EVOLUTION OF MITIGATION COMMITMENTS:

Energy Policies: Local and Global Environmental Linkages in Developing Countries

This paper was presented to an IEA Committee and is presented to the AIXG as a room document given its relevance to the topic of the evolution of mitigation commitments.

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I. INTRODUCTION

1. It has long been recognised that successfully addressing the issue of climate change will require the engagement of developing countries. Currently, developing countries emit more than 40 per cent of world energy-related greenhouse gas emissions (and more than half of global emissions of all greenhouse gases), and the proportions are projected to steadily grow. However, while climate change is of considerable political important to IEA Members, the issue ranks low in the priorities of most developing countries. For these countries, economic and social development, as well as local environmental concerns are more critical and command urgent attention.

2. In order to engage developing countries in climate mitigation efforts, it is therefore imperative that any climate-related actions be linked to these more immediate needs. Preliminary work on this linkage has been undertaken through a series of three case studies on climate implications of energy policies in three Non-IEA Member countries: China, India and Mexico. China and India represent the two major developing country players in the long-term climate issue, while Mexico provides an example of a more industrialised country – now an OECD Member State, but one that under the UNFCCC is still classified as a developing country.

3. Following a brief review of the energy-related environmental issues (from a local standpoint) in China, India and Mexico, the paper examines a number of areas of energy development that could greatly influence the local environment as well as greenhouse gases emissions. They are:

- cleaner power technologies (especially in coal use);
- fuel switching (from coal to oil and gas and/or from oil to gas);
- biomass;
- renewable energies (other than biomass);
- energy efficiency; and
- transport.

4. In each case, the paper first examines the policies currently undertaken, and then assesses the climate implications of a change in course. It seeks to identify the policy needs and barriers to implementation, and finally attempts to give a rough estimate of some of the potential environmental impacts of policy changes at local and global levels. The analysis also includes, where possible and appropriate, an examination of the technical potentials for improvements, and of the environmental effects of policies on a life-cycle basis.

II. ENERGY-RELATED ENVIRONMENTAL ISSUES AND TRENDS

5. Energy production, distribution and use affect the environment in a wide variety of ways, from land and water degradation associated with mining, to oil spills leading to contaminated soils, to water discharges of heat associated with power production, to air pollution associated with fuel combustion. This paper looks only at the major impacts on the atmosphere at global, regional and local levels (including in-door air quality). It does so through three country examples: China, India and Mexico.

6. China, India and Mexico each face severe air quality degradation very much related to diverse energy uses. While these countries' energy policies still have the main objective of meeting a growing energy demand to fuel economic growth and social development, a rising awareness of the environmental implications of energy use has led national and local authorities to integrate this concern in their energy development policies. The urgency of action has been heightened as current environment problems are expected to dramatically worsen in the future as energy consumption levels increase.

7. However, there are important differences in the respective situations of these countries. In China, a local and indoor air quality crisis is mainly due to the large quantities and poor quality of coal and biomass fuels used, while Mexico's air quality problem air is mainly due to traffic; India faces both problems.

Current Energy Situation

8. **China's** primary energy demand grew at over 5 per cent per year between 1981 and 1995, while its GDP grew at an estimated rate of 7.4 per cent (Maddison, 1997). China's declining energy intensity may be partially explained by a combination of factors, including the removal of subsidies and conservation measures. However, China's energy efficiency is still very low. China's high reliance on coal and use of non-commercial energies from biomass by 800 million people in rural areas combine into intense health-related problems arising from local and in-door air pollution.

9. **India**, the world's second most populous country, produces approximately 325 million tons of coal: it is the third largest coal producer in the world. Coal meets about two-thirds of India's commercial energy needs, and accounts for about 70 per cent of national power production. Unlike China, India's energy intensity has been increasing at around 1.4 per cent per year – although it may have now stabilised.

