DOMESTIC ENVIRONMENTAL BENEFITS OF CHINA'S ENERGY-RELATED CDM POTENTIAL

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Abstract. We estimate the domestic environmental and health benefits of exploiting China's energy-related CDM potential. Exploiting the CDM potential may save between 3,000 and 40,000 lives annually. Additional gains are estimated to reach upwards from 1 billion RMB annually. The key to these gains is the fact that actions and measures to reduce CO_2 emissions also reduce emissions of TSP and SO_2. In our estimate, exploiting the CDM-potential will cut SO_2-emissions by between one-half and three million tons annually. To arrive at these conclusions we synthesize a significant body of recent research on co-benefits of climate abatement in China.

1. Introduction

By some accounts, China is home to half of the world's Clean Development Mechanism (CDM) potential (World Bank, 2004, Zhang, 1999). In times when many governments perceive greenhouse gas commitments as too costly to be worthwhile, making use of China's low-cost CDM potential presents itself as a tempting option for reducing global CO_2 emissions.

Recent research has indicated that climate change abatement in China is a lower cost alternative than originally thought. That is because energy-related climate-change abatement reduces emissions to air of SO_2, total suspended particles (TSP), NO_x, heavy metals such as mercury, and a range of organic compounds. Lower emissions to air help meet domestic emission and air quality standards, and contribute to better health, higher crop yields, and less material maintenance. Better health and other improvements are important co-benefits of climate abatement that deduct from the economic cost.

In this paper, we synthesize results from a significant body of recent research, some of which is our own, that quantifies co-benefits of energy-related CO_2 reductions in China. Based on the synthesis, and a discussion of its relevance in the context of China's CDM potential, we assess the extent of the environmental

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co-benefits that would arise if and when China exploits its potential for CDM. The assessment is intended to indicate the magnitude of co-benefits associated with Chinese climate abatement, while also pointing to the policy relevance of recent research on co-benefits in China.

According to our assessment, the co-benefits of greenhouse gas (GHG) abatement are large in China. Large co-benefits may help China unleash its potential for CDM projects and increase its interest in GHG abatement. Unleashing the Chinese potential is important for the success of future climate agreements. Besides, an evaluation of co-benefits gives content to the requirement that CDM-projects contribute to sustainable development. Paying attention to co-benefits could also be useful in the context of climate change policy in China, where economics and foreign policy issues often are allowed to dominate environmental considerations.

2. Research on Co-Benefits in China and Elsewhere

2.1. COMMON THEMES AND DIFFERENT METHODS

As a background for our estimates of co-benefits of CDM, we summarize recent studies of co-benefits in China and supplement with information from some other countries. All studies of co-benefits that we summarize here analyze how energy-related projects, plans or policies reduce emissions to air of local, regional and global pollutants. They also analyze and quantify some, but not all of the benefits that emission reductions bring to public health, materials (less corrosion and maintenance), crops and other vegetation. Finally the studies include monetary valuation of the benefits to public health, materials and crops/vegetation. Benefits of greenhouse gas reductions are not included in the benefit estimates. Figure 1 illustrates the steps from emissions to monetary valuation of a project, plan or policy.

The studies differ in their focus and the methodology used to estimate benefits. At one end are the project-oriented studies. These address specific investment or abatement projects, their impact on air pollution, their benefits and costs. Sometimes the projects are factual, as in Mestl et al. (2005), Morgenstern et al. (2004) and Zhang and Duan (1999). Other times the projects are hypothetical but representative of an actual project of an average type, as in Aunan et al. (2004a), Feng (1999), Cao (2004) and Wells et al. (1994). Project-oriented studies are often called bottom-up studies.

At the other end are studies based on a model description of the whole economy. Sometimes they are called top-down studies. These studies build on economic

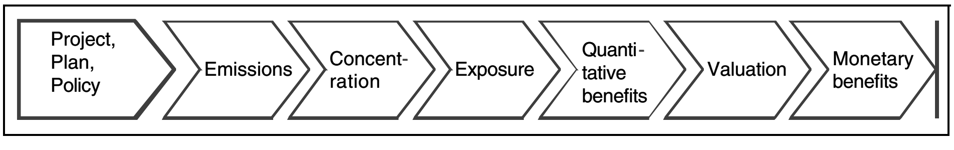

Figure 1. Flow chart of co-benefit estimates.

theory to address impacts of policies on gross industry and household emissions and abatement. O'Connor et al. (2003) and Garbaccio et al. (2000) are examples.

In between the bottom-up and top-down studies are studies that discuss scenarios for emissions and energy use. Some of these use models of the energy sector, for instance the MARKAL model, to help discuss impacts; others do not. Studies in this tradition include, Fang et al. (2002), Gielen and Chen (2001), Chen et al. (2001), Wang and Smith (1999a, b) and Peng (2000).

What conclusions can be drawn from these studies? We begin by assessing emission reductions from energy related CO_2-abating projects, which is the first element of the chain in Figure 1. Several of the above-mentioned studies publish estimates of reductions in SO_2 and TSP, relative to a reduction in CO_2. Such estimates are useful when assessing emission reductions from CDM. The data and sources are given in the appendix.

Given significant variation in methods and scope, it is difficult to derive accurate point estimates from the studies. Rather, we have looked at the range of estimates and deduced various simple statistics. First, we have calculated empirical medians and percentiles, and mostly make use of those later in the paper. But we also report a theoretical approach, starting with the observation that air pollution statistics, in particular ratios, often have been found to fit a log-normal distribution (see, e.g., Rabl and Spadaro, 1999). The hypothesis that the data is generated by a lognormal distribution is tested. We cannot reject the hypothesis that the distributions of SO_2, TSP, avoided deaths, and total benefits are lognormal,[1] and we therefore report estimated means and standard deviations. The results for various selections of studies are given in Table I. Results denoted "Table AI" "Table AII", etc., were obtained by including all studies in the Appendix. We checked the effect of deleting the highest and lowest values and also made a selection of studies that in our judgment are most likely to fit requirements to CDM projects.[2] Finally we looked at studies related to boilers only since these are very important in China both because of the large number of coal fired boilers and since the fairly low emission height imply that health effects of the emitted pollutants are likely to be large.

2.2. EMISSION REDUCTIONS

2.2.1. *Reductions of SO_2*

Values for the SO_2/CO_2 ratio are given in the Appendix (Table AI) and shown in Figure 2. In the figure we also show the median and 15/85 percentiles for all projects, which are 8.8 and 6.7–18.2 kg SO_2/ton CO_2 respectively. "All projects" mean all projects that report SO_2 and CO_2 emissions reductions associated with CO_2 abatement.

