China and the Global Environment[*]

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1. Introduction

China’s remarkable rate of economic growth in recent decades is having important impacts on the world economy. With roughly 20% of the world's population being mobilized into the world economy, a critical input into a growing Chinese economy is energy. China has large reserves of energy and rising capacity but already, rising demand for inputs into production in China is causing increases in global commodity prices, particularly oil. In addition to the economic consequences of this rapid transformation, there are important environmental consequences of rapid industrialization in China, not only within China but on its near neighbors and globally. By 2002 China was the world’s third largest energy producer and the second largest energy consumer[1]. This massive use of energy has had important implication for local environment problems such as air quality, public health problems and local climate change. Energy generation and its related emissions of sulphur dioxide from coal use, has caused local and regional problems with acid rain. The large and growing emissions of greenhouse gases (particularly carbon dioxide emissions from burning coal) are a critical input into the global problem of climate change.

As shown in Table 1, in 1990 China accounted for 7.8% of world energy use (roughly 1.5 times that of Japan and seven times that of Korea). By 2002 this share had risen to 10.5%. By 2025 it is s projected to account for 16.3% of global energy use or more than 4 times the energy use of Japan and eight times that of Korea. Already China is the world’s largest coal producer accounting for 28% of world coal production and as Table 2 shows 27% of world coal consumption by 2002. China’s share of world coal consumption is projected to rise to a massive 39.1% by 2020 (Table 2). China’s share of world oil consumption in 1990 was 3.5% but it is projected to rise to 11.1% by 2020 (Table 2).

Until recently the focus of policy in China has been on economic growth and energy needs rather than the environmental consequences of rapid industrialization. This is beginning to change as income levels in China make the environment a more important issue and as environmental quality continues to deteriorate.

This paper explores the environmental consequences of rapid growth in China with a focus on the environmental consequences of rising energy use. It explores the recent past as well as potential future developments and potential policy options[2]. Although economic growth is a priority, environmental policy is already emerging as an important policy issue in China. This paper summarizes the state of key aspects of environmental policy as related to energy use both in term of local issues as well as in the context of the current global debate on climate change.

A number of existing policies that China has already put in place to tackle local and regional environmental problems are also discussed[3]. Other issues relate to rising energy use, rising greenhouse emissions and the implications for China of a serious climate change policy. This paper outlines a response to carbon dioxide emissions that could be implemented in China in coming years but has not yet entered the Chinese debate. This approach focuses on creating long term property rights and clear incentives in pricing carbon emissions in an effort to reduce greenhouse gas emissions over time. It is in many ways similar to experiments already underway in China with trading sulphur emission permits. However, it is

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1 All data, unless specifically indicated otherwise, are sourced from the Energy Information Administration of the US Department of Energy and are for 2004 (revised in the June 2005 online update.

2 There are many other environmental problems caused by a large population and rapid economic growth in China such as water quality and air quality problems caused by deforestation and desertification in China. There is also a large impact of China's demand for resources which impact on the environment of other countries. These important problems are not the subject of this paper but for an overview see Liu and Diamond (2005).

3 China's Environmental Protection Law was promulgated in 1979 – a nation wide levy system on pollution bean in 1982. Fees for SO_2 pollution from coal began being collected in 1992. See Jiang (2003) for an overview.

important to note that dealing with sulphur emissions is very different to dealing with carbon dioxide emissions. This difference is particularly important for China as a large country that has ratified the Kyoto Protocol[4] and would be expected at some stage in the future to take on binding targets for carbon emissions or at least a commitment to some target. China has already shown a commitment to tackle local environmental problems with encouraging outcomes, but is there is still much to be done[5].

This paper is structured as follows. Section 2 summarizes the history of energy use and projections out to 2020 of energy use in China. As well as considering the environmental problems in China, policy responses and some quantitative evaluation of these for greenhouse emissions are considered in section 3 and a conclusion is summarized in section 4. An Appendix summarizes the G-Cubed multi-country model that forms the basis of some of the analysis in this paper.

2. Energy Use and the Environment

i) Energy

The importance of China in world energy use and projected increases in this importance is summarized in Table 1. In 2002 China accounted for 10.5% of world energy use (compared to North America[6] at 28.6%) and 13.6% of global carbon dioxide emissions from fossil fuel use (compared to the United States at 27.5%). Chinese GDP (in 2003) is estimated in PPP terms to be roughly 59% of the size of the United States[7]. This implies that

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4 Further details on the Kyoto Protocol can be found in section 4.

5 See Jiang (2003) for an overview of China's environmental problems. Jiang and McKibbin (2002) find that Chinese policy has been effective in reducing environmental problems relative to what otherwise would be the case, but other factors related to strong economic growth have offset and masked this improvement. Also see Panayatou(1998)

6 North America is the Unite States, Canada and Mexico.

7 Source: 2004 UNDP Human Development Report.

although carbon emissions per unit of energy use are higher in China than in the United States, energy use per unit of GDP (in PPP terms) is slightly lower in China than in the United States. Many studies of energy intensity (ie. energy use per unit of GDP) suggest that China is far more energy intensive but these tend to use market exchange rates for this comparison rather than PPP. GDP measured at market exchange rates is inappropriate as a benchmark of energy intensity given the problems with comparing GDP across countries at different stages of development[8]. A better measure is what is physically produced and the quantity of energy required.

China has roughly 9.4% of the worlds installed electricity generation capacity (second only to the United States) and over the next three decades is predicted to be responsible for up to 25% of the increase in global energy generation. China's size and compositions of energy use is reflected in carbon dioxide emissions. China is estimated to have emitted 13.6% of global carbon emission from fossil fuels in 2002 (second only to the United States) and this share is projected to rise to 20.5% by 2020 (see Table 1). In an attempt to move away from fossil fuel reliance, China currently has plans for another thirty in the next two decades to supplement the nine nuclear reactors already existing[9]. It is estimated that China has the largest hydroelectric capacity in the world (largely in the south west of the country) which is currently generating 20% of Chinese electricity. The Three Gorges hydroelectric dam on the Yangtze River will be the world's largest power plant when completed around 2009. In March 2005, the National Development and Reform Commission (NDRC) approved the largest wind farm in Asia to begin construction in 2006. Table 3 shows a quickly rising share of both nuclear energy and renewable energy (particularly hydro) in coming years. Although impressive in scale, the emergence of renewable energy will only slightly dent the overall

8 . A large literature on using PPP for energy inter-country comparisons is summarized in Castles and Henderson (2003).

9 Source DOE (2005)

dominance of coal in the foreseeable future in China under current relative prices of energy. This means that China will need to respond to a range of environmental problems resulting from burning fossil fuels, including air quality (including black carbon emissions), acid rain (from Sulphur dioxide and Nitrogen oxides emissions) and climate change (from carbon dioxide emissions).

Figure 1 gives another perspective on the recent history of energy production and consumption in China. Energy demand and supply in China has been rising quickly - more than doubling between 1980 and 1996. In 1998, Chinese energy consumption began to outstrip Chinese energy production. Economic growth and the rising demand for energy in China is now spilling over into global energy prices far more importantly that it did before 2002.

Figure 2 clearly shows that Chinese energy supply has relied predominantly on large supplies of low cost coal (mainly located in the northern part of the country). Crude oil is the next largest source of energy supply followed by hydroelectricity, natural gas and nuclear energy. The major source of demand for energy in China is Industry which accounts for 70% of the total in 2002. This is followed by the household sector at 12% and transportation at only 7%.

Projecting future energy use in China is very difficult. It is very tempting to base future projections on recent trends. However as shown by Bagnoli at al (1996) and McKibbin et al (2005) overall economic growth is not the key determinant of energy use - the sources of economic growth are critical. A number of projections are available. The Energy Information Administration in their Annual International Energy Outlook provides one source of projections. These are shown in Figure 3 for scenarios of high and low economic growth and a reference case. Figure 4 shows the composition of energy use for the mid scenario. Figure 5 shows energy demand projection from the G-Cubed model under the assumption that sectors China have the same productivity growth versus an assumption here they have productivity growth similar to those historically experiences in the United States (currently missing – will be supplied shortly). However uncertain future projections of Chinese energy demand are it is difficult to see major shift in trends away from coal under current energy prices. Interestingly there is also little change in the real price of oil or any fossil fuels throughout the projection period in the International Energy Outlook yet significant changes in the G-Cubed Projections depending on assumptions about the sources of growth.

Under most scenarios, the emergence of China as a key supplier of energy and producer of energy is one of the most important issues in the debate over global energy use for the foreseeable future. As shown below, this is also a critical issue for environmental issues in China, Asia and globally.

ii) Environment

The environmental and health impacts of energy use cover a range of issues from local particulate emissions which have important impacts within China; to acid rain which has both local and regional impacts; and as well to carbon dioxide emissions which have global implications.