10. A Member of NAFTA and the OECD, **Mexico** is a major non-OPEC oil producer and ranks fifth in the world in oil production, and 14th for natural gas reserves. It exports crude oil to the United States and imports back refined fuels. In 1997, its energy sector contributed 10.8 per cent of total exports. Oil is the major energy source for power generation (50 per cent), followed by hydro (19 per cent), gas and coal (11 per cent each), and nuclear (5 per cent). Mexico is the only large country that has so far ratified the Kyoto Protocol.

Prospects for Energy Development

China

11. China expects its power generation to at least triple in the next twenty years, and coal, which currently provides three quarters of this power generation, is expected to account for the lion's share in this increase. Concurrently, sulphur dioxide emissions from power plants are expected to increase from 8.5 million tonnes in 1995 to 21 million tonnes in 2015.

12. Over the 2000 World Energy Outlook (WEO) period, primary energy demand in China is expected to grow on average by 3.4 per cent per annum, compared with growth of 4.5 per cent from 1990 to 1997. Total primary energy supply would be some 1940 million tonnes oil-equivalent (Mtoe) in 2020. Total energy consumption will more than double by 2020. While the rate of improvement in energy intensity is expected to slow down in the future, it will still decline by 1.8 per cent per year on average over the outlook period.

13. Coal will account for the largest share in TPES in 2020, despite its growth rate of 2.6 per cent per year, down from previous growth of 3.5 per cent from 1990 to 1997. Coal demand is projected to be some 1200 Mtoe by 2020. The bulk of the incremental coal demand will be used for power generation.

14. The share of oil will rise to 28 per cent (from 204 Mt to 543 Mt) at the expense of coal, whose share will fall to 62 per cent, down over 10 percentage points from its 1997 share in total primary energy demand. Primary oil demand is expected to grow by 4.4 per cent, with the transport sector accounting for most of the growth.

15. Primary gas demand will rise by 7.5 per cent per year on average over the outlook period, but will still account for only some 6 per cent of TPES in 2020, according to the WEO, while official Chinese projections suggest 7.1 per cent in 2015. While growth in demand for nuclear power is expected to be strong at 10.5 per cent over the outlook period, its share in TPES will still only be some 2 per cent in 2020. Hydropower will account for the remaining 3 per cent of TPES in 2020.

India

16. For India, WEO 2000 foresees a nearly three-fold increase in total primary energy supply from 268 Mtoe in 1997 to 716 Mtoe in 2020, with an average yearly growth rate of 4.4 per cent. The share of coal would decline from 57 per cent to 47 per cent, and the share of gas would increase from 7 per cent to 16 per cent. However, coal will still be the largest contributor to the increase in demand.

17. Total final commercial energy consumption in India is projected to almost triple over the Outlook period. Electricity demand is expected to increase yearly by 5.4 per cent, reaching 22 per cent of final consumption. The transportation sector will be the main driver for the projected increase in oil demand.

18. While industry's emissions of SO_2 and NO_x are expected to increase by 50 per cent in 2020, thermal power related emissions of the same pollutants could increase by 250 per cent in the same time (Reidhead et al., 1998).

Mexico

19. The Mexican Department of Energy foresees an annual increase in energy demand of 5 per cent in the next ten years, based on an annual increase of GDP of 5.2 per cent. By 2010, energy consumption would have roughly doubled over 1996 levels. Final demand for electricity would rise at 6.1 per cent per year and natural gas at 8.7 per cent. Gas will increase its share in power production from 18 per cent in 1998 to 58 per cent in 2008 at the expense of oil. Coal in power production will slightly increase its share from 13 per cent to 15 per cent.

Contribution to Global Warming

20. Table 1 below summarises the situation of China, India and Mexico with respect to energy-related CO_2 emissions – key to the global climate change issue. It is clear that there are large differences amongst them and equally significant variations between these countries and the OECD average.

Table 1

	GDP/ Capita (90 US$)	CO_2/Capita (t)	TPES/Capita (toe)	Electricity/ Capita (kWh)	CO_2/GDP (kg/$)
China	728	2.32	0,84	895	3.19
India	509	0.93	0,49	416	1.82
Mexico	3,495	3.72	1,54	1644	1.07
OECD	18,769	10.92	4.63	7751	0.58

Notes: 1998 figures. China: figures include People's Republic and Hong-Kong. TPES = total primary energy supply, and for China and India includes non-commercial energies as well as commercial energies. CO_2 emissions are from fuel combustion only, calculated using IEA's energy balances and 1996 revised IPCC guidelines.

