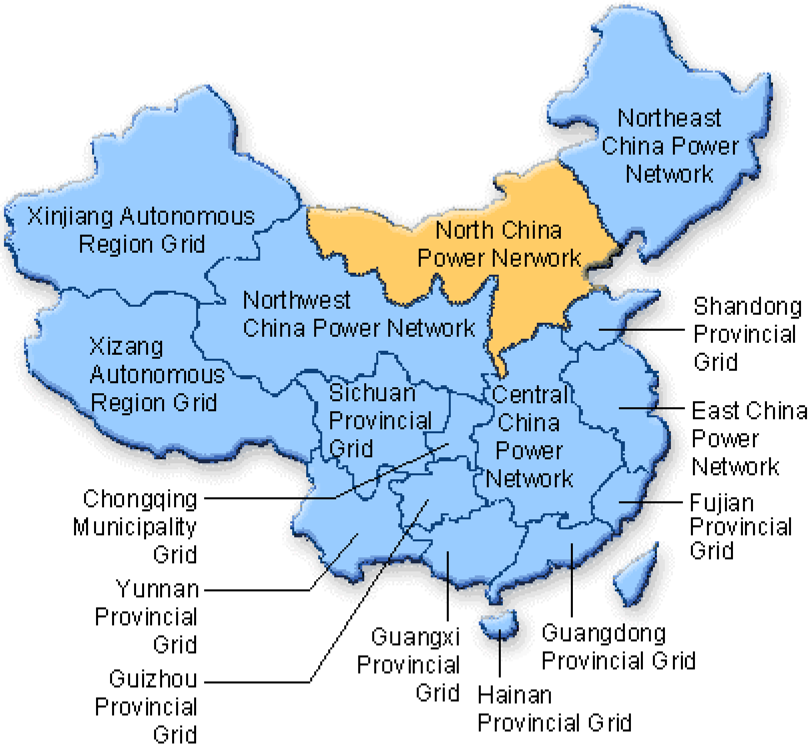

Figure 1: China's power grids [2]

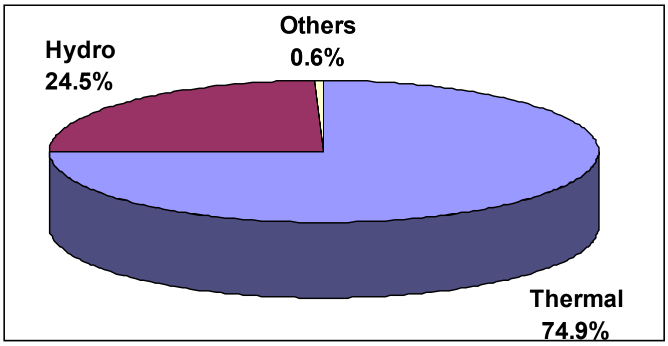

Figure.2: The structure of generation capacity in China as of 2001

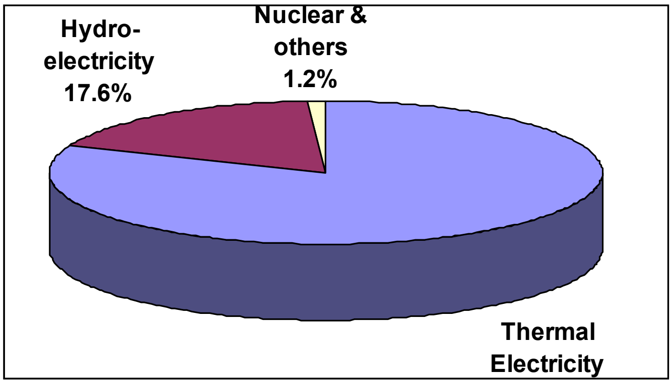

Figure 3: The structure of electricity generation in China in 2001

By the end of 2003, the total generating capacity in China is expected to be approximately 370 GW. Power supply, however, is still poor in many provinces. At present, overall, there is a slight shortage of power supply nationwide. The projected electricity demand and supply situation in 2003 in each region and province of China is shown in Table 1.

Table 1: The status of electricity supply and demand by province in China, 2003

Region	Provinces where demand exceeds supply (15)	Provinces where demand and supply are roughly in balance (8)	Provinces in which supply somewhat exceeds demand (10)
North China	Shanxi, Southern part of Hebei, Western part of In-Mongolia	Beijing, Tianjing, North part of Hebei, Shandong	
Northeast			Heilongjiang, Jilin, Liaoning, East part of In-Mongolia
Northwest	Gansu, Qinghai, Ningxia	Xinjiang	Shanxi
Central China	Henan, Chongqing, Sichuan	Hubei, Hunan,	Jiangxi
South China	Guangdong, Guizhou, Yunnan		Guangxi, Hainan
Eastern China	Jiangsu, Zhejiang, Shanghai		Anhui, Fujian
Others		Tibet	

In general, as noted above, electricity is currently in relatively short supply in

China at present. As shown in Table 1, there are 15 provinces in which there is lack of electricity. These provinces are found in all regions of China except the Northeast[4].