At the local level, a number of studies have explored air pollution caused by energy use in China. The term "air pollution" covers a wide range of problems including emissions of particulates, sulphur dioxide, nitrous oxides and carbon dioxide. The estimated costs of air pollution, largely due to the burning of fossil fuels vary in size. A study by the World Bank (1997) valued health damages from air pollution at 5% of GDP in 1995[10] although other studies such as Yang and Schreifels (2003) suggest this is closer to 2% of GDP.. A study by Garbaccio, Ho and Jorgenson (1999) found that for a reduction in carbon emissions of 5% every year would reduce local health costs by 0.2% of GDP annually. A recent report by the

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10 Panayotou and Zheng (2000) estimate that the cost to China from air and water pollution is 14.6% of GDP in the late 1990s. See also Wang and Smith (1999)

State Environmental Protection Agency (SEPA)[11] on the environment notes that air quality in cities across China has generally improved but this is from a base of significant problems in most major Chinese cities. The World Health Organization (WHO (2004)) notes that only 31% of Chinese cities met the WHO standards for air quality in 2004. A large part of these air quality problems are directly related to energy use. Whether the projection of rising energy use over the coming decade directly lead to projections of increased environmental problems is a critical issue facing policymakers in China. This is well understood in China. Premier Wen Jiabao in his March 5th 2005 report to the National Peoples Congress argued that improved energy conservation was necessary to reconcile rapid economic growth with limited energy resources – he also called for stronger pollution controls. The State Environmental Protection Administration (SEPA) [12] originally established in 1988 as the National Environmental Protection Agency has also been implementing more stringent monitoring and enforcement of environmental legislation.

Particulate emissions cause serious health problems with identifiable economic costs as well as human costs. A recent study by Ho and Jorgenson (2003) finds the largest sources of Total Suspended Particulates (TSP) are the largest users of coal – electricity, nonmetal mineral products and metals smelting as well as transportation.

One of the worst pollutants from burning fossil fuels is sulphur dioxide (SO2) emissions. This has local (health and acid rain) as well as regional (acid rain) implications. The WHO estimates that more than 600 million people are exposed to SO2 levels above the WHO standards[13]. SO2 mixing with nitrogen oxides (NOX) causes acid rain. The WHO

11 See SEPA (2004).

12 The formerly named National Environmental Protection Agency was set up in 1988 and renamed SEPA in 1998 when it was upgraded to a Ministry.

13 WHO (2001)

(2004)[14] estimates that acid rain seriously affects 30% of China. However this is not just a problem for China. Streets (1997) estimates that China accounted for 81% of SO2 emissions in North East Asia in 1990. China is the major source of acid rain across north East Asia. Without any control policies, Streets estimated in 1997 that this share would change little by 2010 except that the quantity of emissions is expected to grow by 213% from 1990 to 2010 by 273% by 2020. Assuming installation of state of the art flue-gas desulphurization systems Streets estimated that this scenario could be transformed so that SO2 emissions fall to 31% of 1990 emissions by 2020. China has begun to address this problem with pilot Sulphur Dioxide emission trading systems in a number of control zones and closing of high sulphur coal mines as well as other direct controls. In fact sulphur dioxide emissions have fallen gradually since from1995 to 2002 but rose again in 2003. The decline was a result of direct controls and other policies, although acid rain problems have not fallen because of a substitution of emission towards high stack sources which spread SO2 over greater areas[15]. Direct policy to deal with sulphur dioxide emissions would seem to have a significant benefit for China and across the region and the Chinese authorities are acting on this16. Experimentation with price based charging and emissions trading systems have yielded encouraging results and should be used more extensively to reduce the emission of sulphur from the projected increasing use of coal for generating energy in the coming decade.

A more recent and potentially more important problem identified by Streets (2000, 2004) and others is the emission of black carbon. Black carbon is the fine particulates that are released from imperfect combustion of carbonaceous materials. Any visitors to Chinese cities are familiar with the thick haze that frequently envelopes many areas. Current work suggests that direct action to reduce the emissions of black carbon from household energy use and

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14 WHO page 6 and SEPA(2004)

15 see Yang and Schreifels (2003) page 7-8.

16 Nakada and Ueta (2004) estimate that the current sulphur price is well below the socially optimal price

burning of forests and agricultural waste is an important issue that needs urgent attention in China. Understanding of black carbon emissions is only fairly recent due to the work of Hamilton and Mansfield (1991), Hansen et al (1998) and Streets (2004). Black carbon is classified as an aerosol and is therefore not included in the Kyoto Protocol. However, studies by Streets and others suggest it is a critical issue for China. The consequences of black carbon are wide ranging: reduced visibility; serious health problems; damage to buildings. Estimates suggest that agriculture crop productivity might be reduced significantly (by up to 30% for rise and wheat)[17]. Streets (2004 p.3) argues that black carbon is the second most important warming agent behind carbon dioxide. Using circulation models, Menon (2002) et al estimate that black carbon is responsible for local climate problems in China such as increased drought in northern China and summer floods in southern China. The time lag between reducing black carbon emissions and significant local climate effects is estimated to be around five years – a far quicker effect on climate than the implications of tackling carbon dioxide emissions which are measured in many decades.

The estimated sources of black carbon are contained in Figure 6. Surprisingly a vast majority of emissions are from residential energy use rather than electricity generation or transportation. Residential burning of coal accounted for 83% of emissions in 1995. This is due to the fact that 80% of Chinese households use solid/biomass fuels for cooking and heating (WHO (2004)). Thus black carbon is likely to be an important issue that authorities are yet to tackle. Part of the reason is that is a relatively recently understood problem and partly because the solution doesn't lie in the energy generation sectors but in the use of energy by households.

There are a number of significant environmental problems associated with energy use in China. These have had large economic costs in the past. With the enormous expected rise

17 See Streets (2004) and the reference therein.

in energy use in China over coming decades outlined in Section 2, the environmental problems associated with rising Chinese energy use is going to accentuate these problems. Policies aimed at these problems will need to broaden in scale and scope. While existing problems are beginning to be tackled, new problems such as global climate change are emerging and China due to its size and speed of economic growth is a major player at the global level.

3. Responding to Energy related Environmental Challenges

China has begun to respond to the local environmental problems associated with rising energy use. These include an attempt to substitute non fossil fuel energy sources such as wind, hydro and thermonuclear energy for fossil fuels in energy generation. China has also implemented a range of policies to reduce the emissions of sulphur dioxide from burning fossil fuels. The problem of black carbon was discussed in the previous section. From a global perspective the one area where China has taken less action is in the emissions of carbon dioxide. This is the focus of this section.

The most important cause of human induced climate change is the cumulation of greenhouse gases in the atmosphere. The most important greenhouse gas is carbon dioxide. The global community has been struggling with how to effectively respond to the threat of climate change for several decades. In 1992, the United Nations Earth Summit in Rio de Janeiro produced a landmark treaty on climate change that undertook to stabilize greenhouse gas concentrations in the atmosphere. By focusing on stabilization, however, the treaty implicitly adopted the position that the risks posed by climate change require that emissions be reduced no matter what the cost. The agreement, signed and ratified by more than 186 countries, including the United States and China (the world's largest CO2 emitters), spawned numerous subsequent rounds of climate negotiations aimed at rolling back emissions from industrialized countries to the levels that prevailed in 1990. To date, however, the negotiations have had little effect on greenhouse gas emissions and have not produced a detectable slowing in the rate of emissions growth[18]. The treaty's implementing protocol, the 1997 Kyoto agreement, has crawled to life after being heavily diluted at subsequent negotiations in Bonn and Marrakech[19]. The Kyoto Protocol entered into force on February 16th, 2005 after ratification by Russia yet there are a still many problems to be faced before it will be evident that Kyoto is actually reducing emissions. More than a decade of negotiations has produced a policy that is very strict in principle but is likely to be ineffective in practice.

The problem at the international level is actually worse than it appears from the troubled process of Kyoto ratification. The Kyoto Protocol only places restrictions on the industrial economies excluding the world's largest greenhouse emitter, the United States. Developing countries, including China, have ratified the agreement but have not taken on any responsibilities for reducing emissions except those that emerge from mechanisms such as the Clean Development Mechanism (CDM) and joint implementation (JI). Developing countries are not taking on targets as commitments is one of the reasons claimed by both the United States and Australia for not ratifying the Kyoto Protocol. The fact that the world's largest emitter, the United States, is not involved in climate policy substantially dilutes global action even further. Because there are no binding commitments by the key developing countries of China, India, Brazil and Indonesia (amongst others) means that effective action against possible climate change is still a hypothetical debate.

Developing countries have a valid point in their argument that while they are prepared to be part of regime to tackle climate change, they should not be required to bear a disproportionate part of the costs of taking action. Current concentrations of greenhouse

18 See McKibbin and Wilcoxen (2002) for a summary of the negotiations and critique of the approach.

19 Earlier estimates of the cost of Kyoto can be found in Weyant (1999). Direct comparisons of the COP3 and COP7 versions of the protocol, can be found in Bohringer (2001), Buchner et al (2001), Kemfert (2001), Löschel and Zhang (2002) and McKibbin and Wilcoxen (2004).

gases in the atmosphere are primarily the result of economic activities in the industrial economies since the Industrial Revolution. Because it is the stock of carbon in the atmosphere that matters for temperature changes, any climate change in the near future will be largely the result of the historical activities of industrial economies. Why should developing countries not be able to follow the same energy intensive development paths of the currently industrialized economies? The answer to this question has inevitably lead to an expectation of compensation paid for by the industrialized economies for action taken in developing countries. One of the biggest dilemmas for developing countries is not just the reality that at some stage they need to make some form of commitment to curbing greenhouse gas emissions but the fact that most estimates of the damages from climate change are borne by developing countries[20].