Environment at Regional Level

21. Regional level environmental impacts are most noticeable in China. Acid rain now falls over 30 per cent of the country, mainly in the central and south-western regions where coal has above-average sulphur content; acid rain arising from Chinese coal combustion has also begun to affect Korea and Japan. It has been estimated to cost $13-14 billion annually in a drop in grain output, health bills and other associated forms of environmental damage. One recent study found that regional haze in China is currently depressing optimal yields of 70 per cent of the crops grown in China by at least 5-30 per cent (Chameides et al. 1999).

22. Regional effects around the Indian sub-continent are also noticeable. In 1999, scientists discovered a brownish haze of pollution over the Indian Ocean, covering a surface area roughly equivalent to that of the United States; the haze was found up to 10,000 metres in altitude. Scientists suggested that the pollution generated acid rain and reduced insolation over the Ocean, leading to reduced evaporation and rainfall. These regional effects are in addition to any possible global effects: while aerosols in general have a negative climate forcing effect (they lead to atmospheric cooling), the

unusually high proportion of soot, which has a positive climate forcing, left scientists unable to assess the sign of the global net effect.

<u>Environment at Local Level</u>

23. Local air and water pollution has long been associated with urban areas in India, China and Mexico. In addition, the use of non-commercial energies accounts for a high share of energy use (particularly in India and china), giving rise to acute levels of indoor air pollution. In China, the use of non-commercial energies accounts for more than 20 per cent in the energy balance, while in India it exceeds 40 per cent. Women and children pay the heaviest toll, with high domestic uses of biomass fuels and coal for cooking and heating causing acute respiratory infections, chronic obtrusive lung diseases, eye problems and low birth weights. Acute respiratory infections alone are the first cause of death of children in both countries. Numerous studies have revealed that in-door pollution greatly enhance the incidence of these infections.

China

24. Major cities in China have been frequently ranked high in top ten lists of the most polluted cities in the world, largely due to high rates of coal use. More than 500 Chinese cities are said to have air quality standards below the World Health Organisation’s (WHO) criteria. Particulate and sulphur levels exceed WHO and Chinese standards by a factor of two to five. Chronic obstructive pulmonary disease is the leading death cause in China, partly because of ambient outdoor and indoor pollution levels. Indoor air pollution, mostly from burning coal and biomass for cooking and heating, is estimated to cause 110,000 premature deaths every year.

25. An investigation based on data for 50 million people in 26 cities showed that the average PM_{10} pollution in urban districts and in control districts were 460 •g/m^3 and 220 •g/m^3, respectively, and the corresponding average mortality from lung cancer was 14 per cent and 7 per cent, respectively. Every 100 •g/m^3 increase in total suspended particulate concentrations also led to a 6.75 per cent increase in the incidence of chronic broncho-pneumonia in coal-burning areas (WHO, 2000).

26. The extensive use of coal throughout China is the main cause of these damages – although transport in a few cities (e.g., Beijing and Guangdong) now plays an equally important role. 21 per cent of particulate emissions and 30 per cent of SO_2 emissions originate in the power sector. While one third of coal is used in the power sector, the remainder is used in other sectors – including in households and millions of small industries with very low efficiency and high CO, VOC and particulate emission levels (IPCC, 1996).

27. In China, national and regional authorities have started to address this environmental issue and new regulations have been put in place. Ambient air standards have been established, for example, limiting SO_2 concentrations in cities to 20 •g/m^3; new emission standards were issued in 1996.

28. Chinese authorities have closed a total of 31,000 small coal mines in the recent past (Facts, 2000) in order to reduce oversupply and economic losses. As a result, consumers have turned to higher quality coal with higher calorific values; this has driven a reduction in quantities consumed as well as local pollutants emitted (Sinton & Fridley, 2000). It should be noted that this change did not

modify the actual carbon dioxide emissions although it may appear to do so when CO_2 emissions are calculated using a fixed average value for heat content (IEA, 2000c).