1.2 Prospects for the development of China's power grid

There is no doubt that electricity demand in China will continue to increase dramatically in the future due to the rapid pace of economic development in the country. Figure 4 shows the pattern of power industry development (generation and capacity) over the past twenty-plus years relative to the pattern of overall economic (gross domestic product, or GDP) growth[5,6,7].

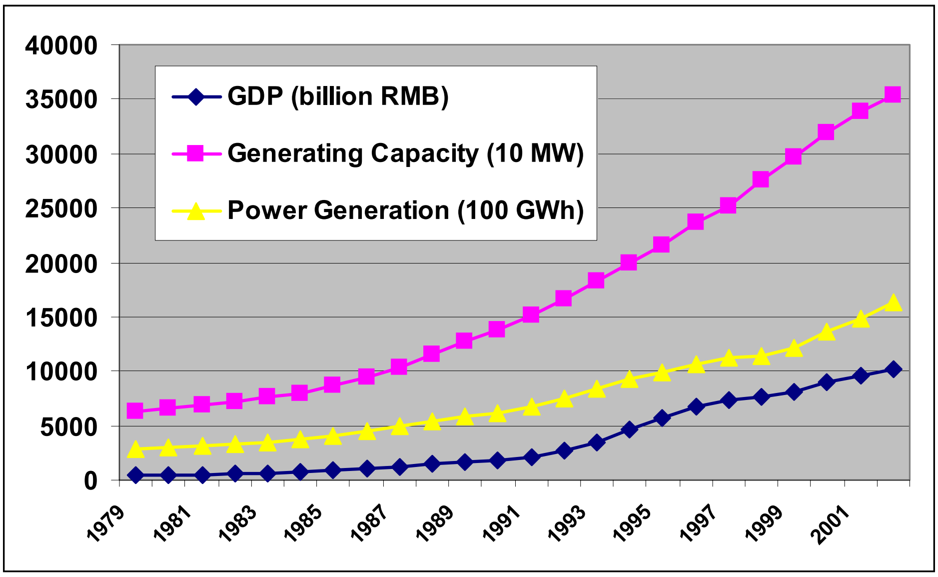

Figure 4: Comparison of trends in China's power industry development with trends in GDP, 1979 to 2002

By the year 2020, China's GDP is expected to increase by 200% over that of 2000, meaning that annual average GDP growth rates are projected to average 7.2% or so over the next 18 years. Under this projection, China's GDP in 2020 will have risen to 35,000 billion RMB. In order to meet this economic growth target, it will be necessary for China's electric power industry to maintain its recent rapid rate of development. Total nationwide electricity consumption in 2010 is projected to rise to about 2,700 billion kWh, with generating capacity increasing to about 600 GW. Total annual electricity demand in 2020 will is estimated to have grown to 4,000 billion kWh or so, with total national generating capacity reaching about 900 GW. On average 30GW of generating capacity will needs to be added each year for the next 18 years to reach these capacity goals[8]. This rate of addition is approximately twice the rate of recent capacity expansion, and is thus a great challenge for the Chinese power sector.

Interconnections between large regional power grids in China, as well as interconnection between regional nets and independent provincial nets, are presently being considered and implemented. Four directional (east, west, south and north) interconnections and circumjacent interconnections among nets are being constructed in order to allow power from West China to flow to the major consuming areas in the East, to allow power to be shared between North and South China during times when available capacity in one region coincides with high demand in the other, and to allow power from the central Three Gorges Hydropower project to be distributed in each of the radiation in all four directions. By the year 2005, power grid interconnection for all of China except Xinjiang, Tibet, Hainan and Taiwan will be preliminarily complete[1].

2. Environmental Impacts of China's Power Industry

2.1 Environmental impacts power generation

Power demand all over the world currently relies preliminarily on fossil fuel combustion (thermal power), as well as hydro and nuclear. The amount of electricity generated from wind, solar, tidal, and geothermal energy accounts for a very small percentage of the current total global generation. There is no doubt that large-scale power generation inevitably causes environmental impacts of varying levels of severity.

Table 2 shows a subjective environmental ranking of various power-generation technologies[9]. Power-generation from solar energy, wind energy, tidal energy and biomass is renewable and sustainable. The environmental impacts of these generation technologies are relatively light.

Table 2: Environmental ranking of various power-generation technologies

Environmental rank (impact from least to most)	Remark
Solar energy	Renewable and sustainable
Wind energy	
Tidal energy	
Biomass	
Hydro	Renewable and potentially sustainable
Geothermal	
Natural gas	Non-renewable and unsustainable
Oil	
Coal	
Nuclear	

Hydroelectric generation is or should be renewable as it burns no fuel and is powered by solar energy via the hydrologic cycle. Prevention of sedimentation in hydroelectric is essential if generation capacity is to be maintained. Reservoir development in which the areas flooded contain considerable biomass (forests or peat, for example), however, can lead to significant greenhouse gas emissions (methane and carbon dioxide from decaying biomass).

The environmental impacts of geothermal power systems are generally easily managed (for example, through re-injection of condensates once heat has been extracted), so it makes sense to utilize this resource where it is available.