In the studies included in Figure 2, emissions of SO_2 and CO_2 originate from the use of coal. When coal is the source, the SO_2/CO_2-ratio is to a first approximation determined by the sulfur and carbon content in the coal and by the extent of SO_2 -

TABLE I
Geometric mean, standard deviation, 68% confidence interval, median, and 15 and 85 percentiles for reductions of SO_2 and TSP relative to CO_2, and the benefit of these reductions

	μ_g	σ_g	68%	Median	15–85 Percentiles	Comment
kg SO_2/ton CO_2	10.8	1.7	6.3–18.6	8.8	6.8–18.2	Table AI
kg SO_2/ton CO_2	10.1	1.9	5.4–18.9	8.8	8.2–15.6	Table AI, highest and lowest deleted
kg SO_2/ton CO_2	8.7	1.7	5.0–14.9	8.7	5.7–11.4	Table AI, "CDM projects" only
kg SO_2/ton CO_2	5.9	1.7	3.5–10.0	8.2	4.5–8.2	Table AI, boilers only
kg TSP/ton CO_2	5.3	2.2	2.4–11.8	4.0	2.7–12.2	Table AII
kg TSP/ton CO_2	5.0	1.9	2.7–9.3	4.0	2.7–9.6	Table AII, highest and lowest deleted
kg TSP/ton CO_2	3.9	1.7	2.3–6.6	3.6	2.4–6.8	Table AII, "CDM projects" only
kg TSP/ton CO_2	4.8	2.0	2.4–9.6	3.6	3.1–10.2	Table AII, boilers only
Cases of avoided deaths/CO_2	60	3.6	17–261	51	23–141	Table AIII[1]
Cases of avoided deaths/CO_2	73	3.8	19–277	70	34–161	Table AIII, Chile and USA excluded
RMB Benefit/CO_2	196.1	4.9	40–951	247	39–902	Table AIV
RMB Benefit/CO_2	173.7	4.3	40–753	247	55–711	Table AIV, highest and lowest deleted
RMB Benefit/CO_2	152	3.8	40–570	198	45–353	Table AIV, "CDM projects" only
RMB Benefit/CO_2	497	2.4	204–1211	291	239–1427	Table AIV, boilers only

[1]One zero value excluded in calculation of geometric parameters.

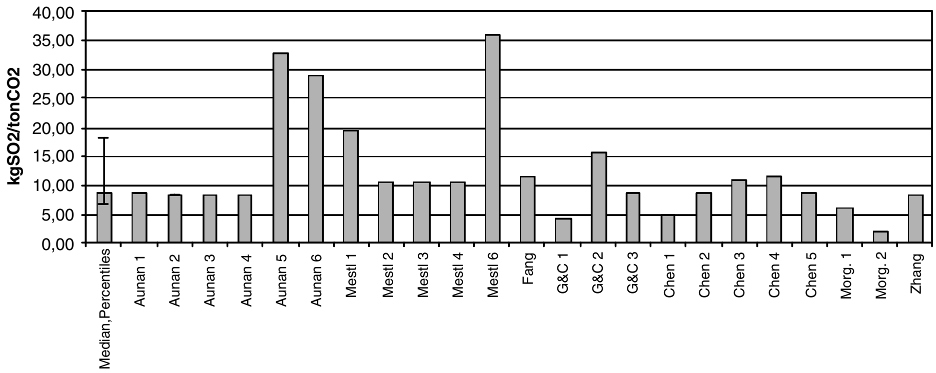

Figure 2. Reductions in emissions of SO_2 relative to CO_2/or the studies and projects included in the Appendix.

abatement. For instance, if coal contains 1.0% sulfur, 90% of which goes through the chimney; and one ton of coal produces about 2.0 tons CO_2, the ratio of SO_2/CO_2 prior to abatement is 9 kg SO_2/ton CO_2.[3] Estimates clustering around the median in Figure 2, including most estimates from Shanxi and Shanghai as well as the one from Shenzhen, are probably built on input values of this order and reflect the fact that SO_2 abatement is still rare in China. Particularly high estimates are found in the coal-washing estimate from Shanxi (Aunan 5) and briquetting in Shanxi (Aunan 6) and Taiyuan (Mestl 6). It is reasonable that values for coal washing are high since coal washing washes away sulfur rich impure particles from the coal. The high values for briquetting relate to the assumption that lime that binds sulfur is added to the briquettes.

Looking at Table I, and excluding the "Boilers only" category, we find that the geometric means and medians for the SO_2/CO_2 ratio fall in the range 8.7–10.8 kg SO_2/ton CO_2. Thus, fairly similar values are obtained using different methods and samples.

2.2.2. *Reductions of Total Suspended Particles*

Values for the TSP/CO_2 ratio are given in the Appendix (Table AII) and shown in Figure 3. The median and percentiles for all projects are in this case 4.0 and 2.7–12.2 kg TSP/ton CO_2. The range of geometric means and medians is 3.6–5.3 TSP/ton CO_2, depending on the sample (all studies, CDM projects, etc.).

The estimates vary in fairly predictable ways. The very high value for one of the projects in Taiyuan (Mestl 2) can be explained by a reduction of process dust in addition to fly ash, and a small CO_2 reduction. The low estimate from Shanghai (Chen 1) includes power plants and other units with high cleaning efficiencies. The Aunan et al. (2004a) study of coal washing in Shanxi (Aunan 5) is relevant for households without cleaning equipment and obtains a higher ratio of 9.6.

Similarly to the SO_2-case, one can compare these estimates to estimates based on emission factors. One ton of coal is generally thought to generate 20% ash

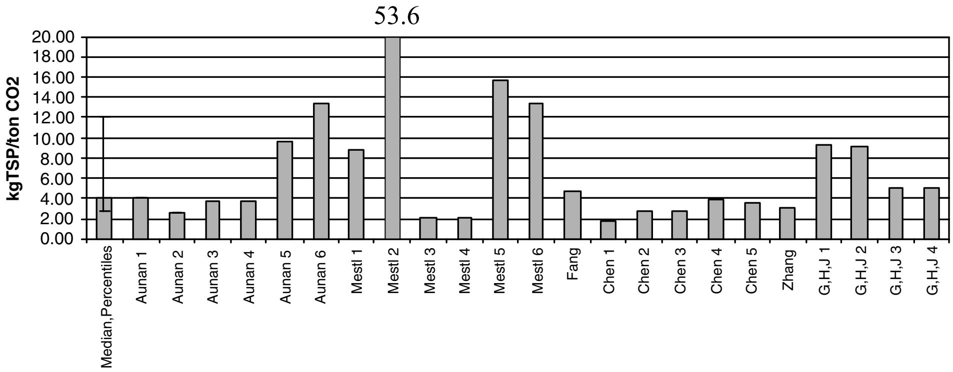

Figure 3. Reductions in emissions of TSP relative to CO_2/or the studies and projects included in the Appendix.

(e.g., Fang et al., 1999). Of this, fly ash makes up 10–20% in industrial combustion (industrial boilers), household stoves, etc., and 90% in utility boilers (power plants). The maximum potential emission of TSP is therefore 40 kg per ton coal in industrial combustion, and a much higher 180 kg per ton coal in utility boilers. However, almost all industrial and utility boilers have dust collectors that reduce the emissions. The cleaning efficiency of these varies between 50 and 90% among industrial boilers, and between 80 and 99.5% in utility boilers. Using 80% for industrial boilers and 98% for utility boilers, the emission factor for TSP is 8 and 3.6 kg TSP per ton coal respectively, giving 3.3 and 1.5 kg TSP/ton CO_2 respectively. The former value is in good agreement with the median obtained from our sample. The latter value may indicate that utility boilers with high collection efficiency are not well represented in our studies.