Standing back from the intensity of international negotiations it is worth clarifying several important facts about the costs and benefits of climate policy and exploring whether there are approaches possible in China and other Developing Countries that are not being considered because of the standard refrain that "Kyoto is the only game in town". This mindset has already hindered effective action for the past decade as countries and industries postpone action until agreements are clarified. Given the uncertainties of climate change and the decisions on energy systems being made in the regions of the developing world that are growing rapidly, this delay in providing clear incentives for moving away from fossil fuel based systems, may ultimately prove to be extremely costly.

One of the largest sources of anthropogenic greenhouse gas emissions is the burning of fossil fuels. The cheapest means of changing of the global energy system so that it is less reliant of fossil fuels, is to remove these emissions from future energy systems rather than from existing energy systems. As we showed in Section 2 China is heavily reliant on coal for

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20 See IPCC (2001).

energy production and is likely to be for many decades to come. There are huge investments in physical and human capital surrounding existing energy systems which are costly to change. However, future investments (largely to occur in developing countries) are much cheaper to change before they are undertaken. Technology will ultimately be the source of reductions in emissions whether through the development of alternative sources of energy or through ways of sequestering carbon released from burning fossil fuels. Developing countries have huge potential to avoid the pitfalls in terms of carbon intensities, experienced by industrialized economies in their development process. The key issue is how to encourage the emergence of energy systems in developing countries that are less carbon intensive over time. Ultimately if climate change does emerge as a serious problem, developing countries will have to move towards a less carbon intensive future. It is likely to be significantly cheaper to do this over time than to face a massive restructuring at some future period – the sort of problems being faced within industrialized economies today.

The current state of global policy on climate is that the United States (the largest emitter of greenhouse gases) has rejected Kyoto and is arguing for following policies that directly or indirectly reduce emissions through technological change; the European Union is committed to emission targets (assuming Russia provides a great deal of those reductions required through selling emission permits) and has implemented a Europe wide emissions trading scheme (that exempts key sectors such as aluminium, motor vehicles and chemicals), on January 1, 2005, but with actual caps that appear only to bind by the end of 2008; Japan is considering what it can do given current emissions are 16% above target in an economy recovering from a decade of recession; and developing countries have refused to officially discuss taking on commitments.

Given this background, there are a number of ways a country like China could begin to address carbon emissions and make a major contribution to a global response. One step would be the removal of energy subsidies. The second would be to further raise the price of energy to further reflect the true economic and environmental cost of burning fossil fuels. A further approach could be direct importation of less carbon intensive technologies provided by the CDM. This latter outcome is possible but not likely as already outlined above. Thus the focus here will be on the other alternatives.

Economic theory provides guidance about the structure of a possible climate change policy for China[21]. Since greenhouse gases are emitted by a vast number of highly heterogeneous sources, minimizing the cost of abating a given amount of emissions requires that all sources clean up amounts that cause their marginal cost of abatement to be equated. To achieve this, the standard economic policy prescription would be a market-based instrument, such as a tax on emissions or a tradable permit system for emission rights. This type of market based incentives for environmental pollution is already being undertaken in China through pollution charges and permit trading in sulphur dioxide. Richard Cooper (2005) has advocated a carbon tax for China. Garbaccio, Ho and Jorgenson (1999) and McKibbin and Wilcoxen (2004) find that a price signal would be effective in changing China's future emissions profiles. In the absence of uncertainty, the efficient level of abatement could be achieved under either a tax or a permit trading system, although the distributional effects of tax and emissions trading policies would be very different.

Under uncertainty, however, the situation becomes more complicated. Weitzman (1974) showed that taxes and permits are *not* equivalent when marginal benefits and costs are uncertain, and that the relative slopes of the two curves determine which policy will be better[22]. Emission permits are better than taxes when marginal benefit schedules are steep and marginal costs are flat: in that situation, it is important to get the quantity of emissions down to the threshold. A permit policy does exactly that. In the opposite situation, when marginal costs are rising sharply and marginal benefits are flat, a tax would be a better policy.

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21 See McKibbin and Wilcoxen (2002a) for a survey and Pezzey (2003) for a comparison of taxes and permits.

The potential inefficiency of a permit system under uncertainty is not just a theoretical curiosity: it is intuitively understood by many participants in the climate change debate by the expression of the concern about a policy that "caps emissions regardless of cost."

Applying this analysis to climate change shows that a tax is likely to be far more efficient than a permit system under the uncertainties surrounding climate change. All evidence to date suggests that the marginal cost curve for reducing greenhouse gas emissions is very steep, at least for developed countries. Although there is considerable disagreement between models on how expensive it would be to achieve a given reduction in emissions, all models show that costs rise rapidly as emissions targets become tighter. At the same time, the nature of climate change indicates that the marginal benefit curve for reducing emissions will be very flat.

Given the advantages and disadvantages of the standard economic instruments is it possible to combine the attractive features of both systems into a single approach? Secondly, is it possible to develop a system which is common in philosophy across developed and developing economies but in which developing economies do not incur the short run costs to the economy in the form of higher energy prices until they have reached a capacity to pay?

There are a number of goals that should be at the core of any climate change regime. These involve the recognizing the tradeoff between economic efficiency and equity within and between countries. The policy should also be based around clear property rights over emissions and clear long run emission targets but near certainty in the short run costs to the economy. A sensible climate policy should also create domestic institutions that allow people to self-insure against the uncertainties created by climate change. There should be market mechanisms that give clear signals about the current and expected future costs of carbon. There should be coalitions created within countries with the self interest of keeping climate

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22 See also Pizer (1997) for a more recent discussion of the issue.

change policy from collapsing rather than creating a system of international sanctions in order to sustain the system.

The McKibbin Wilcoxen Blueprint (see McKibbin and Wilcoxen (2002a, 2002b)) was created to attempt to explicitly deal with these issues. It is a Hybrid system that blends the best features of taxes and emission permit trading[23]. It is a system that can be applied across developed and developing countries but which recognizes that developing countries should not bear the same economic costs as industrial countries in the short run.

Although set out in detail in McKibbin and Wilcoxen (2002a) the approach can be briefly outlined here. The basic idea is to impose a requirement that energy producers have an annual emission permit to produce energy each year, based on the carbon content of that energy. A fixed quantity of long term permits would be created that allow a unit of emission every year for 100 years. These long term permits are traded in a market with a flexible price. The government would also be able to create additional annual permits in any year at a guaranteed price. Permits which satisfy the annual constraint for energy production can be either a long term permit or an annual permit that is provided by the government at a fixed price. The price of emissions in any year would never be higher than the fixed price set by the government and the amount of emissions in any year would be whatever the market delivers. Thus we have a long term target in terms of emissions but an annual target in terms of the maximum cost of carbon to industry. In a developing country like China, the annual price would initially be zero if we allow an allocation of long term permits well in excess of current emissions. However, the price of long term permits would reflect the expectation that China would eventually reach the emission levels that caused the carbon emission constraint to be binding. Thus the market for long term permits with positive prices would provide a financial incentive to begin to change Chinese carbon emissions over time even though the annual cost to industry of a carbon permit would initially be zero.

McKibbin and Wilcoxen (2002a) argue that the allocation of long term permits would be determined by each country. The long term permits could be auctioned, in which case the permits are actually a tax. The long term permits could be given away to existing carbon emitters in which case the permits are a way of grandfathering or compensating existing emitters. The allocation mechanism of long term permits is a wealth transfer that has little impact on the subsequent economic incentives facing emitters of greenhouse gases.

The implication of differential allocations of long term permits is illustrated in Figure 8. These numbers are hypothetical and intended to show the relationship between the annual permit price trajectories and the long term permit price under different assumption. . The top chart shows the annual permit price for industrial economies and for China when allocated a doubling of emissions from 2002 levels ("China Double") and a tripling of emissions from 2002 levels ("China Triple"). The bottom chart shows the value of long term permits in each case where a discount rate of 3% real is used in the calculation. In the upper panel it is assumed that permit prices in industrial countries begin at $US10 per ton for a decade beginning in 2007. It then rises each decade by agreement reaching $140 per ton by 2047. In China, because there are more long term permits than annual emissions in the earlier years of the agreement, the price of annual permits in zero. In the case where double emissions are allocated, the annual permit price will be zero until the emission reach the number of long term permits. At that time (assumed to be 2023 in this example), the annual price begins to rise towards the price on annual permits in the industrial economies. In the example, the price is equalized by 2033. In the second example for China it is assumed that 3 times 2002 emissions are allocated and that the constraint begins to bind by 2040. In both cases the price of annual carbon emissions are equalized in China and the industrial economies eventually

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23 The intellectual idea actually dates back to Roberts and Spence (1976) for general environmental policy and

but allowance is built in for China's level of economic development. There is a differential cost to economies in the short run which is intended in the policy design.