Utilization of all fossil fuels is unsustainable by definition. The combustion of fossil fuels, especially coal, can produce heavy environmental impacts. Coal combustion produces smoke dust (particulate matter), sulfur dioxide, NO_X, and CO_2 emissions. In addition, some wastewater, as well as and fly ash and bottom ash, are also produced by coal-fired power plants. Generators can use advanced technologies and equipment to reduce dust, SO_2 and NO_X emissions from fossil fuel-fired power plants to minimum levels, but these technologies are generally are not widely used in China today. So far, however, power generation equipment cannot use coal without excessive CO_2 production. If coal technology improves such that CO_2 emissions can practically and economically be largely eliminated, or CO_2 from coal-fired generation can be collected and adequately disposed of, prospects for future development of coal-fired power would improve.

Nuclear power plants do not emit many air pollutants, but their operation results in the production of radioactive wastes, and pose safety problems. If the radioactive waste storage problem in China (or regionally) is solved, and if in addition “inherently” safe reactor designs are achieved, uranium mining impacts are reduced, nuclear weapons proliferation issues are fully addressed, and shipment of radioactive materials becomes safe, then prospects for future deployment of nuclear power generation would improve[10].

2.2 Environmental impacts caused by China's thermal power plants

As mentioned above, most power in China is generated in power plants burning fossil fuels, especially coal. In 2002, for example, power generated using fossil fuels in China totaled 1342 billion kWh, accounting for 81.8% of the total 1640 billion kWh of power generated in China. The key environmental impacts caused by China's power industry are the results of air pollutant emissions from coal-fired power generation. Figure 5 shows the trends of national SO_2 and dust emissions from thermal power plant operation compared with the development of the power industry (electricity generation and capacity) and with total nationwide SO_2 emissions over the past two decades.

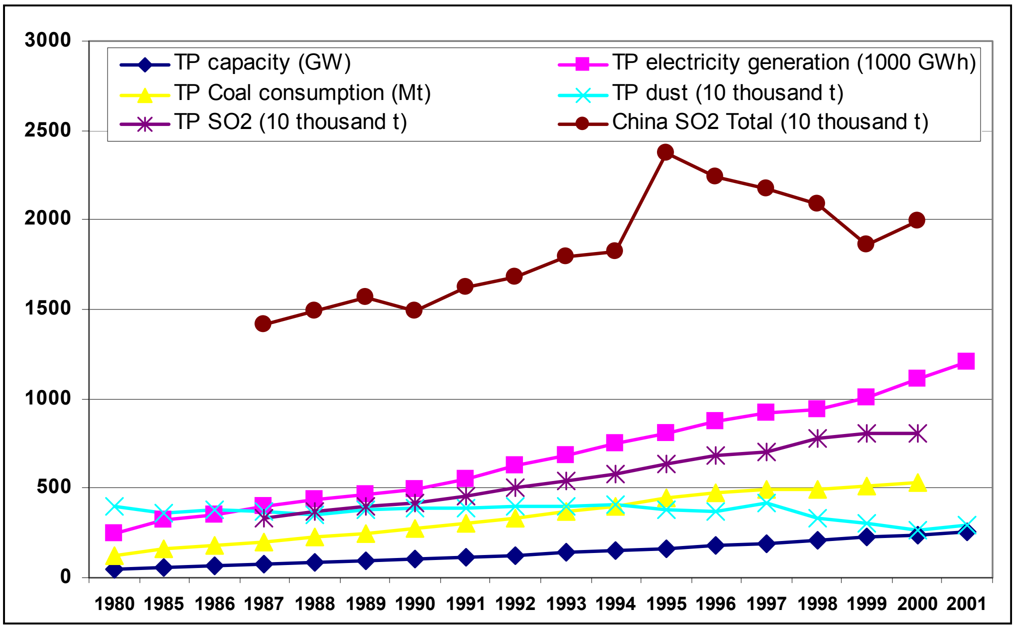

Figure 5: SO_2 and dust emitted from thermal power plants (TP) in China

As shown in Figure 5, with the increase of thermal power electricity over the past twenty years, coal consumption has increased gradually. In 2002 total coal consumption in China was more than 1.3 billion tons, of which about 50% was used for power generation. At present, about 8 million tons of SO_2 emitted from coal-fired power plants each year, which accounts for about 50% of total industrial SO_2 emissions in China. The 3 million tons or so of dust emitted from coal-fired power plants each year amounts to about one-third of total industrial dust (particulate matter) emissions. It is estimated that in China over 4 million tons per year of NO_X is emitted to the air from fossil-fueled power generation.

Emissions of SO_2, NO_X and dust from coal-fired power plants can cause increases in ambient concentrations of these air pollutants. Table 3 shows SO_2 concentrations in the ambient air and sulfur precipitation contributed by thermal power plants by province in China as of 2000. Emissions of pollutants from thermal power plants were major contributors to these ambient levels of pollution . In most regions of North and Northeast China, and particularly in cities, the amount of ambient SO_2 concentration that is contributed just by coal-fired power plants is higher than the total average ambient concentration over all of China.