29. The State Environmental Protection Administration is currently undertaking a major reform of the existing pollution levy system, with a view of refocusing it from low charge rates to rates higher than pollution abatement costs. This new levy, evaluated in studies published by the Chinese Research Academy on Environmental Sciences, would have led to tax collections of approximately 50 billion yuan in 1995, rather than the 4 billion yuan raised in that year. Two pollutants would be responsible each for one third of these payments: SO_2 and CO_2 (OECD, 1999).

30. The legal requirement for setting emissions standards was established in 1996, when, pursuant to a decision of the State Council, all industrial enterprises in China were required to comply with limits by the end of 2000 or be closed down. At the same time, provincial capitals and directly administered cities (Tianjin, Beijing, Shanghai and Chongqing), as well as special economic zones and key tourist cities were required to meet national standards for both ambient air and surface water quality (known as the “meet two targets at one stroke” policy). At the end of July, according to the State Environmental Protection Administration, 90 per cent of the country’s 238,000 industrial enterprises, but only two-thirds of the 620 largest state-owned ones had met the standards. More than 2,000 of enterprises emitting above the standards in February were removed from the list at the end of April – half having closed and half having reduced their emissions.

31. Local authorities also have been recently taking drastic measures in order to meet air quality standards. Beijing and Shanghai, in particular, have expressed a strong interest in fuel switching. Cities have also implemented local, more stringent regulations on local and criteria pollutants. Strict zoning ordinances have required most polluting factories to move outside city limits.

32. Last August, in the northern city of Shenyang, for the first time in China, the municipal authorities closed a large enterprise (*Shenyand Smelter*) for its large contribution to local polluting emissions. Although the poor economic performance of this plant (built during the Japanese occupation in 1936) might provide a primary explanation for its closure (it will put 20,000 people out of work), the closure has been cited by the State Environmental Protection Administration as a threatening example for others. Observers, however, doubt that all large enterprises exceeding the standards – like *Capital Iron and Steel* in Beijing, that employs 170,000 workers and also has not met the standards – could be either in compliance or closed before the end of this year.

33. A sweeping amendment to the 1987 Air Pollution Control Law (last amended in 1995) was approved by the Standing Committee of the National People’s Congress in April 2000, and went into effect 1st September, 2000. The new law aims sets new air quality standards, including:

- mandating that the total volume of air pollutants at not exceed 1995 levels by 2010;
- calling for slightly reduced SO_2 emissions within the SO_2 and acid rain control zones;
- requiring that 34 of the 47 key cities be brought to “fair” air quality standards;
- require construction sites in Beijing to reduce dust emissions by 70 per cent.

India

34. In **India**, air pollutants originating from industries, power sector and a rapidly increasing transport sector all contribute to a severe degradation in air quality. In 1998, levels of suspended matter particulates were deemed to be at or above “critical” levels (more than 210 •g/m^3 in annual mean concentration) in Dhanbad and Patna (Bihar), Parwanoo (Himachal Pradesh), Bangalore (Karnataka), Bhilai, Bhopal, Indore, Raipur (Madhya Pradesh), Dombivali, Pune and Solapur (Maharashtra), Alwar, Jaipur, Jodhpur, Kota and Udaipur (Rajasthan), Dehradun, Kanpur, Varanasi and Lucknow (Uttar Pradesh), Delhi and Pondichery. In a number of other cities, including Agra, Bombay, Calcutta, and Jalhandar, the information for 1998 is not available, but this “critical” level was exceeded for these cities in 1997. In Chandigarh, Nasik and Vishakhapatnam, however, the “critical” level reached in 1997 was reduced to “high” level (140-210 •g/m^3) in 1998.