2.3. ESTIMATES OF LIVES SAVED

Epidemiological research into air pollution has shown that air pollution is damaging to human health. Just how damaging is a matter of debate and new studies focusing on mortality impacts continue to appear. The impact that air pollution has on an individual depends, for instance, on health status, on the exposure pattern, and on co-exposure to other health hazards, like smoking. An estimate that has been employed in several studies was suggested by WHO (1999): 1% additional daily deaths for every 10 $\mu g/m^3$ increase in daily ambient concentration of particles smaller than 10 μm, PM_{10}. In the United States, more recent studies have indicated a considerably higher exposure-response coefficient for the long-term effect; i.e. a 2.4% increased mortality rate for every 10 $\mu g/m^3$ increase in the long-term PM_{10} concentration (Pope et al., 2002). On the other hand, recent studies in Europe and in developing countries indicate a smaller coefficient (0.4%) for the short-term effect than the one suggested by WHO (1999), see e.g. EC (1998) and Aunan and Pan (2004). In two of our own studies in China (Aunan et al., 2004a and Mestl et al., 2005), we focused on the long-term effects on mortality, which results in rather large estimated mortality impacts. On the other hand, we used avoided life years lost in different age groups as the end-point – not the total number of avoided premature deaths – which typically reduces the estimated economic impact to about half the ones obtained by using avoided premature deaths as end-point (Aunan et al., 2004a). Clearly, from the available studies in different parts of the world, the conclusion can be drawn that improvements in air quality will save lives, although any point estimate is likely to be uncertain.

As part of their exposure-response step, see Figure 1, all the studies we mentioned above estimate the expected number of lives, or life-years, saved using the WHO estimate or other estimates. Taken collectively, the estimates provide a useful background for the expected number of lives saved if China realizes its CDM potential. Figure 4 presents estimates of lives saved from recent relevant studies, and

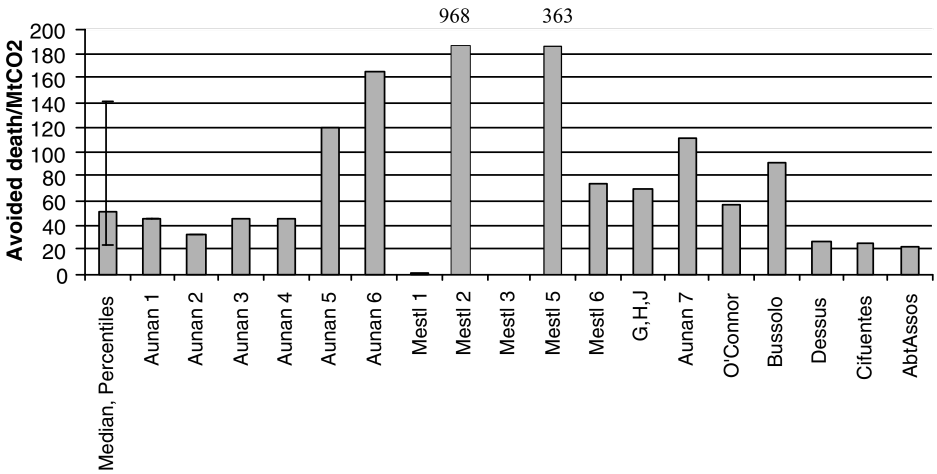

Figure 4. Avoided deaths per million tons CO_2 (acute mortality) as estimated from different studies. (The estimates listed to the left are derived from the authors' own studies in Taiyuan (T) and Shanxi (S); Mestl et al. (2005) and Aunan et al. (2004a), using the 0.4% estimate for acute mortality mentioned in the text.)

compares results for China with similar exercises elsewhere. The median is 51 and the 15/85 percentiles 23 and 141 if we use all the data (Table AIII). Excluding the two studies from Chile, and the one from the United States, the median becomes 70 and the percentiles 34 and 161. Part of the reason for the low values in studies in Chile and the United States is that more people are affected by a given amount of air pollution in the crowded Chinese and Indian cities. It might also be the case that industry and the power sector have higher cleaning efficiencies in Chile and the United States than in China and India. In what follows, we choose to focus on the sample that excludes the studies from Chile and the United States.

Like Figure 2, Figure 4 indicates that there is more variation in the results at the bottom-up project level (e.g. Aunan 1–6 and Mestl 1–6) than at the top-down economy level (i.e Bussolo, Aunan 7, and G,H,J). This is to be expected since projects can be very different, while economy-wide figures are meant to indicate an *ex ante* average of the bottom-up projects. Still, the variation serves as a reminder that benefits may vary substantially from project to project. There are at least three reasons for that. One, as we have seen, the SO_2/CO_2 and TSP/CO_2 ratios differ a lot between individual projects. Two, the emission stack height differs between the projects, leading to quite different exposure results. A third reason is that the potential for CO_2-reduction differs a lot between individual projects. If the CO_2-reduction potential is small relative to the potential for SO_2-and TSP-reductions, the number of lives saved per unit of CO_2-reduction will necessarily be large. This and other reasons why scale matters are further discussed in Aunan et al. (2004b).

With the caveat that there is significant variation behind the average numbers, we estimate that between 34 and 161 lives are saved for each million ton of CO_2

reduced in China. For some purposes it is useful to assess the monetary equivalent of these savings.

2.4. MONETARY BENEFITS AND COSTS

2.4.1. *On the Monetary Value of Lives Saved*

How much is saving a life worth? The monetary value of lives saved has been the topic of many discussions in environmental economics. We review the various approaches taken in order to decide what we will do in this paper.

One method that has been employed in the literature is to conduct a survey where people are asked for their willingness to sacrifice in the form of taxes and other expenses to reduce mortality risk.[4] An important challenge is to design the questions in order to reveal answers that are as truthful and accurate as possible and recent procedures have been developed with that in mind. A second method is to judge the difference between well paid, but risky jobs compared to less well-paid, but less risky jobs that are otherwise similar. A third method is to assess purchases of risk-reducing equipment, and a fourth is to assess how much society sacrifices in other areas in order to reduce risk. Comparison with other areas gives a benchmark for the level of sacrifice to put into the environmental area. Avoided serious disease is often valued as a fraction of an avoided statistical death.

In mainland China, only the survey method has been tried as far as we are aware.[5] Table II provides results from some surveys, including Taiwan and India. These estimates range between 240 000 and 8.6 million RMB. The two Chinese mainland studies seem to suggest 1 million RMB or lower, while studies from Taiwan, and even India, a poorer country than China, suggest 2–3 million RMB or higher.