China's emissions of SO_2, CO_2, and substances that deplete the O_3 (ozone) layer rank, respectively, first, second and first in the listing of global emissions by country[11]. Without doubt, the power industry is the largest contributor to these emissions. In addition, SO_2 emitted from coal-fired power plants is one of the principal precursors of acid rain formation. Acid rain has been spreading in China in recent years. The areas of China affected by acid rain has extended from affecting some districts in the southwest as of the 1980s, to a situation where it now affects most parts of southwest and southern

China, as well as much of central and eastern China. The area of land in China where the annual pH of precipitation averages below 5.6 now accounts for about 40% of the land area of the entire nation [12].

Table 3: SO_2 concentration in ambient air and sulfur precipitation contributed by thermal power plants in China in 2000

Province	SO_2 concentration (μg/m3)				Sulfur in precipitation (g/m^2-yr)			
	City aver.	City max.	Regional aver.	Regional max.	City aver.	City max.	Regional aver.	Regional max.
Beijing	19.5	19.5	4.5	19.5	2.9	2.9	1.1	2.9
Tianjing	24.2	24.2	7.7	24.2	4.1	4.1	1.8	4.1
Hebei	12.8	24.2	3.8	12.8	2.2	4.1	1	4.1
Shanxi (NW)	6.4	21.2	2.3	21.2	1.2	2.9	0.6	2.9
In-Mongolia	5.6	16.4	0.3	16.4	0.8	2.1	0.1	2.1
Liaoning	5.6	14.2	2.1	14.2	0.9	1.9	0.5	1.9
Jilin	1.7	4.6	0.5	4.6	0.3	0.6	0.1	0.6
Heilongjiang	1.5	3.3	0.2	3.3	0.2	0.4	0.1	0.4
Shanghai	15.2	36.1	15.2	36.1	10.2	10.3	4.5	10.3

Table 3 (continued): SO_2 concentration in ambient air and sulfur precipitation contributed by thermal power plants in China in 2000

Province	SO_2 concentration (μg/m3)				Sulfur in precipitation (g/m^2-yr)			
	City aver.	City max.	Regional aver.	Regional max.	City aver.	City max.	Regional aver.	Regional max.
Jiangsu	10.8	25.4	4.9	25.4	2.7	4.6	1.5	4.6
Zhejiang	4.3	18.9	1.7	18.9	1.1	4.9	0.5	4.9
Anhui	3.3	8.8	1.5	10.1	0.8	1.8	0.5	2.1
Fujian	1.3	5.1	0.6	5.1	0.3	1	0.3	1
Jiangxi	2.7	6.1	0.6	6.1	0.7	1.1	0.4	1.1
Shandong	9.2	17.4	5.2	17.4	2	3.5	1.5	3.5
Henan	7	22.5	2.5	22.5	1.4	3.5	0.8	3.5
Hubei	1.9	18.3	0.9	18.3	0.6	3	0.4	3
Hunan	2	9.4	0.6	9.4	0.6	1.7	0.4	1.7
Guangdong	6.5	23.4	1.7	23.4	1.2	3.5	0.5	3.5
Guangxi	1.6	5.1	0.8	25.2	0.4	0.9	0.3	3.7

Hainan	0.2	0.9	0	0.9	0	0.1	0	0.1
Sichuan	6.6	38.2	1.3	38.2	1.5	7.4	0.4	7.4
Guizhou	5.9	19.4	1.7	20.6	1.4	4.1	0.7	4.1
Yunnan	1.6	9.2	0.2	9.2	0.3	1.8	0.1	1.8
Tibet	0	0	0	0	0	0	0	0
Shanxi (N)	11.5	38	1.9	38	1.8	6.3	0.5	6.3
Gansu	1.1	4.4	0.2	4.4	0.2	0.5	0.1	0.5
Qinghai	1.5	1.5	0	1.5	0.2	0.2	0	0.2
Ningxia	5.1	8.4	0.8	8.4	0.7	1.1	0.2	1.1
Xinjiang	1.4	7.1	0.1	7.1	0.2	0.9	0	0.9
China	4.9	38.2	0.8	38.2	1	10.2	0.2	10.2

In 2001, the cities where the annual pH value of the precipitation is under 5.6 were mainly located in north China, south China, mid-China and in the southwest. In the north, the annual pH values of precipitation in the Tumen area of Jilin, in Weinan, Tongchuan and Lueyang County of Shaanxi, and in Tianjin are under 5.6 (as shown in Figure 6).