35. An estimated 2,000 tonnes of air pollutants are emitted into the atmosphere every day in Delhi. Vehicular sources contribute about 63 per cent of total pollutants emitted, followed by industries and thermal power plants, 29 per cent, and 8 per cent from the domestic sector (Reidhead et al., 1998). One of the primary contributors to decreasing urban air quality is the rapid increase in transport demand. A study conducted on benzene concentrations in Delhi carried out by the Netherlands Institute for Applied Research showed that air concentrations on open roads in Delhi was six times higher than that in a traffic tunnel in Rotterdam. Even comparison with a similar large city such as Cairo was shocking: Delhi air has about three times the benzene concentrations as that in Cairo, the study found. These high-levels of carcinogenic benzene are though to be associated with the very large number of old two-stroke engines in the streets and the poor quality of gas and lubricating oil.

36. The present air quality regulations were created under the Air (Prevention and Control of Pollution) Act of 1981 that established the Central Pollution Control Board (CPCB), and the Environmental Protection Act of 1986. These acts empowered government agencies to set and uphold Minimal National Standards (MINARS) for effluents from industries and to set National Ambient Air Quality Standards (NAAQS). The CPCB is also responsible for the National Ambient Air Quality Monitoring (NAAQM) network, which presently includes 290 monitoring stations in 92 cities across India.

37. As with ambient air quality and emissions data, statistics regarding the number of violators (and documentation related to the enforcement of these regulations) have been collected only recently. A CPCB nation-wide study that took place in 1994 of medium to large industrial sites found that of the 1,551 existing units, 1,125 had adequate facilities to meet the ambient quality and effluent standards. Of the balance, 107 had closed, 258 of those in violation were constructed before the advent of the 1981 law, and 61 were constructed after (Reidhead et al., 1998). Furthermore, urban areas have taken action to improve their ambient air quality by relocating some of the more polluting industries from high density, highly polluted areas, to lower density areas that can accommodate emissions with less damage to inhabitants. For example, Delhi, which has experienced a massive growth in small-scale industries in the last 15 years and has been directed by the Supreme Court to relocate its 114 highly polluting stone crushers outside its city boundaries. Consequently, many of these offenders have moved into the neighbouring state of Haryana (WWF, 1995).

Mexico

38. One of the major environmental concerns in Mexico is the degradation of quality of air in Mexico City and other urban areas. In particular, ground-ozone levels are especially high in the Metropolitan Area of Mexico's Valley (ZMVM), almost continuously exceeding the national standard (established in December 1994). In 1991 and 1992, daily ozone levels exceeded levels of twice the standard during 173 and 123 days respectively, while reaching the threshold of emergency action 56 and 37 days.

39. Particulates remain the second most severe problem in Mexican urban areas, although concentrations have been reduced in particular in Mexico City after the closure of a refinery in 1992. Annual mean levels of $NO_{2,}$ however, are increasing, as is the number of days that the particulates standard is exceeded.

40. Overall air quality degradation is partly due to unique characteristics of this area. With an altitude of 2,240 meters, oxygen content of the air is reduced by 23 per cent below that at sea level, therefore reducing energy efficiency in combustion processes. Neighbouring mountains prevent cleansing winds, and the region is also influenced by anticyclones over the Mexican Gulf of the Pacific Ocean that tends to stabilise the atmosphere, leading to build-up of dangerous pollutant concentrations. In addition, temperature inversions are frequent, and solar insolation is abundant, promoting the more rapid reaction of NO_x, VOC and CO in the photochemical process of forming ozone.

41. The transport sector is primarily responsible for the ongoing decline in air quality. In 1994, transportation was responsible for 99.5 per cent of CO emissions, 71.3 per cent of NO_x, and 54.1 per cent of VOC. Only in SO_2 emissions was the industry the main emitter with 57.3 per cent of emissions. Wind erosion – fostered by traffic on unpaved roads – is the principle cause of high particulate levels.

42. Neither the refinery sector nor the power sector gives rise to significant emissions, the Mexican government has undertaken an effort to promote the use of natural gas in the power sector and end-use sectors, aiming at increasing the country's economy competitiveness as well as achieving its environmental objectives. While not uniquely inspired by environmental concerns, the Mexican government has implemented an aggressive policy of energy efficiency improvements at both conversion and end-use levels, notably through an extensive use of standards.