Now consider the value of long term permits in both regions. Even though China is given significant time to adjust. The price of long term permits is positive from the beginning of the policy. These prices reflect the expected future price of annual permits which in the example is assumed to be known by the market. This long terms permit price is used for making energy investment decisions in China whereas the short term prices are the cost to Chinese industry. In the industrial economies (under the assumed profile) the long term permit value is $977 per ton of carbon emissions. In China in the double allocation case, the price of long term permits is $US716 per ton and in the triple allocation $US333 per ton. These prices give a powerful incentive for carbon saving technological investment in China even thought initially the annual permit price is zero.

The attractiveness of the Blueprint for creating institutions to aid in economic development in a developing country like China should not be underestimated. The ability of investors in energy systems to effectively hedge their investment over a long period of time should be very attractive for the development of energy systems in developing countries. The time frame of the assets we propose to be created (by committing to a global climate regime) is currently unparalleled. China could use this new asset as a way of attracting foreign investment and enhance the development process by creating what is effectively a futures market in energy (for example by not allocating all long term permits to current emitters by holding a reserve for foreign investors). This is far more likely to induce foreign investment than the CDM or other similar mechanisms that face very high administrative costs. Critics might argue that the problem with China is the inability to create the sorts of institutions the above scheme would require. This is a problem in the near term but it is easier for China to

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McKibbin and Wilcoxen (1997) for climate change policy.

create property rights and institutions within China according to the philosophy and characteristics of China, than it would be to impose within China the sorts of institutions and property rights based on Western approaches that would be required under the Kyoto Protocol for China to be able to sell carbon rights into a global markets. The required synchronization of property rights globally in a form reflecting developed countries practices is exactly why it is difficult to see how the Kyoto Protocol could be implemented outside the small group of industrialized countries with similar institutional structures that are already involved.

4. Policy Implications and Conclusion

China currently faces serious environmental issues and these are likely to become more important over coming years particularly given the likely rise in energy use in China that will be required to sustain the momentum of economic growth generated through economic reforms over recent decades. It is likely, given global energy price structures that future energy will be largely generated by use of coal which under current technologies in China is likely to have serious environmental consequences. Current plans to increase the use of nuclear energy and renewable energy such as hydroelectric power and wind power are impressive but will likely have little impact in a rapidly expanding energy sector unless there is a significant change in the expected relative price of carbon.

China is already taking action on local environmental issues. This has been particularly true in dealing with air and water quality as well as sulphur dioxide emissions. Action is already under way to reduce emissions of sulphur dioxide by substituting away from high sulphur coal, by closing small, high sulphur coal mines, with direct controls on SO2 emissions, implementation of pilot schemes for SO2 emission charges and pilot schemes for SO2 emissions trading. These are having an impact of emissions of sulphur although the impact on acid rain has been less clear. As Nakada and Ueta (2004) point out there are likely to be gains for other economies in the region such as Japan and Korea to cooperate with China in controlling sulphur emissions since these economies are also directly affected by acid rain emanating from China.

The problem of black carbon and its direct health, economic and environmental consequences is a promising area for close attention and direct policy intervention within China. This is not an issue of technological change at the power utilities as might usually be the focus of energy policy. A reduction in the emissions of black carbon will require a technology shift in the way households generate heating and cooking and in the way farmers clear their land after harvest. It appears that it would be feasible to implement a phase-in of alternative technologies at the household level over coming years with the potential to generate a range of environmental, health and economic benefits. Addressing black carbon is a good candidate for consideration under the "Asia Pacific Partnership for Clean Development and Climate" (APPCDC) announced on July 28, 2005 which consists of the United States, Japan, Australia, South Korea, China and India. Black carbon is an aerosol and therefore is not covered by the Kyoto Protocol and the payoffs for taking action in both development terms and climate outcomes is likely to be large and achieved within a decade.

The largest issue facing the global environment from Chinese energy use is likely to be the emissions of carbon dioxide. China is yet to take effective action on greenhouse gas emissions. However this is not surprising since there has been insufficient action in most industrial economies. Even if rapid action was possible, the payoff in terms of potential climate change, won't be realized for many decades into the future. Although some researchers believe that global responses such as through the clean development mechanism (CDM) of the Kyoto Protocol is one way to proceed[24], it is doubtful that much can be achieved through this approach alone. This may change in coming years in Japan takes its

24 See Ueta et al (2005).

Kyoto target seriously but it is unlikely given the current state of international negotiations. A strong case can be made for responses to be developed within China, Korea, Japan and other economies in the Asia Pacific region for dealing with carbon dioxide emissions. This has already begun to emerge within the APPCDC. The idea within this group of countries of technology transfer without a carbon price signal, which currently underlies that approach, is unlikely to be an effective way forward. However, within the APPCDC framework potential exists for experimenting with Hybrid market/government control schemes such as the McKibbin-Wilcoxen Blueprint in which important institutions are created to begin a long process of reduced carbonization of the Chinese economy. This would allow China to continue to grow but would put in place a pricing mechanism for future carbon emissions as an incentive to gradually shift Chinese energy systems to low carbon emitting technologies. Foreign investment in these technologies could be doubling rewarded directly through allocation of long term permits within China to foreign technology investment and indirectly through the profits likely to be generated from trading these permits and from the technological innovation itself. The creation of institutions for environmental management, particularly through market incentives between now and 2010 will be the most important steps to be taken in China. The demonstration effect of such an approach could have an even bigger impact of global emissions if it encouraged other developing countries and the United States to begin to price carbon more appropriately given the current state of knowledge about the potential of climate change.

China and other countries in the Asia Pacific region are at a critical juncture in determining the potential global environmental impact of a rapidly growing China. Many of the solutions to environmental problems open to China are also yet to be implemented in many Asia pacific economies. There are few areas in multilateral policy cooperation that could have a larger environmental and economic impact than working cooperatively within the region to address looming environmental problems from China's emergence into the world economy.

Appendix : The G-Cubed Model for Projecting Energy Use and Greenhouse Emissions in China

The G-Cubed model is an intertemporal general equilibrium model of the world economy. The theoretical structure is outlined in McKibbin and Wilcoxen (1998)[25]. A number of studies—summarized in McKibbin and Vines (2000)—show that the G-cubed modeling approach has been useful in assessing a range of issues across a number of countries since the mid-1980s.[26] Some of the principal features of the model are as follows:

- The model is based on explicit intertemporal optimization by the agents (consumers and firms) in each economy[27]. In contrast to static CGE models, time and dynamics are of fundamental importance in the G-Cubed model. The MSG-Cubed model is known as a DSGE (Dynamic Stochastic General Equilibrium) model in the macroeconomics literature and a Dynamic Intertemporal General Equilibrium (DIGE) model in the computable general equilibrium literature.
- In order to track the macro time series, the behavior of agents is modified to allow for short run deviations from optimal behavior either due to myopia or to restrictions on the ability of households and firms to borrow at the risk free bond rate on government debt. For both households and firms, deviations from intertemporal optimizing behavior take the form of rules of thumb, which are consistent with an optimizing agent that does not update predictions based on new information about future events. These rules of thumb are chosen to generate the same steady state behavior as optimizing agents so that in the long run there is only a single intertemporal optimizing equilibrium of the model. In the short run, actual behavior is assumed to be a weighted average of the optimizing and the rule of thumb assumptions. Thus aggregate consumption is a weighted average of consumption based on wealth (current asset valuation and expected future after tax labor income) and consumption based on current disposable income. Similarly, aggregate investment is a weighted average of investment based on Tobin's q (a market valuation of the expected future change in the marginal product of capital relative to the cost) and investment based on a backward looking version of Q.
- There is an explicit treatment of the holding of financial assets, including money. Money is introduced into the model through a restriction that households require money to

25 Full details of the model including a list of equations and parameters can be found online at: www.gcubed.com

26 These issues include: Reaganomics in the 1980s; German Unification in the early 1990s; fiscal consolidation in Europe in the mid-1990s; the formation of NAFTA; the Asian crisis; and the productivity boom in the US.

27 See Blanchard and Fischer (1989) and Obstfeld and Rogoff (1996).

purchase goods.

- The model also allows for short run nominal wage rigidity (by different degrees in different countries) and therefore allows for significant periods of unemployment depending on the labor market institutions in each country. This assumption, when taken together with the explicit role for money, is what gives the model its “macroeconomic” characteristics. (Here again the model's assumptions differ from the standard market clearing assumption in most CGE models.)
- The model distinguishes between the stickiness of physical capital within sectors and within countries and the flexibility of financial capital, which immediately flows to where expected returns are highest. This important distinction leads to a critical difference between the quantity of physical capital that is available at any time to produce goods and services, and the valuation of that capital as a result of decisions about the allocation of financial capital.

As a result of this structure, the MSG-Cubed model contains rich dynamic behavior, driven on the one hand by asset accumulation and, on the other by wage adjustment to a neoclassical steady state. It embodies a wide range of assumptions about individual behavior and empirical regularities in a general equilibrium framework. The interdependencies are solved out using a computer algorithm that solves for the rational expectations equilibrium of the global economy. It is important to stress that the term ‘general equilibrium’ is used to signify that as many interactions as possible are captured, not that all economies are in a full market clearing equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to a neoclassical steady state growth equilibrium, unemployment does emerge for long periods due to wage stickiness, to an extent that differs between countries due to differences in labor market institutions.