Most researchers agree that there are still far too few studies from China and other developing countries to rely solely on those. An alternative is to look outside the developing world. In Europe and the United States, numerous studies on the price of

TABLE II
Estimates of statistical value of life, some developing countries

Study, country	Million RMB
Wang et al. (2001), China	0.3–1.25
Zhang (2002), China	0.24–1.7
Liu and Hammitt (1999), Taiwan	5.2
Liu et al. (1997), Taiwan	3.75
Simon et al. (1999), India	1.27–3.0
Shanmugam (2000), India	6.31–8.6
Shanmugam (1997), India	3.32

risk and a statistical value of life have been carried out. The wage-difference method is the most common. European and U.S. estimates of an avoided statistical death range between 16 and 45 million RMB (2–5 million Euro/USD), see, e.g., USEPA (1997). These estimates cannot be transferred directly into a Chinese context given differences in income, education and culture. An obvious correction is related to income. According to official GDP figures, the income level in Europe and the United States is approximately 20 times that of China. Europeans and Americans therefore have the possibility to spend 20 times more on everything, including risk reduction. This argument has led researchers to downgrade American and European estimates by a factor of approximately 20. The result is an estimated range of 0.8–2.25 million RMB, which is inside the range of the Chinese, Taiwanese and Indian studies.[6] Based on studies from several countries, Miller (2000) suggests a formula for the statistical value of life as a multiple of GDP/capita. His preferred multiple is 122, suggesting, in the case of China, an estimated statistical value of life of approximately 1 million RMB.[7] While everyone acknowledges that downscaling using GDP/capita or multiplying by 122 are crude methods, they are widely used and provide useful tools to cost-benefit analyses of policies and programs.

Given the estimate obtained above of 34–161 lives saved per million ton CO_2, and using 1 million RMB to illustrate the value of a statistical life saved, one obtains as a rule of thumb that between 34 and 161 million RMB are saved per million ton CO_2 related to the avoidance of premature deaths.

How much a society is willing to sacrifice in order to reap the benefit of avoided deaths is both a political and ethical question. Some impacts are perhaps best left non-valued. We follow that approach later, and indicate the monetary equivalent of all benefits except lives saved. The expected number of lives saved is then presented as a stand-alone item next to the monetized benefits.

2.4.2. *All Inclusive Monetary Benefits*

In addition to increased mortality, local pollution has a number of health related and other impacts. The studies under review perform benefit estimation of main impacts.

Epidemiological research has shown that lower air pollution implies fewer cases of respiratory disease, fewer asthma attacks, and fewer cases of hospital admissions, outpatient visits and sick leaves. Moreover, lower air pollution in general means higher agricultural yields, better forest growth, less corrosion, less wear and tear of buildings and cultural heritage, better visibility and less dust removal. Studies of co-benefits have attempted to translate these other impacts into estimates of monetary benefits.

To arrive at estimates of benefits in monetary terms, researchers must of course make concrete assumptions on the values of impacts. The value of a statistical life is only one example, if important. The tradition in the literature cited here, is to take a practical approach to valuation of non-mortality impacts. Additional agricultural yields are valued at market prices. So is forest growth, and studies generally ignore

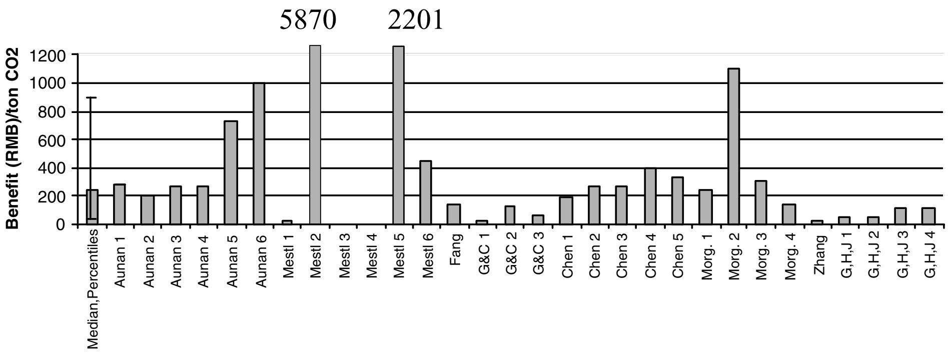

Figure 5. Co-benefits obtained in the studies and projects included in the Appendix. (An exchange rate of 8.3 RMB/USD has been used in the cases where the benefit was originally stated in USD.)

the value of ecological benefits associated with more healthy forests and agricultural fields. Corrosion and wear and tear are valued by the costs of maintenance and repairs that are avoided. Hospital admissions, outpatient visits and lighter cases of disease are valued by an estimate of real resources spent, on medicines, doctor's time and, at least in principle, an appropriate share of hospital's capital cost, and finally user fees. The decrease in individual welfare, which is the reason for seeking treatment, is not valued.

Obtaining a consensus range from these studies is useful for indicating the potential benefits of carrying out the CDM and CO_2-abatement potential in China.

Figure 5 and Table AIV show how studies estimate the combined monetary benefit of abatement projects, expressed relatively to the reduction in CO_2-emissions. These figures include both the value of lives saved and other benefits. The large variation reflects the obvious fact that not all projects that reduce CO_2 will improve local environmental conditions similarly, and that the studies differ in what effects are included in the estimate and how effects are estimated.

As with reduced mortality, we see that broad policies that comprise a representative average of projects imply co-benefits of significant value. Table I shows that, except for the "Boilers only" category, the geometric means and medians are in the range 152–247 RMB per ton of CO_2 reduction. In Section 3.4, we will use the 15/85-percentile range for likely CDM projects, i.e. 45–353 RMB, as a starting point for calculating benefits of CO_2 reductions.

3. CDM in China

In the previous section we worked out indicators per ton of CO_2 to apply to energy related CDM-projects. In this section we briefly discuss the status of CDM capacity in China, show various sources' estimates for the country's CDM potential, discuss applicability of the indicators and finally apply the indicators to translate the relevant potential into lower local pollution levels and improved living conditions for the Chinese population.

3.1. BACKGROUND

The Clean Development Mechanism is sometimes portrayed as a win–win solution to the problem of global warming: Countries that have signed the Kyoto Protocol are being helped to reach their CO_2 reduction commitments, while developing countries receive much- needed financial and technological transfer.

China recently reported its emissions of greenhouse gases to the United Nations for the first time. In 1994, the country emitted 2.6 billion tons of CO_2, 34.3 million tons of methane and 850 000 tons of nitrous oxide.[8] With a population projected to increase by 300 million people by 2043, and growing per-capita energy use, emission levels are expected to continue to increase rapidly. The country does not have any emissions reduction targets under the Kyoto Protocol, but is among the developing countries that are likely to be put under heavy pressure to take on obligations post-2012. For the time being, however, it is considered an increasingly interesting supplier of CDM projects. In fact, China was recently ranked as the fifth best country for CDM investments worldwide by the information agency Point Carbon.[9]

The ratification of the Kyoto Protocol requires the establishment of a Designated National Authority (DNA) that can approve CDM projects. China's DNA is under the Office to National Climate Change Coordination Committee. The existence of a DNA is only a signal that the country is interested in CDM projects. How easily projects are implemented depends on the regulatory framework as well as experience of the DNA. With just one approved project as of December 2004, China has limited experience in these matters so far.