43. More directly related to controlling local air pollution, national and regional authorities in the atmospheric "basins" of Mexico City, Gudalajara, Monterey and Toluca have taken aggressive policies to slow and reverse the degradation of air quality since 1988.

III. ENERGY DEVELOPMENT POLICIES

44. While environmental quality is clearly connected to development in the energy sector, most energy policy in these three countries has been taken to promote electrification, improve availability and consistency of power supply (including to rural and impoverished areas), and promoting energy security and national competitiveness. Although policy approaches differ from one country to another, all three have financed the construction of new power plants, devoting resources to energy efficiency, and establishing policies to promote renewables. Each also has programmes in the transport sector. This section describes these policies, and evaluates the environmental implications of changes to these policies.

Cleaner Power Technologies

45. There are numerous options to produce power and heat from coal and oil while considerably reducing polluting emissions. These may apply – but on different economic circumstances – to existing plants and to new plants. While some of these techniques will reduce CO_2 emissions, others would leave them unchanged if not slightly increased. In this section, we will consider potential improvements in the power sector, while potential improvement at consumer level will be looked at in the section "energy efficiency".

Current policies

46. Power generating capacity in 1997 in China was 263 GW (from 1,700 thermal plants) and 103 GW in India. The 2000 WEO foresees increases in installed capacities of 500 GW in China and 205 GW in India between 1997 and 2020 (of which respectively about 350 and 127 GW will be from coal plants). Of this, about 650 and 127 GW respectively will be new coal plants. Proposals have been made to displace some existing coal-fired power generation through fuel switching, including power from biomass, power from other renewable energies, and better energy efficiency in end-use. Furthermore, a portion of the existing capacity might be closed for both environmental and economic reasons. No new coal-fired plant is currently projected in Mexico.

47. In 1996, standards were established in China requiring all new coal-fired power plants burning medium or high sulphur coal to add SO_2 control technology and meet an emissions limit of 650 mg/m^3. They also establish limits for particulate emissions. As a result, electrostatic precipitators (ESP) and scrubbers for particulate have been installed, and emissions have fallen from 16.5 g/kWh to 4.2 g/kWh from 1980 to 1996. The government has set a target calling for 80 per cent of units to be equipped with ESP in 2000, up from 60 per cent in 1996.

48. The Chinese Ministry of Coal Industry has also set an ambitious target of 500 million tonnes of coal to be washed in 2000. Coal washing removes some of the inert material and thus reduces transport requirements. A lower volume of inert material also leads to less power station ash production, and often removes some of the sulphur. The share of coal washed in China has remained fairly constant from 1980 to 1993 at 18 per cent.

49. Energy efficiency in the power sector is relatively low in India and China, at around 30 per cent. This contrasts sharply with efficiency in the OECD: Germany, the largest European coal consumer, has an average efficiency of around 40 per cent, while newly-build power plants operate at efficiencies of 46 per cent or even higher. However, IEA statistic suggest efficiency in China's power

sector is rapidly increasing (over a per cent in the last year alone), probably as a result of the closure of numerous small, inefficient power plants. In India, according to the Tata Energy Research Institute (TERI), coal plant efficiency in many cases is below 20 per cent (less than half the capability of current coal technology).

50. Most new coal plant construction (even for new build-to-operate contracts joint with OECD companies) is for sub-critical plants – with efficiencies of around 37 per cent. Current policy seems to focus on closing the least-efficient facilities but not on enhancing the efficiency of new plants. Exceptions exist, such as the Anhui Fuyang project, for which the Chinese government has requested a loan from the Asian Development Bank. It includes the building of a 2x600 MW coal-fired SCPF power plant with 45 per cent efficiency, upgrading of transmission lines, and the closing of 21 small, inefficient and polluting power plants totalling 273 MW of capacity as well as afforestation programme; the project is designed to expand rural electrification.