Table A-1: Overview of the G-Cubed Model (version 63E)

Regions
United States Japan Australia Europe Rest of the OECD China Oil Exporting Developing Countries Eastern Europe and the former Soviet Union Other Developing Countries
Sectors
Energy: Electric Utilities Gas Utilities Petroleum Refining Coal Mining Crude Oil and Gas Extraction Non-Energy: Mining Agriculture, Fishing and Hunting Forestry/ Wood Products Durable Manufacturing Non-Durable Manufacturing Transportation Services Capital Producing Sector

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Table 1: Shares in Global Energy Consumption and CO2 Emissions (%)

Energy Consumption						
	1990	2001	2002	2010	2015	2020
China	7.8	10.1	10.5	14.5	15.6	16.3
Japan	5.3	5.4	5.3	4.5	4.3	4.0
Korea	1.1	2.0	2.0	2.1	2.1	2.1
India	2.3	3.4	3.4	3.9	4.1	4.3
North America	29.0	28.5	28.6	26.6	25.9	25.6
Other developing countries	14.2	18.9	19.1	20.4	21.2	21.8
Eastern Europe/Former Soviet Union	21.9	13.2	13.0	12.5	12.4	12.2
Other Industralised Countries	18.5	18.4	18.0	15.4	14.5	13.7
World Total	100.0	100.0	100.0	100.0	100.0	100.0
CO2 Emissions						
	1990	2001	2002	2010	2015	2020
China	10.5	13.2	13.6	18.3	19.5	20.5
Japan	4.6	4.9	4.8	4.0	3.7	3.4
Korea	1.1	1.8	1.8	1.8	1.9	1.9
India	2.7	4.2	4.2	4.5	4.8	5.0
North America	26.9	27.5	27.5	25.4	24.6	24.3
Other developing countries	9.5	13.8	14.1	15.9	17.0	17.8
Eastern Europe/Former Soviet Union	22.8	13.0	12.8	12.1	11.8	11.5
Other Industralised Countries	21.9	21.6	21.2	17.9	16.6	15.6
World Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Energy Information Administration / International Energy Outlook 2004
revised July 2005

Table 2: Shares in Global Consumption of Fossil Fuel Energy Components (%)

Consumption Coal						
	1990	**2001**	**2002**	**2010**	**2015**	**2020**
China	21.3	26.2	27.0	34.5	37.3	39.1
Japan	2.4	3.3	3.4	2.8	2.5	2.3
Korea	0.9	1.4	1.5	1.5	1.6	1.7
India	4.9	8.0	8.0	8.2	8.5	8.7
North America	18.4	22.1	21.9	19.9	19.0	18.8
Other developing countries	7.0	9.8	9.5	9.7	9.7	9.5
Eastern Europe/Former Soviet Union	26.0	15.1	14.7	12.5	11.7	11.1
Other Industralised Countries	19.0	14.0	14.0	11.0	9.7	8.9
World Total	100.0	100.0	100.0	100.0	100.0	100.0

Consumption Oil						
	1990	**2001**	**2002**	**2010**	**2015**	**2020**
China	3.5	6.3	6.7	9.7	10.4	11.1
Japan	8.0	6.9	6.8	5.6	5.2	4.9
Korea	1.5	2.7	2.8	2.7	2.7	2.6
India	1.8	2.8	2.8	3.3	3.6	3.8
North America	30.9	30.4	30.5	28.7	28.3	28.0
Other developing countries	19.3	24.4	24.5	27.1	28.2	29.0
Eastern Europe/Former Soviet Union	15.1	7.3	7.0	6.7	6.5	6.5
Other Industralised Countries	20.0	19.2	19.0	16.2	15.1	14.2
World Total	100.0	100.0	100.0	100.0	100.0	100.0

Consumption Natural Gas						
	1990	**2001**	**2002**	**2010**	**2015**	**2020**
China	0.7	1.2	1.3	2.3	2.7	3.0
Japan	2.6	3.0	2.9	2.7	2.7	2.5
Korea	0.1	0.8	0.9	1.1	1.1	1.1
India	0.5	1.0	1.0	1.3	1.4	1.6
North America	30.6	29.8	29.8	28.1	27.2	26.6
Other developing countries	12.4	20.0	20.7	21.4	22.7	24.1
Eastern Europe/Former Soviet Union	38.2	26.3	26.0	26.6	26.3	25.6
Other Industralised Countries	14.8	17.9	17.5	16.6	16.0	15.4
World Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Energy Information Administration / International Energy Outlook 2004
revised July 2005

Table 3: Shares in Global Consumption of non-Fossil Fuel Energy Components (%)

Consumption Nuclear						
	1990	**2001**	**2002**	**2010**	**2015**	**2020**
China	0.0	0.7	0.9	2.5	4.5	5.1
Japan	10.1	12.1	11.5	11.0	10.9	11.1
Korea	2.6	4.3	4.4	5.8	5.9	5.9
India	0.3	0.7	0.7	2.3	2.9	3.9
North America	34.1	33.8	33.6	32.4	31.4	30.4
Other developing countries	2.6	2.7	2.8	3.4	3.8	4.3
Eastern Europe/Former Soviet Union	13.4	11.2	11.8	12.6	12.4	13.9
Other Industralised Countries	36.9	34.6	34.2	29.9	28.2	25.4
World Total	100.0	100.0	100.0	100.0	100.0	100.0

Consumption Renewables						
	1990	**2001**	**2002**	**2010**	**2015**	**2020**
China	4.9	8.4	9.7	13.1	13.5	13.7
Japan	4.2	3.2	3.4	3.0	3.1	3.3
Korea	0.0	0.0	0.0	0.3	0.2	0.2
India	2.7	2.6	2.2	3.3	3.3	3.1
North America	36.1	29.0	29.6	28.4	28.6	28.7
Other developing countries	22.8	26.1	26.8	26.9	27.0	26.7
Eastern Europe/Former Soviet Union	10.6	9.7	9.7	8.5	8.0	7.9
Other Industralised Countries	18.6	21.0	18.7	16.6	16.3	16.3
World Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Energy Information Administration / International Energy Outlook 2004
revised July 2005

Table 4: Urban Air Quality

Year	1998	1999	2000	2001	2002	2003	2004
Numbers of monitored cities	322	338	332	341	343	340	342
air quality reaching or better than National Air Quality Standard for Grade II, %	27.6	33.1	34.9	33.4	34.1	41.7	38.6
air quality reaching Grade III standard, %	28.9	26.3	30.1	33.4	34.7	31.5	41.2
air quality worse than Grade III,%	43.5	40.6	34.9	33.1	31.2	26.8	20.2
Average concentration of TSP	0.284	0.264	0.263	0.272	0.254		
Average concentration of SO2	0.057	0.054	0.053	0.052	0.047	0.049	0.049
Average concentration of NOx	0.045	0.046	0.044	0.035	0.033		
Average concentration of PM10				0.113	0.120		
Cities with TSP exceeding the standard (TSP≤ 0.20 mg/m3), %	63.8	60.0	61.6	64.1	63.2	54.4	46.8
Cities with SO_2 exceeding the standard (SO2≤ 0.06 mg/m3), %	36.2	28.4	21.7	19.4	22.4	25.6	25.7
Cities with NOx exceeding the standard, %	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source:

Table 5: Emissions of Main Air Pollutants from Waste Gases in Recent Years (in 10,000 tons)

	1998	1999	2000	2001	2002	2003	2004
SO2 Emission	2091.4	1857.5	1995.1	1947.8	1926.6	2158.7	2254.8
Industrial	1594.4	1460.1	1612.5	1566.6	1562	1791.4	1891.4
Household	497	397.4	382.6	381.2	364.6	367.3	363.5
Soot Emission	1455.1	1159	1165.4	1069.8	1012.7	1048.7	1095
Industrial	1178.5	953.4	953.3	851.9	804.2	846.2	886.5
Household	276.6	205.6	212.1	217.9	208.5	202.5	208.5
Emission	1321.2	1175.3	1092	990.6	941	1021	904.8

Source: Report on the State of the Environment in China 2004, SEPA,
available at http://www.zhb.gov.cn/english/SOE/soechina2004/air.htm

Table 6A: Acid Rain situation in the monitored cities

	2000	2001	2002	2003	2004
Frequencies of Acid Rain Occurrence (Percentage of Cities)					
0%	38.2	41.2	49.7	45.6	43.5
＞0%	61.8	58.8	50.3	54.4	56.5
Annual Average PH Value of Precipitation (Percentage of Cities)					
PH≤ 5.6	36.2	36.9	32.6	37.3	41.4
PH＞5.6	53.8	63.1	67.4	62.7	58.6
Numbers of monitored cities	254	274	555	487	527

Source: SOE 2002 & http://www.zhb.gov.cn/eic/650490891709972480/20030214/1036814.shtml