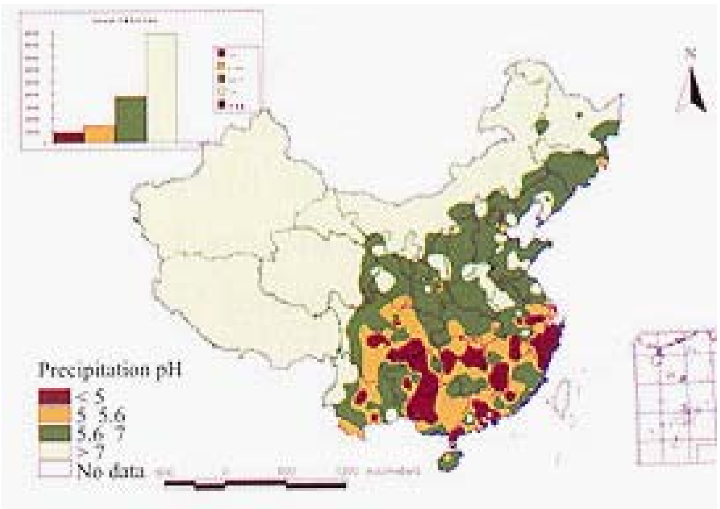

Figure 6: pH values of precipitation in China in 2001

As of 2001, of the 274 cities in China where the pH value of precipitation was regularly monitored. The pH values recorded were in the range 4.21~8.04. Of the cities monitored, there were 101 cities where the annual average pH value of precipitation was less than or equal to 5.6. These cities account for 36.9% of the cities monitored. There were 161 cities with episodes of acid rain, accounting for an additional 58.8% of the total. Compared with results from the previous year, the percentage of cities with acid rain had declined somewhat.

In the 107 cities (cities over the prefecture level and prefectures) located in the Acid Rain Control Zone of China, there are 78 cities where pH values ranges from 4.21~7.21 and the annual average pH value of precipitation is less than or equal to 5.6, accounting for 72.9% of the cities included in the statistics. There is acid rain in the precipitation of 98 cities, accounting for 91.6% of the cities in the Acid Rain Control Zone.

It has been estimated that the damage incurred by acid rain and SO_2 pollution each year in China adds up to hundred of billions RMB[13].

As mentioned above, electricity demand is projected to continue to increase dramatically in China. If some of the projected growth in coal-fired generation capacity can be avoided by importing clean electricity such as hydroelectricity, then the atmospheric environment will undoubtedly benefit, and acid rain will be reduced.

3. Environmental Benefits of Power Grid Interconnection for China

There are a number of benefits that can be obtained from regional power grid interconnection[14/15]. These include:

- Optimization of the operation of power sources and power supply, and upgrading of the quality of electricity (power quality).
- Reduction in the required reserve capacity in each single network because of the availability of power from other grids to help to compensate when accidents (outages) occur.
- The ability to take advantage of staggered power peaks, including time differences in high demand, providing seasonal benefits and power load structure benefits to the interconnected systems.
- Allowing hydro station output to be adjusted inter-valley to help to meet overall demand on the interconnected system.
- Upgrading the power-supply reliability of marginal areas of independent single grids.
- Helping to stabilize the frequency of the power grid.
- Providing powerful support in the event that an important accident occurs on the power system (for example, if a large power plant stops operations suddenly).

The remainder of this section focuses on the environmental benefits of grid interconnection. There are three main environmental benefits related to regional power grid interconnection. First, the need for some new power generation capacity will be avoided. This will avoid damages that would have been incurred during the construction of these new power plants. Second, grid interconnection allows the use of natural resources to be optimized for generate electricity over a larger geographical area. This can reduce the overall environmental impacts caused by power generation. Finally generation sources can be further separated from the major areas of electricity use (for example, in cities). This separation can help to minimize damage to human health resulting from power sector emissions.

3.1 Avoid damages incurred by some new power sources construction

Regional power grid interconnection can offer the opportunity for mutual compensation of spare (reserve) generating capacity. This can reduce the spare generating capacity on each individual single network. Based on the study done by Dr. Sergei Podkovalnikov, the interconnection of RFE-NEC-RK (Russian Far Eastern, Northeastern China, and Republic Korea) power grids will save generating capacity and investment, as shown in Table 4.

Table 4: Capacity and investment saving due to interconnection[16]

	RFE	NEC	RK
Capacity saving, GW	0.76	3.7	2.75
Investment saving, $Bin.	0.7	4	4.1

As shown in Table 4, the interconnected grid will save 7.21 GW capacity, of which the 3.7 GW saved in the NEC accounts for 51.3%. That means that requirements for 3.7 GW of power generation capacity will be reduced in NEC without a reduction in the power supply available to NEC . The 3.7 GW saved accounts for around one-tenth of the total northeast China power network capacity.

There is only one large hydro station over 1 GW (Fengman Hydro) on the NEC grid. Most of the electricity used in NEC is generated by coal combustion. Saving 3.7 GW of capacity can therefore avoid direct damages (such as kicking-up of dust, discharge of wastewater, noise, resettlement of people, land occupation, ecosystem damage, etc.) incurred by construction of 3.7 GW of power-generating sources, as well as indirect impacts incurred by related construction such as building of roads to various power plants, extended or new coal mining, transportation of coal and oil, and so on.

Similarly, saving 0.76 GW of capacity in the RFE and 2.75 GW in the RK can also avoid direct and indirect damages related to construction of power plants.