Another factor that puts in danger the implementation of projects is the cost related to the CDM procedure – *transaction cost.* Sending a project through the CDM approval cycle is expensive. Projects with small volumes of emission reductions cannot absorb the same amount of transaction costs as larger projects – in fact, high transaction costs can prevent them from going ahead at all. A comprehensive, recent review of China's CDM potential is World Bank (2004). According to the World Bank "it is assumed that transaction costs for small projects ($<$10 000 tCO_2/year) will be prohibitive to their implementation under the CDM at the range of market prices estimated in this study" (p. 112). This will exclude a number of small-scale projects in the industry, transport, rural, urban and commercial sectors in China.

A key concept in CDM is *additionality.* Current CDM legislation requires that to qualify as CDM, a project cannot have the potential of being implemented in the absence of CDM – that is, the additional financing available from selling certificates must be necessary to make the project bankable. The World Bank (2004) suggests that additionality may not be a barrier at this point in China, as most projects that have been suggested as CDM projects so far concern technologies that are neither widely implemented nor commercially viable under current circumstances in China. Another key concept in this context is *sustainability.* The international rules for CDM state that CDM projects should contribute to sustainable development. CDM projects in China that both reduce local air pollution and improve the economy, e.g. through improved provision of electricity and technological transfers, will contribute towards reaching such a goal. Quantifying co-benefits, as we are doing in this paper, can be viewed as a step in the direction making sustainability explicit.

Certain project types are more "popular" than others in the context of CDM. For instance, large hydroelectric dams are viewed by many as having too many negative social implications. Whether to allow afforestation projects is another thorny issue – difficulties relate to how to define the crediting period for certified emission reductions (CERs) and what to do in case of forest fires. However, in the case of China, there is an ample supply of industrial boiler and thermal power projects that should be relatively easy to get through the CDM approval process.

There has been much debate concerning the demand for CERs and their projected prices. The World Bank warns of this uncertainty when estimating potential related to the demand for CER: "... unless the demand for CERs does pick up significantly until 2006 the...projected potential in China in 2010 of 79.2 Million tons CO_2 will be difficult to be realized ..."(p. 117). It is generally recognized that one of the major obstacles to CDM implementation is the low price of CERs. This is why it is important to highlight the existence of co-benefits – they represent another source of "income" resulting from reduced CO_2 emissions.

It is generally recognized that CDM alone cannot overcome all barriers of for instance renewable energy projects, and that efforts are needed to reduce transaction costs, and restructure the regulatory framework to promote the renewable sector. The recent initiative of the National Peoples Congress to create a law promoting renewable energy and to revise current electricity and energy-saving laws is a step in the right direction in this respect. It is also important to more generally provide a welcoming environment for foreign investment in China. Being the largest recipient of FDI in the world, China would seem to have a welcoming environment, but there might still be barriers in the energy sector (Michaelowa et al., 2003), including political insecurity, transparency of the regulatory framework, security of repayment from projects, and lack of initial project support.

3.2. China's CDM potential

Against the backdrop of the previous discussion of CDM issues in a Chinese context, we now review various estimates of the magnitude of China's CDM potential. The comprehensive World Bank (2004) review discusses key methodological issues related to CDM from China's perspective and includes recommendations for a Chinese CDM strategy. The approach to assessing potential is top-down in the sense that it uses an equilibrium model for the carbon market to produce the forecast. The model uses inputs from other models (baseline assumptions, marginal abatement costs) and calculates different scenarios. Assuming 10% voluntary US participation, price leadership of Eastern Europe and the former Soviet Union, a 30% implementation rate of projects, and a location-dependent price of CERs averaging 6 USD/tCO_2, the world CDM market in 2010 is estimated at 164 million tons CO_2. China's energy-related potential is estimated at almost 50% of that, at 79.2 million tons CO_2. Depending on factors such as supply and demand for hot air, marginal abatement costs of potential buyers, market structure, fraction of CDM potential that is actually realized, etc., the potential in China may go as low as 0 and as high as 211 million tons. The authors point out that reaching 79.2 million tons CO_2 will require a significant number of new power projects registered as CDM projects, as well as up to 100 renewable power projects in operation by 2006/7.[10]

The World Bank study is, however, not the first of its kind. Several other studies have recently been published. The studies are listed in Table III, where we compare both the estimates and the approach taken to arrive at these estimates.[11]

The estimates of China's CDM potential vary greatly between sources (Table III), with World Bank (2004) presenting by far the lowest potential. Part of the difference is explained by the treatment of implementation rates, that is, the institutional, managerial and technical barriers that reduce actual implementation compared to the theoretical potential. As indicated by our discussion above, implementation barriers related to CDM have come into increased focus in recent years. World Bank (2004) assumes a 30% implementation rate. Other studies are less explicit. Michelowa et al. (2003) for instance assume 50% realization of the theoretical potential for renovation of industrial boilers, but do not discuss implementation of

TABLE III
Estimates of total CDM potential in China

	World Bank (2004)	Zhang (1999, 2000)	Michaelowa et al. (2003)	Wei (2002)	Zou and Li (2000)
CDM Potential (Mt CO_2)	79.2(0–211)	290–788[1]	~350	532[2]	620[2,3]
30% implementation	79.2(0–211)	87–236	~101	160	186
Type of estimate	Top-down	Top-down	Bottom-up	Bottom-up	Bottom up

All estimates apply to 2010, except for Michaelowa et al. who look at the period 2000–2008.
[1]Highest estimate (both reduction potential and price) corresponds to a zero limit on hot air, the lowest to EU ceilings on trading (that at least 50% of GHG emission reductions must be achieved via domestic action).
[2]This figure refers to *abatement* potential, and thus represents an upper limit to the potential for CDM projects.
[3]The estimate of 620 does not include potential for anaerobic technology for wastewater treatment and energy recovery, solar energy, geothermal, or afforestation. These are sectors the authors discuss the abatement potential of, without suggesting concrete estimates for (except for geothermal).

other categories of projects. Zou and Li (2000) assume that 40% of China's wind power potential can be turned into projects, but end up with a much higher estimate for wind than other sources. When we apply the 30% implementation rate that the World Bank uses to the rest of the studies the estimates are much more similar (second row of Table III). While a 30% implementation rate imposed on the non-World Bank estimates could be an overcorrection we believe that it increases the realism of the estimates.

After adjusting for implementation rates, the two top-down studies of World Bank and Zhang are in reasonable agreement. Zhang's estimate is somewhat higher, since the United States was still a potential buyer at the time the study was made, while the World Bank assumes only a 10% voluntary US participation rate. This difference in assumptions is reflected in a higher price range for CERs in Zhang's study.

Even with a 30% implementation rate, two of the remaining studies, Wei et al. give noticeable higher potentials than World Bank (2004). The third remaining study, Michaelowa et al., give a similar potential to the World Bank. Table IV indicates that much of the difference between Wei et al. and Michealowa et al. can be attributed to wind power. All three studies agree on the potential (250 GW), but while Zou and Li assume 40% of this can be made into projects, resulting in 110 million tons CO_2/year, Wei arrives at an estimate of only 1.5 million tons CO_2 year, and Michaelowa et al. arrive at 4.2 million tons CO_2/year. Besides, Michaelowa et al. focus on energy in power plants and industrial combustion, while the two other studies reach wider in their search for potential and include, for instance, technical renovation of motors (Wei). Finally, Michaelowa et al. apply a 50% implementation rate on the Zou and Li estimate for renovation of industrial boilers and ends up with a considerably lower total estimate than the other two.