Technologies, Costs, Potentials and Barriers

51. Scrubbers, electrostatic precipitators and other end-of-pipe technologies can drastically reduce SO_2 and particulate emissions at a relatively low cost, especially in the energy conversion sector (existing refineries and power plants). More costly, albeit more efficient options include flue-gas desulphurisation. To reduce NO_x emissions, low-NO_x burners are an inexpensive option. However, selective catalytic reduction, which entails very high investment costs, is required for further reductions in NO_x emissions. While effective at NO_x, SO_2 and particulate reductions, end-of-pipe techniques slightly reduce the energy efficiency of power plants. This means such local pollution-reducing technologies tend to increase rather than decrease CO_2 emissions. However, reducing CO, NO_x and VOC may entail climate benefits through reduced ground-level ozone formation.

52. Efficiency improvements and air emission reductions for pulverised coal plants can be achieved with higher steam cycle operating pressures and temperatures. While newly built conventional (sub-critical) pulverised fuel (PF) power plants show an efficiency of 38 per cent, supercritical pulverised fuel (SCPF) power plants can reach efficiencies of 41 per cent, and advanced SCPF efficiencies of 45 per cent. Compared to PF plants, CO_2, SO_2, NO_x and particulate emissions would be reduced by 8 per cent with SCPF plants and 15 per cent with advanced SCPF plants. The potential scale of improvements is huge: the combined effect of power plant efficiency improvements from 38 to 45 per cent in India and China is more than 10 billion tons CO_2.

53. Advanced SCPF plants cost only approximately one per cent more in capital construction costs than conventional PF plants (although it may be as much as 5 to 10 per cent of the costs for critical parts of the plant). Thus, even with high capital costs and low coal costs, electricity prices might be slightly reduced in a changeover from conventional PF to advanced SCPF.

54. The economic advantage would be higher with parameters that the Coal Industry Advisory Board (CIAB, 1998) suggests for China: low coal price ($16.5/t, heating value 4,400 kcal/kg) but low capital costs ($620/kW). Under such a scenario, emission reductions of local pollutants would be achieved at no cost – being paid for by fuel consumption reduction. However, a survey conducted by the CIAB with some Independent Power Producers operating in China and India revealed that their technology of choice would be sub-critical pulverised fuel: SCPF technologies – although proven and "state-of-the-art" in industrialised countries – are thought to be too risky and costly. Another factor

that could impede the building of advanced SCPF coal plants is a reluctance to rely on an imported technology – with its concomitantly smaller level of local corporate profits, and reduced local work force participation.

55. The CIAB survey suggests that the pace of the transfer of proven, cost-effective and more efficient coal-burning technologies will be one of the critical determinants of future GHG emissions from India and China. This resistance to the adoption of these new technologies also limits the rapidity at which the market compels lower costs of the even more efficient technologies that are now under demonstration or development in the industrialised countries (such as fluidised bed combustion or integrated gasification combined cycle).

56. While a certain level of reductions in environmental pollutants can be achieved cost free, more aggressive emissions reductions require additional policy action. For example, use of coal with low-sulphur content could remove 40 to 60 per cent of the SO_2, while the use of dry and wet scrubbers could remove up to 90 per cent of SO_2 emissions. Chinese authorities have shown some interest in emissions trading as a cost-effective means to foster these improvements (Hoi & Tam, 2000) and some pilot experiences have taken place with the support of the US NGO "Environmental Defense". These policies would not, however, reduce GHG emissions.

Fuel Switching

57. China, India and Mexico are all actively promoting fuel switching from coal to oil and gas, or oil to gas. One major motivator of this policy is a demand from citizens that local air quality be improved. This will in turn have dramatic effects on their CO_2 emissions.

58. Fuel switching (away from coal and to oil or gas) also brings CO_2 benefits. Carbon emission factors relative to primary energy supplies are 15.3 tC/TJ for natural gas, circa 20 tC/TJ for liquid fossils (oil), and circa 27 tC/TJ for solid fuels. Thus, if energy efficiencies are unchanged, a shift from coal to oil would imply a reduction in carbon emissions of 26 per cent, a shift from oil to gas a reduction of 23.5 per cent, a shift from coal to gas a reduction of 43 per cent per unit of primary energy.