3.2 Reduce environmental impacts incurred during power generation

As mentioned above, different types of power generation produce different environmental impacts. Hydropower is renewable and potentially sustainable source of electricity. It is clean power energy. The use of coal-fired power plants results in emissions of SO_2, NO_X, CO_2 and dust. These pollutants result in ambient air pollution and can make the earth warmer through their contribution to climate change. At present, more than 80% of the electricity used in China is produced from fossil fuel combustion. This proportion is even higher in the north parts of China. Air pollutants from coal-fired power plants have caused serious environmental problems. As examples, the poor air quality in Shenyang, Taiyuan, Lanzhou, Tianjin, Beijing, and other Chinese cities is very famous around the world, and is largely the result of coal combustion[17]. Interconnection of regional power grids makes it possible to use of cleaner energy (natural gas, hydro, and other clean fuels) for generating electricity for use over a larger range.

Chinese coal resources are mainly distributed in northern China. Coal resources in northern China account for 64% of all of China's coal resources. Shanxi province and the western part of Inner Mongolia have the richest coal resources in northern China. The second richest regions are the northwest and southwest areas, respectively, accounting for 12% and 10.7% of total resources (as shown in Table 5).

China's petroleum and natural gas resources are distributed mainly in the northeast and north parts of the country, which account, respectively, for 48.3% and 18.2% of the total. Petroleum and natural gas are cleaner energy for electricity generation than coal. Unfortunately, the availability of these resources is relative poor in China, so it is impossible for China to use largely petroleum and natural gas for electricity generation.

Hydro energy resources are distributed preliminarily in Southwest China, which accounts for 70% of all hydro energy resources. Hydro energy availability in the Northwest region is second in importance, comprising 12.5% of the national total. As a result, China's hydro energy resources are centralized in the western part of the country, which is too far away to transport power to consumers in the northeast. In fact, Northeast China is relatively poorly supplied with energy resources, having only 3.8% of the total energy resources of China. Obviously, with limited hydroelectricity resources in the Northeast China region, with no nuclear experience, and with no plans to utilize scarce, expensive oil and gas resources, any increases in electricity demand in the area will have to be met by coal-fired power plants if the power grid of Northeast China is not interconnected.

Table 5: Distribution of energy resources in China[18]

Region	Fraction of energy resource (percent)			
	coal	hydro	Petroleum & natural gas	total
North	64.0	1.8	14.4	43.9
Northeast	3.1	1.8	48.3	3.8
East	6.5	4.4	18.2	6.0
South &	3.7	9.5	2.5	5.6

central				
Southwest	10.7	70.0	2.5	28.6
Northwest	12.0	12.5	14.1	12.1

Note: North includes Beijing, Tianjing, Hebei, Shanxi (N), Inner Mongolia.

Northeast includes Liaoning, Jilin, Heilongjiang.

East includes Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong.

South and Central includes Hebei, Hubei, Hunan, Guangdong, Guangxi, Hainan.

Southwest includes Chongqing, Sichuan, Guizhou, Yunnan, Tibet.

Northwest includes Shanxi (NW), Gansu, Qinghai, Ningxia, Xinjiang.

The energy resources of the Russian Far East and East Siberia are, however, much more abundant in contrast to the neighboring regions of other countries. Hydroelectric resources are particularly plentiful. The technical potential for hydroelectric development in East Siberia is about 660 TWh yr^{-1}, of which 14% is currently utilized, while the technical potential of for hydro in the Far East Russia is 680 TWh yr^{-1}, of which only 2% is utilized. Natural gas reserves are also huge in eastern Russia, estimated at 2 Tcm, out of which almost none are presently exploited[19].

At present there are 22 GW of installed hydroelectric capacity and 8 GW of coal-fired thermal generating capacity in the region. Russia is also considering exploiting tidal power, with more than 80 GW of capacity under consideration for the future. The far eastern part of Russia is expected to undergo rapid economic growth in the future, due to its largely unexploited minerals and energy potential. As a result, there are an additional 12 GW of capacity presently under construction (about 5 GW of hydro and 6 GW of coal thermal), with another 15 GW planned, including 2 GW of nuclear power. Construction of most of this generating capacity is likely to go ahead even without electricity exports, in order to meet expected increases in local demand. At present, however, electricity supply exceeds demand, so Russia wishes to generate ancillary revenues from the sale of excess electricity—thereby acquiring capital to build additional plants in the future. Though Russia does hold sizeable coal deposits and presently uses coal for power generation in the region, it is likely that the electricity supplied to the neighboring regions of the other countries would not come from coal-fired plants[19/20].

In spite of the relative good supply of electricity in the Northeast network, the North China grid is suffering from a shortage of electricity at present. The North China Grid and Northeast China Grid have been interconnected since May 13, 2001[21]. If the Northeast China Grid interconnects with that of the Russian Far East, imported electricity from Russia can be transported to the North China Grid through the Northeast China Grid. Of course, interconnection between the North China grid and the Russian Far East is also a possible scheme.

If regional power grid interconnections are realized, the connected regions (neighboring countries) can use their overall energy resources to generate electricity in an optimized fashion. For example, North China and Northeast China can import hydroelectricity from Russia. This will reduce greatly SO_2, NO_X, CO_2 and dust emissions (as shown in Table 6). The interconnection is not only is it useful for improving air quality in these regions, but is also good for abatement of acid rain in other regions of China (due to transport of acid gases from Northeast China to other parts of China) and of global climate change.