Table 6B: Acid rain situation in Acid Rain Control Zones

	1998	2000	2001	2002	2003	2004
Percentage of Cities with Different Frequencies of Acid Rain Occurrence						
0%	0	6.86	8.41	8.65	10.4	9.8
0-20%	17.9	19.6	21.5	20.19	20.8	17
20-40%	16.1	21.57	18.69	23.08	15.1	13.4
40-60%	33	26.47	16.82	15.38	16	19.6
60-80%	21.4	13.72	20.56	17.31	24.5	21.4
80-100%	11.6	11.76	14.02	15.38	13.2	18.8
Annual average PH Value of Pecipitation (Percentage of Cities)						
PH≤ 4.5	9.8	3.9	7.5	15.38	15.1	21.5
4.5<PH≤ 5	45.5	31.4	38.3	28.85	33	33
5<PH≤ 5.6	27.7	35.3	27.1	25.96	22.6	19.6
5.6<PH≤ 7	16.1	29.4	23.4	27.88	28.3	25.9
PH＞7	0.9	0	3.7	1.92	0.9	
Numbers of monitored cities	112	102	107	104	106	112

Source: SOE 2002 & http://www.zhb.gov.cn/eic/650490891709972480/20030214/1036814.shtml

Table 7: Ambient Air Quality in Main Cities (2003)

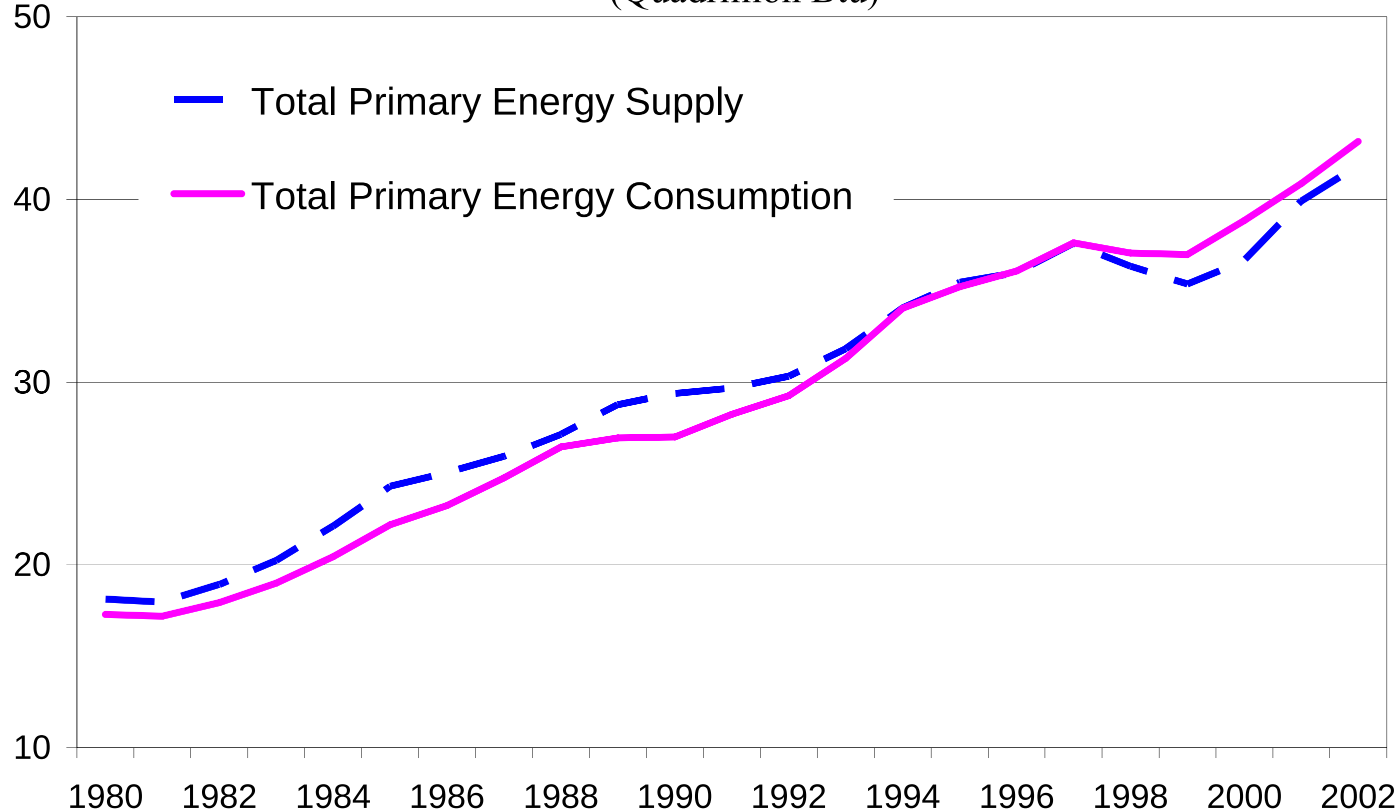
(milligram/cu.m)

City	Paticulate Matters (PM_{10})	Sulphur Dioxide (SO2)	Nitrogen Dioxide (NO2)	Days of Air Quality Equal to or Above Grade II (days)	Main Pollutants
Bejing	0.141	0.061	0.072	224	PM10
Tianjin	0.133	0.074	0.052	264	PM10
Shijiazhuang	0.175	0.152	0.044	211	SO2
Taiyuan	0.172	0.099	0.031	181	PM10
Hohhot	0.116	0.039	0.046	286	PM10
Shenyang	0.135	0.052	0.036	298	PM10
Changchun	0.098	0.012	0.022	342	PM10
Haerbin	0.121	0.043	0.065	297	PM10
Shanghai	0.097	0.043	0.057	325	PM10
Nanjing	0.12	0.03	0.049	297	PM10
Hangzhou	0.119	0.049	0.056	293	PM10
Hefei	0.1	0.012	0.025	287	PM10
Fuzhou	0.08	0.008	0.034	344	PM10
Nanchang	0.1	0.051	0.034	315	PM10
Jinan	0.149	0.064	0.046	214	PM10
Zhengzhou	0.107	0.05	0.033	308	PM10
Wuhan	0.133	0.049	0.052	246	PM10
Changsha	0.135	0.081	0.038	245	PM10,SO2
Guangzhou	0.099	0.059	0.072	314	PM10
Nanning	0.072	0.047	0.032	348	SO2
Haokou	0.03	0.009	0.013	365	PM10
Chongqing	0.147	0.115	0.046	237	SO2
Chengdu	0.118	0.052	0.046	312	PM10
Guiyang	0.104	0.089	0.019	351	SO2
Kunming	0.086	0.045	0.033	363	PM10
Lasa	0.065	0.002	0.029	353	PM10
Xi'an	0.136	0.057	0.035	252	PM10
Lanzhou	0.174	0.086	0.05	207	PM10
Xining	0.139	0.031	0.031	261	PM10
Yinchuan	0.132	0.063	0.037	291	PM10
Urumuqi	0.127	0.097	0.055	282	SO2

Source: China Statistical Yearbook 2004, National Bureau of Statistics of China

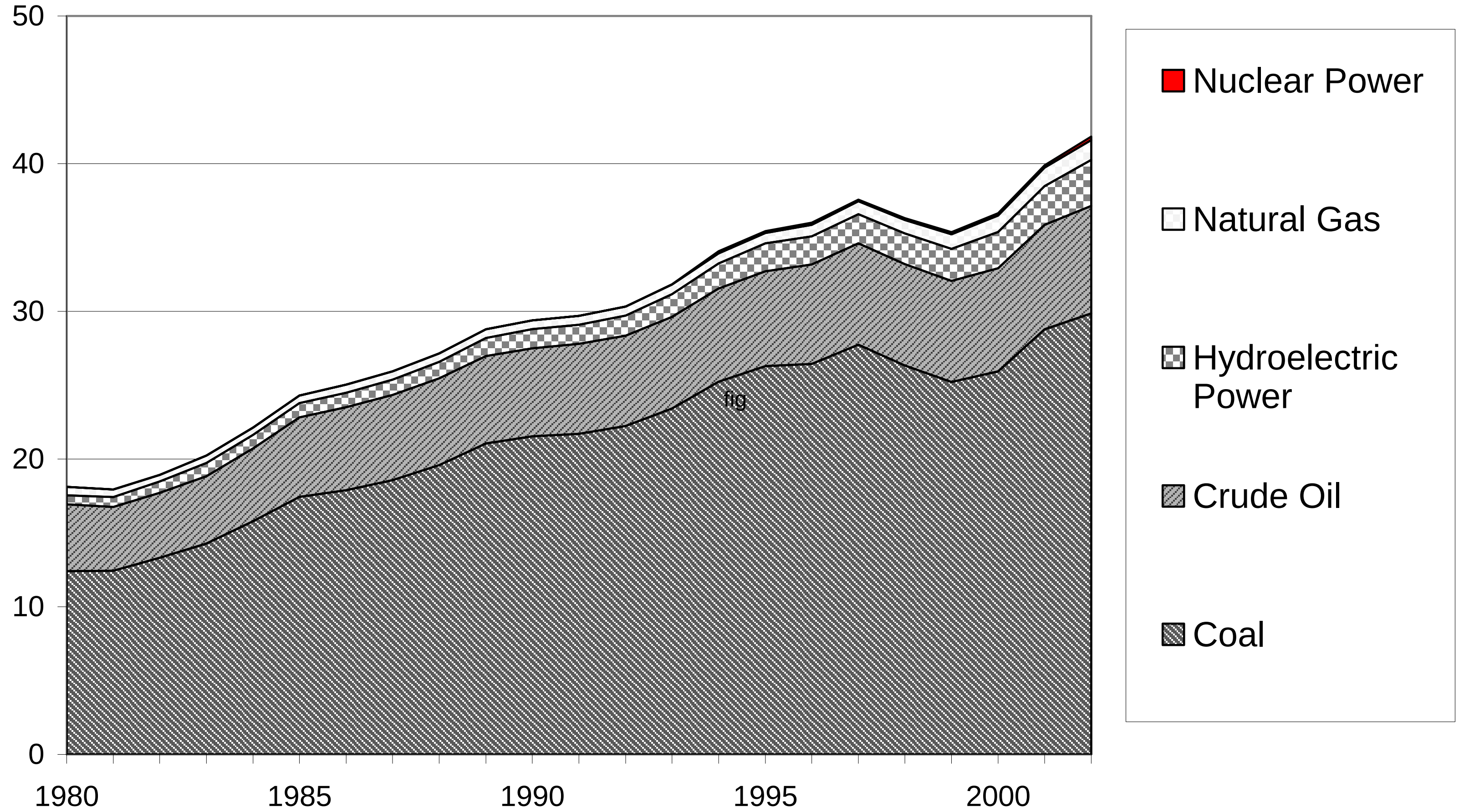
Figure 1: China's Total Energy Consumption and Supply,1980-2002