3.3. CO-BENEFITS: CDM PROJECTS LEAD TO LESS LOCAL AIR POLLUTION

One interpretation of the studies under review is that they suggest a potential for CDM projects in China in the range of 80–100 million tons in the short run, and perhaps double that potential in the longer run when more favorable conditions for CDM have been allowed to take root. Given their energy focus, it is clear that the projects will generate co-benefits – that is, we are looking at projects that do indeed reduce local pollution as well as global pollution. Using the 15–85 percentile range for local pollution reductions, and the CDM-relevant sample arrived at in section 2.2, we obtain the following possible reductions in local air pollution (Table V).

We see that the potential for SO_2 reductions varies from about half a million to almost 3 million tons. To put these numbers into perspective, China's SO_2 and emissions in 2001 were 19.5 million tons (NBS, 2004). The potential for reduction is 2.5–15% of current emissions. The TSP reduction ranges from 0.2 million tons to 1.6 million tons, or 2–15% of current emissions of "smoke dust". If we, as an illustration

TABLE IV
CDM potential by sector (million tons CO_2/year)[1]

Study/sector	Wei (2002)	Zou and Li (2000)	Michaelowa et al. (2003)	World Bank (2004)
Total energy	20	119	20–28	40
Thermal power renovation/ new technologies	17	9	16–23[2]	
Wind energy	1.5	110[3]	4.2[4]	
Solar thermal	1.7		0.6	
Electric engines	30			
Renovation of industrial boilers	23	67	39[5]	<12[6]
All other sectors	86[7]		38–45[8]	28[9]
Total	<160	<186	~101	~79.2

[1]Zhang (1999) does not specify sectors and is therefore not included. Figures refer to a 30% implementation rate (assumption used for World Bank estimate, and applied to all in this study). The basis for comparing studies is not ideal, with the various authors often emphasizing different types of projects. For instance, Michaelowa et al. consider *efficient coal power* and *upgrade of coal power* projects in the "Thermal power renovation" category, whereas Wei looks at *IGCC* and *renovation and reconstruction of conventional thermal power plant* (without specifying further) in the same category. Thus, to some degree we may be "comparing apples and oranges".
[2]Estimate varies according to the assumed efficiency of the CDM plant (38–41%).
[3]This estimate is based on 40% of total wind potential. Note that Zou and Li, Michaelowa et al., and Wei agree on the total potential for wind (250 GW).
[4]Assuming addition of 0.5 GW per year during eight years.
[5]Based on Zou and Li (2000) and assuming approx. 50% realized.
[6]Sector is referred to in World Bank study as "other industry sector".
[7]Consists of hydro power (60 Million tons CO_2), energy saving lighting, and other.
[8]Consists of fuel switching (Chinese-Russian gas pipeline), coalbed methane, lighting and domestic appliances, biomass, and geothermal.
[9]Includes steel making, cement and chemical industry as well as non-CO_2 projects (methane reduction from gas flaring and HFC-23 decomposition). The World Bank total estimate for CDM include a 1–2% share of gas flaring as well as potential for HFC-23 decomposition. Together, non-CO_2 projects are assumed to make up 10% or less of CER sales.

TABLE V
SO_2 and TSP emission reduction associated with realizing China's CDM potential

	The World Bank (2004)	Zhang (1999, 2000)	Michaelowa et al. (2003)	Wei (2002)	Zou and Li (2000)
CDM Potential (Mt CO_2, annually)	79.2	87–236	~101	<160	<186
Reduction in SO_2 (Mt)[1]	0.45–0.9	0.50–2.69	0.57–1.15	0.91–1.82	1.06–2.12
Reduction in TSP(Mt)[2]	0.19–0.54	0.21–1.60	0.24–0.69	0.38–1.08	0.45–1.26

[1]Using a 15–85 percentile range from "CDM projects" sample (5.7–11.4 kg SO_2/ton CO_2).
[2]Using a 15–85 percentile range from "CDM projects" sample (2.4–6.8 kgTSP/CO_2).

assume a 80–100 million tons potential for the short run and approximately double that for the long run, the lower halves of the percent ranges are associated with the short run and the upper halves are associated with the long run.

3.4. HEALTH AND MONETARY BENEFITS OF CDM PROJECTS

Improved local air quality has immediate benefits to society. We have previously discussed estimates of lives saved, and other benefits, per ton CO_2 reduced. For each estimate of the potential for CDM, Table VI lists the corresponding number of lives saved and the value of other benefits to society.

From Table VI we see that if China were to realize its CDM potential, it could save between 2700 and 38 000 lives annually. As indicated in Aunan et al. (2004a), the lion's share of the mortality impact is expected to occur in the elderly. However, 10–15% of the avoided life years lost is estimated to occur in younger age groups (<50 years of age). Reducing air pollution may therefore have a considerable impact on life expectancy in the population.

Total monetary benefits, and benefits excluding the value of lives saved, amount annually to between 4 and 83 billion RMB, and 1 and 45 billion RMB, respectively. Again we may perhaps associate the lower half of the range for lives saved and benefits with the short run, and the upper half we may associate with the longer run.

Total benefits include production gains (like increased crop yields), cost savings (like lower hospital expenses), and the monetary value of reduced material damages. However, one must also keep in mind that several environmental benefits are not included (e.g., the suspected impact of particles on crops) or values are estimated conservatively (e.g., the welfare loss of morbidity is not valued). Besides, environmental benefits do not include the regular and immediate project benefits of the CDM investment (the outcome of the project, and employment, sub-contracts,

TABLE VI
Health and monetary benefits of CDM projects

	The World Bank (2004)	Zhang (1999, 2000)	Michaelowa et al. (2003)	Wei (2002)	Zou and Li (2000)
Lives saved	2,693–12,751	2,958–37,996	3,434–16,261	5,440–25,760	6,324–29,946
Monetary benefits-excluding lives saved (billion RMB)	1–15.3	1–45	1.1–19.4	1.8–31	2.1–36
Total monetary benefits (billion RMB)	3.6–28	3.9–83.3	4.5–35.7	7.2–56.5	8.4–65.7

The table uses a 15–85 percentile range for all three estimates.

etc. related to building and operating the project). Finally, the benefits of reducing the risk of climate change are not included in the estimates.

4. Conclusions

We have attempted to reconcile various estimates of China's energy related CDM potential and combine the potential with estimates of local air pollution reductions and benefits resulting from CO_2 abatement. The estimates are uncertain in nature and more research is necessary. The large ranges given for co-benefits illustrate that it is necessary to analyze different projects or project types separately. However, we believe that the exercise we have undertaken is useful since it highlights the local benefits available from a global pollution reducing policy. It should be particularly relevant in the Chinese policy context, where climate change often has been by-passed as a priority issue.