Table 6: Reduction of emissions as a result of substitution of hydro for coal-fired electricity in Northeast China

Capacity	Coal saved (Mt)	SO_2 (t)	NO_X (t)	Dust (t)	CO_2 (Mt)
1 GW	2.42	28350	18275	8260	5.03
3 GW	7.26	85050	54825	24780	15.10
5 GW	12.1	141750	91375	41300	25.17

Note: annual operation 5000 hours; emission index based average level in 2002 in China[22].

If the regional interconnection of power grids is realized, use of the interconnection will also eliminate environmental impacts related to the extraction of coal use that is avoided in China. The environmental impacts from transporting coal from coal mines to power plants are also avoided.

In addition, if regional interconnection is realized, electricity supplies in the interconnected portions of China are likely to be more plentiful. More citizens in North and Northeast China will have the opportunity to use electricity for home heating in the winter instead of coal, resulting in reduced indoor and local air pollution . If electricity is not expensive, it will be used by farmers in rural areas to displace bio-fuel and straw combustion for home heating and cooking. All of these trends would help to greatly improve ambient air quality.

3.3 Minimize damage to human health

Environmental damage to human health is closely related to pollutant concentrations. If pollutant concentrations in the ambient air are lower than Grade II of China's national standard, then damage to human health resulting from pollution is considered acceptable.

In 2001, there were 341 cities in China being monitored for air pollutant concentrations, of which 114, or 33.4%, have attained or are better than the national standards for Grade II.. The air quality in ten cities, including Haikou, Sanya and Zhaoqing, attained Grade I levels, while the air quality in an additional 114 cities (33.4% of the total monitored) was at the Grade III level. The air quality in 113 cities

(33.2%) was worse than Grade III levels. These figures underscore the fact that air pollution in Chinese cities is a rather serious problem.

Particulate matter (or dust) remains the key pollutant affecting air quality in China. The annual concentration of the urban particulates in 64.1% of the cities exceeded Grade II. The annual concentration of particulate matter in 101 cities exceeded Grade III levels, accounting for 29.7% of the cities (as shown in Figure 7)[23]. The cities with high concentrations of airborne particulates are mainly located in Xinjiang, Qinghai, Gansu, Shanxi, Inner Mongolia, Shaanxi, Ningxia and Hebei provinces, as shown in Figure 8. As a result, most parts of North China (including Northwest and Northeast China) have serious particulate pollution problems.

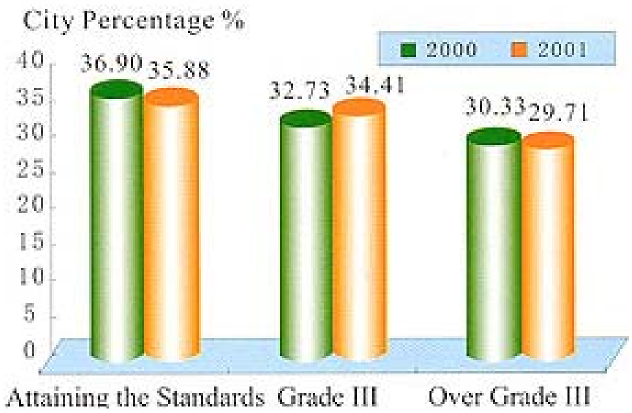

Figure 7: Percentage of 341 cities meeting particulate grade standards in urban air in China

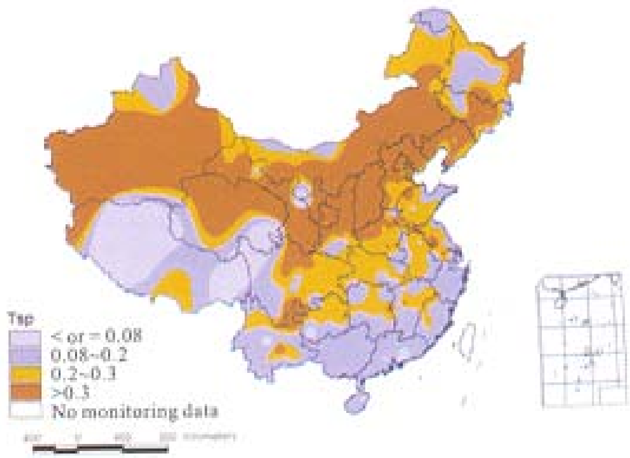

Figure 8: Total Suspended Particulate (TSP) concentrations in China

The cities where the annual concentration of SO_2 did not attain national Grade II standards as of 2001 account for 19.4% of the cities included in SO_2 statistics. The cities exceeding national Grade III standards account for 9.7% of the total sample. Of the 341 cities of the group sampled (including county level municipalities), 64 cities are located in the SO_2 Pollution Control Zone, and 118 fall into the Acid Rain Control Zone. The cities in the SO_2 Pollution Control Zone and the Acid Rain Control Zone where the annual concentration of SO_2 attained Grade II standards account, respectively, for 48.4% and 79.7% of the group of cities covered by the pollution statistics. Compared with statistics from the year 2000, the percentage of cities in the SO_2 Pollution Control Zone attaining the standards increased somewhat, and the percentage of the cities with worse than Grade III SO_2 pollution declined by 4.3% (as shown in Figure 9). The cities with serious SO_2 pollution are mainly located in Shanxi, Hebei, Guizhou, Chongqing and parts of Gansu, Shaanxi, Sichuan, Hubei, Guangxi and Inner Mongolia provinces (as shown in Figure10).