(Quadrillion Btu)



Source: Energy Information Administration

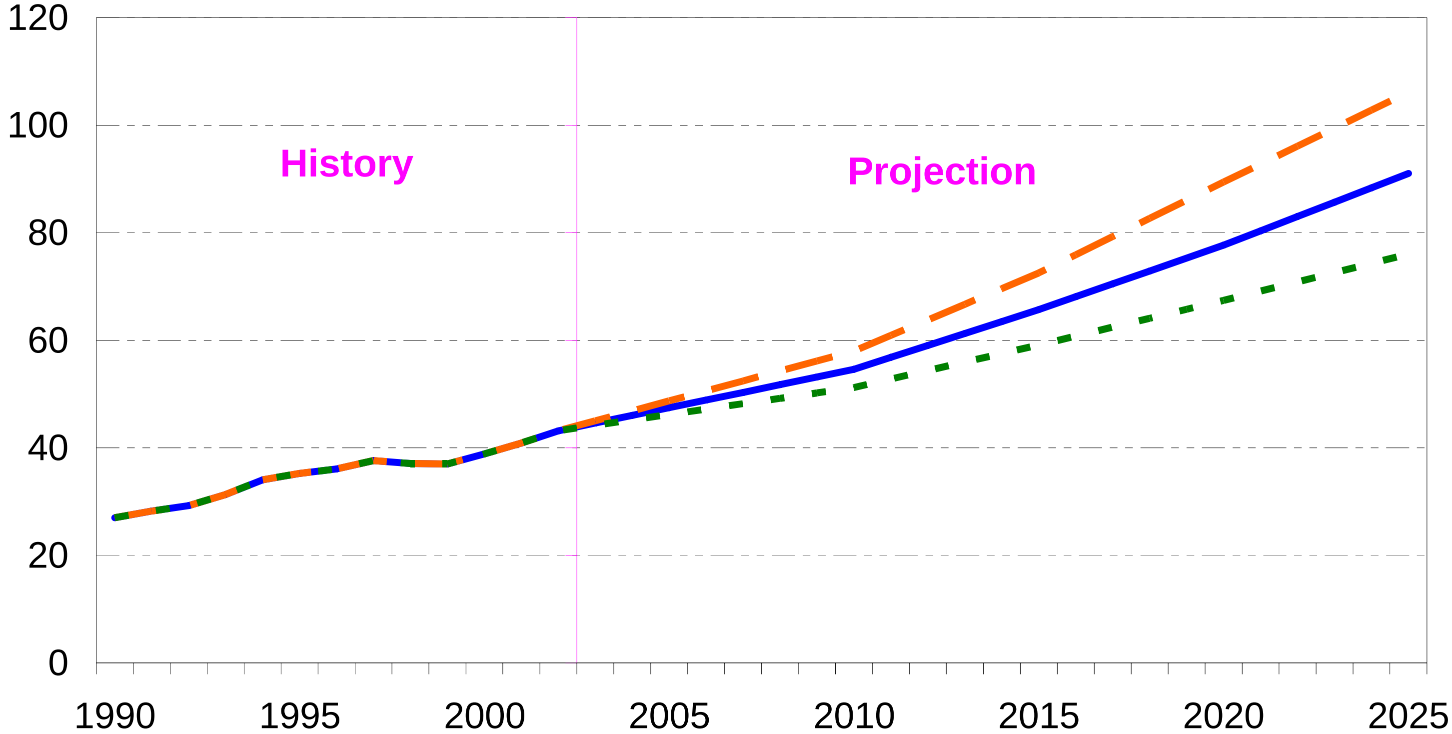
Figure 2: Energy Production by Fuel Type, China,1980-2002



Source: Energy Information Adminishtration

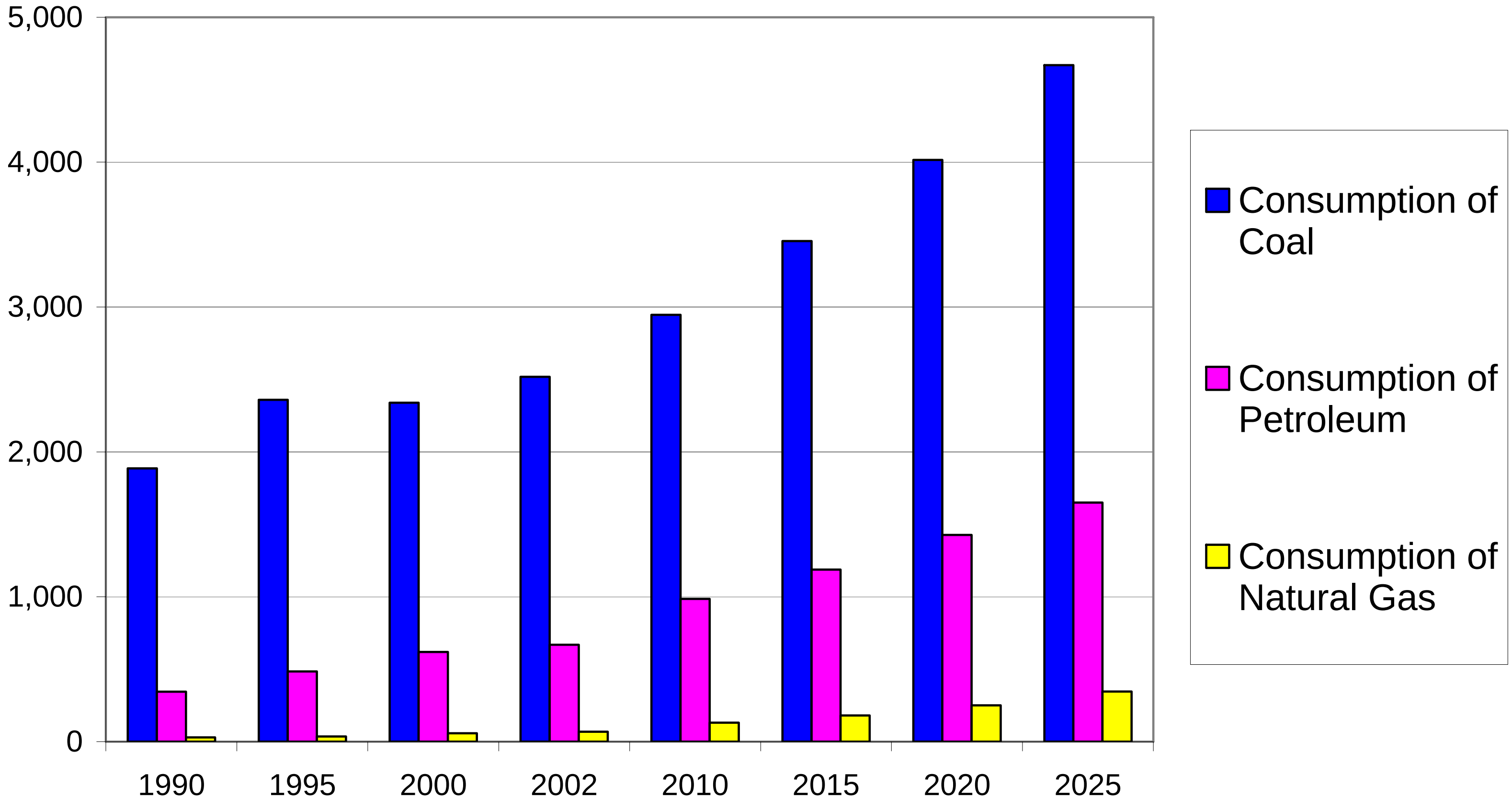
Fig 3: Total Energy Consumption,China, 1990-2025