Our results indicate that realizing the Chinese energy related CDM-potential will reduce SO_2-emissions between one-half and three million tons, or 2.5–15% of current emissions. Perhaps even more remarkably, between 2,700 and 38,000 lives may be saved annually if China realizes its CDM potential. A third item is the additional benefits to health and other receptors. The monetary value of additional benefits has been estimated at 1–45 billion RMB per year.

These benefits do not depend on using CDM, which merely is a financing mechanism, to realize CO_2-abatement. They follow from any program that reduces CO_2-emissions in China, be they increases in power plant efficiency, upgrades of industrial boilers, or fuel switches. If China wishes to pursue a more ambitious climate change agenda than waiting for CDM financing, it may reap these benefits sooner.

Sometimes the existence of significant benefit of CO_2-abatement projects is taken as evidence that the projects will be implemented outside of the CDM mechanism. The benefit we estimate in this study does in fact on a per ton basis exceed the World Bank expected CER price of 6 USD/tCO_2. However, unlike CERs the estimated benefit cannot be turned into financial profit. The benefit demands the involvement of government or other entity that has the overall welfare of the population in mind. It is in our view best viewed as an indicator of sustainability and as a motivation for overcoming barriers and transaction costs.

Some of the co-benefits of climate abatement can be achieved without considering GHG abatement. As an example, end-of-pipe abatement in the form of scrubbers to reduce SO_2 and electrostatic precipitators to reduce TSP do not reduce CO_2-emissions. However, even if end-of-pipe technologies are installed, emissions will remain. Therefore, some co-benefits of GHG abatement are likely to be realized even in a future situation with more end-of-pipe abatement of local pollutants. Carrying out the CDM potential may render many of those end-of-pipe installations superfluous, freeing up money and resources for other purposes.

The fact that some policy aims can be achieved in more ways than one, begs the question of which policy should be credited the benefits. In the end there is no clear-cut answer to that question. The claim of this paper is simply that - given the present state of the Chinese economy – realization of the energy related CDM-potential may result in large co-benefits in terms of reduced air pollution.

Appendix

TABLE AI
SO_2/CO_2 ratios

Source	kg SO_2/ton CO_2
Aunan et al. (2004a)	
Co-generation (Aunan 1)	8.67[1]
Modified boiler design (Aunan 2)	8.23[1,2]
Boiler replacement (Aunan 3)	8.24[1,2]
Improved boiler management (Aunan 4)	8.22[1,2]
Coal washing (Aunan 5)	32.94
Briquetting (Aunan 6)	28.82
Mestl et al. (2005)	
Coke dry quenching (Mestl 1)	19.37
Electrical arc furnace (Mestl 2)	10.53
Combined cycle power production (Mestl 3)	10.54[1]
Top gas pressure recovery turbine (Mestl 4)	10.55[1]
District boiler house (Mestl 5)	N/A[2]
Coal briquetting factory (Mestl 6)	36.00[1]
Fang et al. (2002)	
IBEI program (Fang)	11.41[1]
Gielen and Chen (2001)	
Energy policy (2020) (G&C 1)	4.29[1]
Local environmental policy (2020) (G&C 2)	15.63[1]
Sustainability policy (2020) (G&C 3)	8.61[1]
Chen et al. (2001)	
Energy efficiency improvement (eff) (2020) (Chen 1)	4.93[1]
Energy switch at demand side (gas 2) (2020) (Chen 2)	8.80[1]
SO_2 target (SO_2) (2020) (Chen 3)	10.84[1]
SO_2 and NOx targets (SO_2 + NOx1) (2020) (Chen 4)	11.53[1]
Targets plus 200 RMB CO_2, tax (SO_2 + NOx1 + CO_2) (2020) (Chen 5)	8.81[1]
Morgenstern et al. (2004)	
All boilers (case A) (Morg 1)	6.13[1,2]
44 boilers with complete data (p. 11) (Morg 2)	2.08[1,2]
Zhang and Duan (1999)	
Mawan plant (Zhang)	8.28[1]

[1]Considered to be a likely CDM project (see Section 2.1 and Table I).
[2]Included in “boilers only”.

TABLE AII
TSP/CO_2-ratios

Source	kg TSP/ton CO_2
Aunan et al. (2004a)	
Co-generation (Aunan 1)	4.00[1]
Modified boiler design (Aunan 2)	2.66[1,2]
Boiler replacement (Aunan 3)	3.64[1,2]
Improved boiler management (Aunan 4)	3.62[1,2]
Coal washing (Aunan 5)	9.63
Briquetting (Aunan 6)	13.29
Mestl et al. (2005)	
Coke dry quenching (Mestl 1)	8.72
Electrical arc furnace (Mestl 2)	53.60
Combined cycle power production (Mestl 3)	2.12[1]
Top gas pressure recovery turbine (Mestl 4)	2.08[1]
District boiler house (Mestl 5)	15.63[2]
Coal briquetting factory (Mestl 6)	13.33[1]
Fang et al. (2002)	
IBEI program (Fang)	4.77[1]
Chen et al. (2001)	
Energy efficiency improvement (eff) (2020) (Chen 1)	1.69[1]
Energy switch at demand side (gas 2) (2020) (Chen 2)	2.73[1]
SO_2 target (SO_2) (2020) (Chen 3)	2.70[1]
SO_2 and NOx targets (SO_2 + NOx1) (2020) (Chen 4)	3.93[1]
Targets plus 200 RMB CO_2 tax (SO_2 + NOx1 + CO_2) (2020) (Chen 5)	3.48[1]
Zhang and Duan (1999)	
Mawan plant (Zhang)	3.1[1,3]
Garbaccio et al. (2000)	
5% CO_2 reduction, year 1(G,H,J 1)	9.23[1]
10% CO_2 reduction, year 1 (G,H,J 2)	9.20[1]
5% CO_2 reduction, year 15 (G,H,J 3)	4.95[1]
10% CO_2 reduction, year 15 (G,H,J 4)	4.93[1]

[1]Considered to be a likely CDM project (see section 2.1 and Table I).
[2]Included in "boilers only".
[3]There is a misprint in the original publication and the value has been adjusted. Details are available on request.