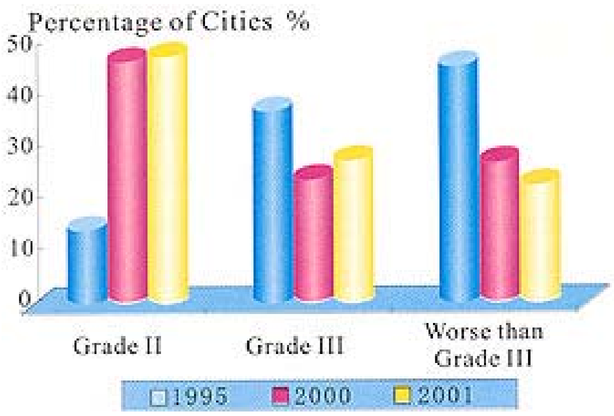

Figure 9: Attainment of SO_2 pollution Grade levels by cities in the SO_2 pollution control zone of China

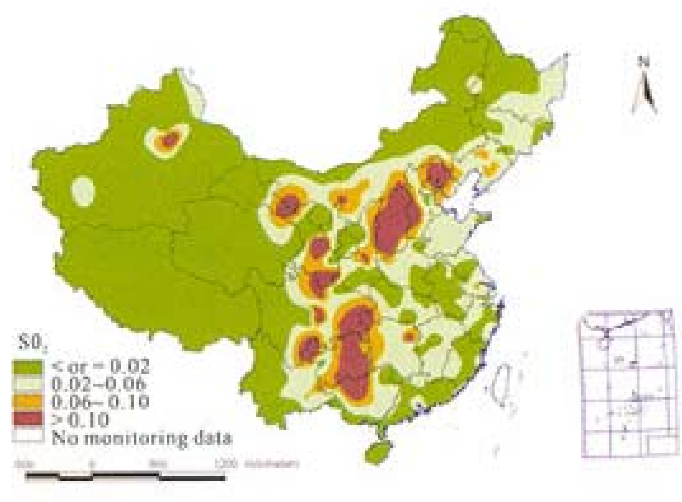

Figure 10: SO_2 concentrations by location in China, 2001

Comparing Figure10 with Table 3, we can conclude that SO_2 concentration caused by operation of coal-fired power plants contributes to high ambient levels of SO_2 concentrations in most cities. The primary reason for this correlation is that in most regions of China, existing power plants are usually geographically co-located with the centers of electricity use, that is, power plants are located in urban centers. In order to ease combined access to labor, transport, and electricity supply, there has generally been no effort in China to distance power plants from population centers. These urban power plants are typically large, coal-fired stations with only electrostatic precipitators (sometimes Venturi water film precipitators) for control of particulate matter, and with no SO_2 or NO_X controls. The location of coal-fired power plants in urban centers results in a maximum exposure of populations to elevated ambient pollutant concentrations, and impairs human health, largely through the presence of inhalable particulate matter[24]. Inhalable particulate matter is largely a mixture of primary particles and secondary sulfate (through ambient SO_2 itself is a health danger in some northeastern cities).

If electricity grid interconnections are enhanced, added generating plants can increasingly be separated from points of electricity use, namely urban centers. This separation will help to alleviate human exposure to elevated air pollutant concentrations.

4. Environmental Impacts of Regional Power Grid Interconnections

4.1 Construction of grid interconnection

Regional power grid interconnections require the construction of at least some new transmission lines and transformer substations. These lines and substations will occupy some land. In some instances, a relatively few people will need to be relocated. During construction, kicked-up dust, noise, and vegetation damage may accrue. In general these environmental impacts are transient, and are not heavy. Construction-related environmental impacts can be acceptable if some reasonable control measures are used.

4.2 Operation of grid interconnection

Operation of power grids can produce electrical fields and magnetic fields near transmission lines. Up to now, however, there is no accurate evidence to testify that electric and magnetic fields near transmission lines have harmful impacts on human health. In addition, operating power transmission lines or transformer substations may have some impact on radio transmission and reception.

5. Conclusions

There are a number of potential benefits of power grid interconnection. Gradually enlarged power grids, and power grid interconnection, have been part of the general pattern of power system development in China. Regional power grid interconnections (including China, Russia, and other nations in Northeast Asia) may offer at least 3 types of environmental benefits for China.

① The construction of 3.7 GW of electricity generation capacity will be avoided. This will in turn avoid the direct and indirect environmental damages that would be caused by construction in China of new power plants to meet the same capacity requirements.

② The optimization at a regional scale of the use of natural resources to generate electricity. China can import some hydroelectricity from Russia. Doing so will reduce the environmental impacts caused by power generation in China. The use of imported power will particularly help to improve ambient air quality in North (including northwest and northeast) China.

③ Generating sources can be separated from centers of electricity use. Doing so will reduce damage to human health.

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