(Quadrillion(10^{15}) Btu)



Source: Energy Information Administration / International Energy Outlook 2004

Figure 4: Projections for CO2 Emissions, China
(Million Metric Tons Carbon Dioxide)

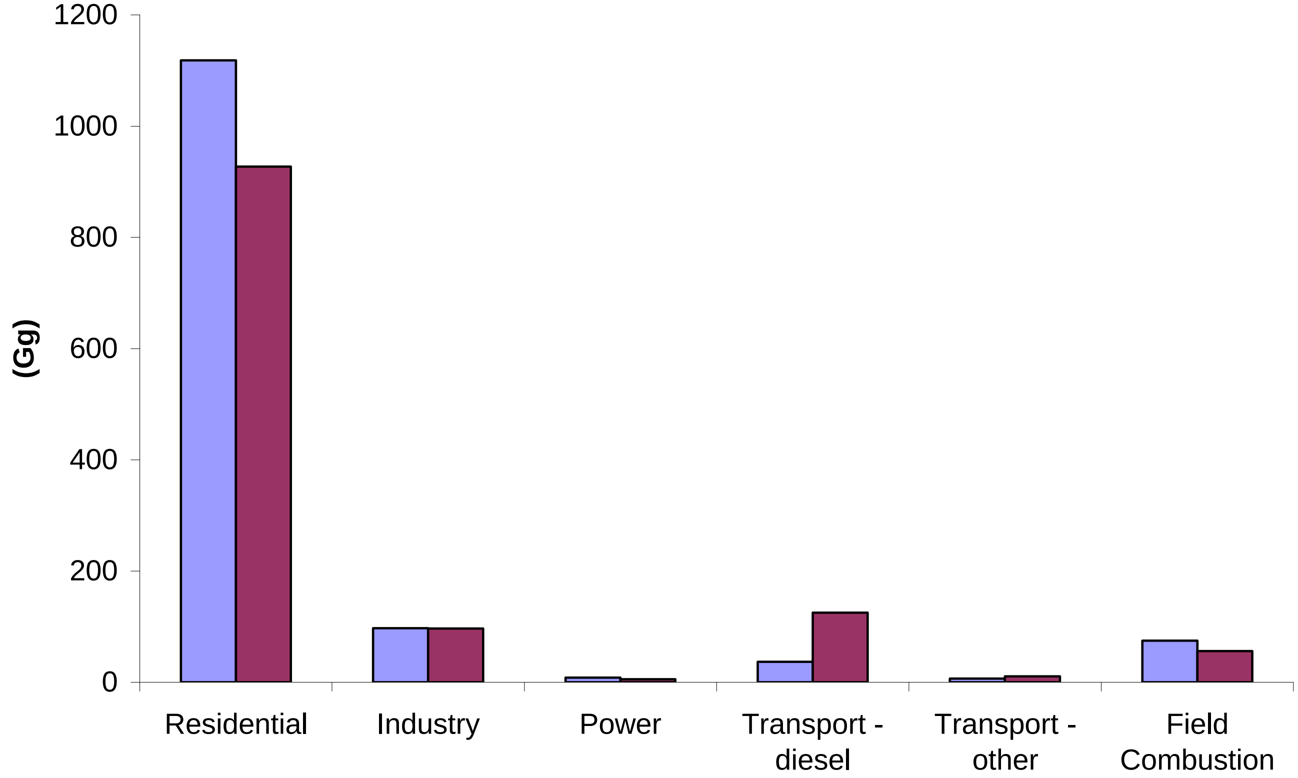


Source: Energy Information Administhtration/International Energy Outlook 2004

Figure 5: Projections of Energy Use in China from the G-Cubed Model

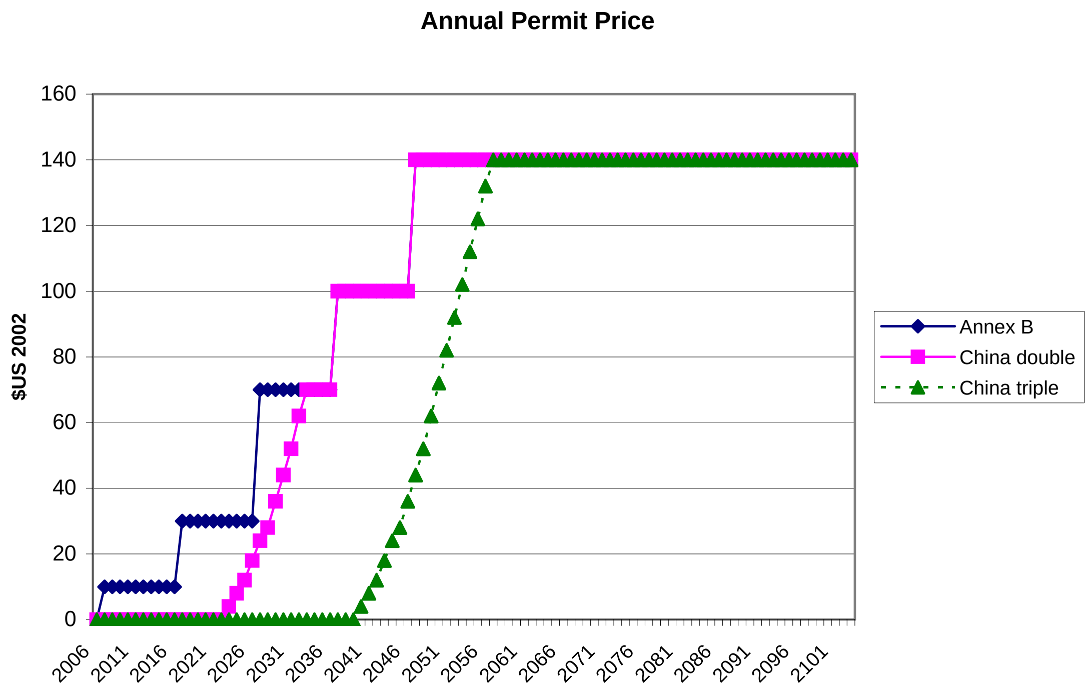
(TO BE ADDED)

Figure 6: Sources of Black Carbon in China in 1995 and 2020



Source: Streets D. (2004) "Black Smoke in China and Its Climate Effects" paper presented to the Asian Economic Panel, Columbia University, October 2004

Figure 8:Stylized Permit Price for an Allocation of double and triple China's 2002 Emissions



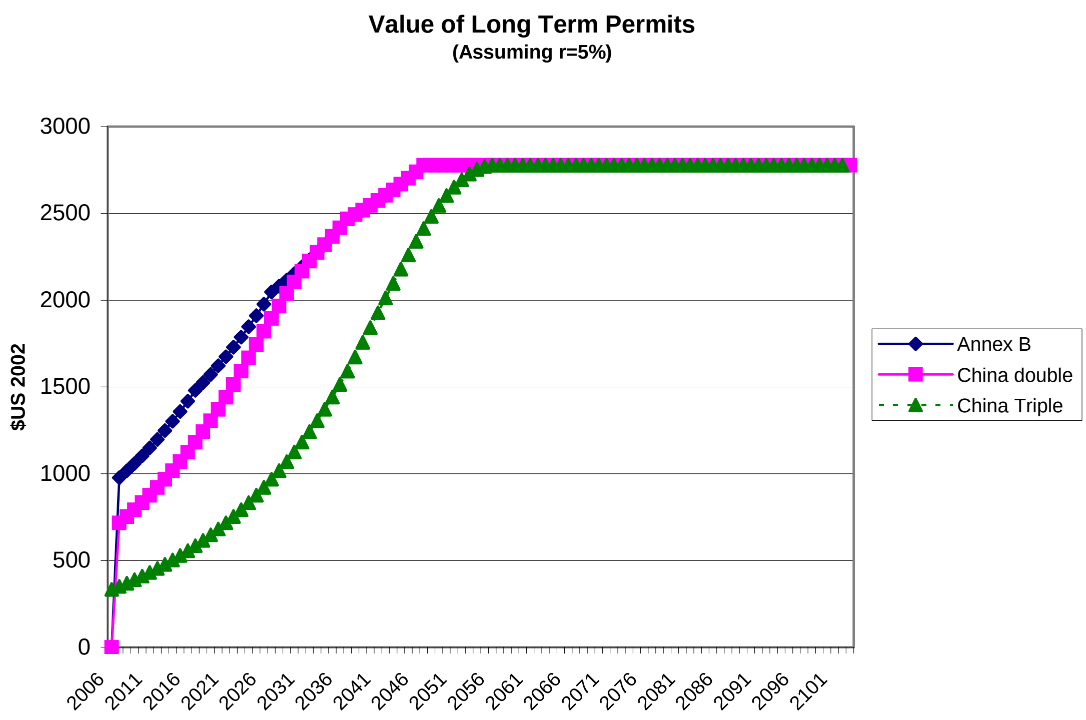


Figure 9: Results for a $US10 per ton Carbon Tax in China from 2007

To BE ADDED