TABLE AIII
Avoided deaths per million ton CO_2

Source	RMB/ton CO_2
Aunan et al. (2004a)	
Co-generation (Aunan 1)	45
Modified boiler design (Aunan 2)	33
Boiler replacement (Aunan 3)	45
Improved boiler management (Aunan 4)	45
Coal washing (Aunan 5)	120
Briquetting (Aunan 6)	166
Mestl et al. (2005)	
Coke dry quenching (Mestl 1)	2
Electrical arc furnace (Mestl 2)	968
Combined cycle power production (Mestl 3)	0
District boiler house (Mestl 5)	363
Coal briquetting factory (Mestl 6)	74
Aunan et al. (1998)	
Hungary (Aunan 7)	112
O'Connor et al. (2003)	
China (O'Connor)	57
Bussolo and O'Connor (2001)	
India (Bussolo)	91
Dessus and O'Connor (2003)	
Chile (Dessus)	27
Cifuentes et al. (1999)	
Chile (Cifuentes)	24
Abt. Associates (1997)	
USA (AbtAssos)	22
Garbaccio et al. (2000)	
China (G,H,J)	70

TABLE AIV
RMB benefit per ton CO_2

Source	RMB/ton CO_2
Aunan et al. (2004a)	
Co-generation (Aunan 1)	286[1]
Modified boiler design (Aunan 2)	198[1,2]
Boiler replacement (Aunan 3)	271[1,2]

(*Continued on next page*)

TABLE AIV
(*Continued*)

Source	RMB/ton CO_2
Improved boiler management (Aunan 4)	269[1,2]
Coal washing (Aunan 5)	725
Briquetting (Aunan 6)	997
Mestl et al. (2005)	
Coke dry quenching (Mestl 1)	14
Electrical arc furnace (Mestl 2)	5870
Combined cycle power production (Mestl 3)	2[1]
Top gas pressure recovery turbine (Mestl 4)	0[1]
District boiler house (Mestl 5)	2201[2]
Coal briquetting factory (Mestl 6)	448[1]
Fang et al. (2002)	
IBEI program (Fang)	138[1]
Gielen and Chen (2001)	
Energy policy (2020) (G&C 1)	30[1]
Local environmental policy (2020) (G&C 2)	124[1]
Sustainability policy (2020) (G&C 3)	68[1]
Chen et al. (2001)	
Energy efficiency improvement (eff) (2020) (Chen 1)	194[1]
Energy switch at demand side (gas 2) (2020) (Chen 2)	262[1]
SO_2 target (SO_2) (2020) (Chen 3)	257[1]
SO_2 and NOx targets (SO_2 + NOx1) (2020) (Chen 4)	384[1]
Targets plus 200 RMB CO_2 tax (SO_2 + NOx1 + CO_2) (2020) (Chen 5)	332[1]
Morgenstern et al. (2004)	
All boilers (case A), low value (Morg 1)	237[1,2]
All boilers (case A), high value (Morg 2)	1 101[1,2]
44 boilers with comp lete data (p. 1 1), low value (Morg 3)	311[1,2]
44 boilers with complete data (p. 1 1), high value (Morg 4)	1444[1,2]
Zhang and Duan (1999)	
Mawan plant (Zhang)	23[1]
Garbaccio et al. (2000)	
5% CO_2 reduction, year 1(G,H,J 1)	55[1]
10% CO_2 reduction, year 1 (G,H,J 2)	55[1]
5% CO_2 reduction, year 15 (G,H,J 3)	115[1]
10% CO_2 reduction, year 15 (G,H,J 4)	115[1]

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Notes

[1]That is, the *Kolmogorov-Smirnov* asymptotic test statistic is such that we cannot reject H_0 that the samples come from a log-normal distribution. The Kolmogorov-Smirnov test compares theoretical and observed cumulative distribution functions and finds the point of maximum absolute difference between the two (the *D*-statistic). A high *D*-statistic score means it is improbable that the observed frequency is generated by the theoretical distribution. H_0 is usually rejected when the probability is less than 0.05 or 0.10. We find values of 0.20, 0.43, 0.73, and 0.75 for SO_2, TSP, avoided deaths, and benefits, respectively, and are not able to reject the hypothesis.

[2]Projects with significant CO_2 reduction potential, low transaction costs, facing few institutional barriers have a greater chance of success as a CDM project. They are marked with an asterisk in the Appendix.

[3]There are interesting differences in the S-content of coal in China. According to Mao et al. (1998) the content increases from North to South and goes from 0.54% in North-East China, through 0.92% in North China; to 1.12% in East China; 1.18% in the Middle-South, 1.42% in the North-West, and 2.13% in the South-East. The national average is 1.16%. When it comes to carbon content anthracite coal has a higher content than bituminous coal, but the combustion efficiency of anthracite is lower. The CO_2-emission factor is actually higher for anthracite coal, 26.35t-c/Tj vs. 24.26t-c/TJ for bituminous coal. Bituminous coal has more than 90% of the market in China. An emission factor of 25t-c/TJ equals 2.7 kg CO_2/kg ce. According to Li et al. (2000), 2.77 (IEA), 2.75 (GEF), 2.67 (ADB) and 2.41 (Li et al.) have all been used in China recently. The base in these factors is standard coal (ce, with a heating value of 7000 kcal/kg or 29.3 MJ/kg. Common coal in China has a heating value of 5000 kcal/kg or 20.9 MJ/kg). A factor of 2.7 kg CO_2/kg ce equals 1.9 kg CO_2/kg common coal. Finally, 90% of sulfur is released since there is a 10% cleaning impact in the furnace because of alkali components in the ash.

[4]It is important to point out that estimates of the value of a statistical life actually is an estimate of how much to sacrifice in order to reduce the statistical *risk* of excess mortality. It is not a question of individual lives and deaths. The classic reference on this is Schelling (1968).

[5]The *human capital approach* has also been used, where the value of life is calculated as the present value of net foregone earnings. However, most international researchers do not recommend this approach as it is difficult to reconcile with standard economic theory (see, e.g., ECON, 2000).

[6]The difference between Chinese and Western income levels may actually be smaller than a factor of 20, since both prices and incomes are lower in China, and since there may be more unregistered transactions. If a factor of 10 is used as an illustration, the transferred range would be 1.6–4.5 million RMB.

[7]In 2002, GDP in China was approximately 10.2 trillion RMB, see, e.g. http://www. worldbank. org/data/countrydata/aag/chn aag.pdf. With a population of 1281 million the estimate emerges.

[8]See http://www.scidev.net/news/index.cfm?fuseaction=readnews&itemid=1761&language=1

[9]See http://www.pointcarbon.com/article.php?articleID=5424.

[10]While the emphasis is on the energy related potential, World Bank (2004) suggests that 0–10% of the potential is non-energy related, including decomposing HFC23. Since the potential is a range 0–211 we believe it does not increase accuracy for our purposes to deduct a small percentage non-energy from the 79.2 point estimate. Recently, Schwank (2004) has claimed that there is potentially a large ($\approx$60 million tons CO_2) non-energy potential in China related to decomposing HFC23. Schwank warns the CDM Executive Board against allowing this potential to be eligible for Certified Emission Credits, however.

[11]The list is not exhaustive. Three models were estimated in Austin and Faeth (1999). The OECD, G-cubed, SGM and EPPA models are relate to global trading scenarios and assume perfect trading options. However, the authors refer to them as applying to an idealized CDM situation and they were estimated in 1999, before the United States withdrew from Kyoto. Finally, they assume permit prices of between USD 13 and 26 per ton CO_2. We have therefore decided not to include them in our study, since they seem unrealistic given today's developments. Another source is a study by the Pembina and Teri Institutes from October 2002. They arrive at an estimate of 21 million tons CO_2 per year, thus far below other estimates. The publication includes very little information on how the estimate was arrived at and what assumptions were made. We therefore decided to leave out this estimate as well. Finally, after completion of our paper results from a 5-year study by Keiko University and Tsinghua University, Beijing has been published as Yamaguchi et al. (2004). It finds a CDM potential of 102 Mt CO_2, and therefore supports the estimates of the table.

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