59. In many cases, and especially in the power sector, the shift from a solid or liquid to a gaseous fuel is accompanied by a dramatic increase in energy efficiency. Modern combined-cycle gas-fired power plants might have an efficiency close to 60 per cent, and newly-built coal-fired power plants have efficiencies exceeding 45 per cent. This compares favourably to many old plants, with theoretical conversion factors close to 30 per cent (lower values are seen, especially in developing countries, in actual operations). Thus, a shift from coal to gas would in practice imply an emission reduction of 60 per cent (if one considers that a new plant would have been built anyway) or even more (if one replaces an old plant).

Environmental Effects

60. The climate change mitigating benefits of fuel switching might be somewhat reduced if calculated on a life-cycle basis. For example, CO_2 emissions are frequently associated with the production of natural gas. In addition, there are energy requirements associated with the removal of impurities from gas, and there is often a problem of methane leakage in the pipeline and transport infrastructure.

61. CO_2 emissions in the extraction of natural gas occurs as CO_2 in the reservoir is vented during gas production. The extent of the releases depends on the CO_2 content in the reservoir; for most currently exploited fields, the CO_2 is content is less than 1 per cent and emissions are less than 14 kg C/GJ of natural gas. However, some fields contain approximately 50 per cent CO_2 (e.g., the Krahnberg field in Germany, Catania in Italy). Others contain even more. For example, the still unexploited Natuna field in Indonesia contains up to 70 per cent of CO_2 – and this field has been proposed for development to serve future Chinese imports of LNG.

62. Methane leakage also occurs in the production and transport of natural gas and other fossil fuels. Although leakage rates may seem relatively small, the high global warming potential of methane (21 times the effect of carbon dioxide) may partially offset the advantages of fuel switching. At the global level, methane leakage rates are estimated at approximately 1.3 per cent. This corresponds to emissions of 20 Mt, or 0.92 g/kWh. Methane leakage associated with oil production is estimated at 17 Mt, or 0.45 g/kWh. Methane leakage associated with coal is estimated at 22 Mt, or 0.75 g/kWh. In CO_2-equivalent terms, these figures correspond to 19.32 g/kWh for gas, 9.45 g/kWh for oil and 15.75 g/kWh for coal (Beukema, 2000).

63. Studies have attempted to compute the "break-even leakage rate" for methane, i.e. the rate of leakage that would make its use "neutral" for the climate compared to that of coal or oil. They found rates of between 4 per cent and 6 per cent relative to oil, and 8 per cent and 13 per cent relative to coal – depending on the specific circumstances of oil and coal production – and not taking into account any difference in the efficiency in the conversion or final use of the different fuels (Beukema, 2000). Other analysis has suggested that on average, the methane emission factor using oil and coal is higher than using gas: 8 g/GJ of CH_4 for oil, 5.5 g/GJ of CH_4 for coal and 3 g/GJ of CH_4 for gas, (Smith et al., 1994). However, leakage rates largely depend on the length and conditions of gas transport. New construction projects that are well maintained have low leakage rates – suggesting that the actual benefit for climate change must be assessed on a case-by-case basis.

64. While leakage issues can reduce the climate benefits of switching to gas, the converse also applies: there are significant climate benefits that accrue from reducing gas venting in oil production and methane leakage in coal mining. Currently, 20 billion cubic metres (Gm^3) of coal bed methane escape into the atmosphere each year (WEO 1999, EIA/CIAB 1999). US-EPA has estimated methane emissions from coal mining in China in the range of 8.5-13 Tg/y, or 178.5 – 273 $MtCO_2$-Eq, i.e. from 6.2 to 9.4 per cent of CO_2 emissions from China. Mexico ranks fourth in the world in gas flaring and venting (after Nigeria, Saudi Arabia and Iran), with 10.7 Gm^3 flared and vented and otherwise lost – compared to a marketed production of 28 Gm^3. A policy designed to increase gas availability may also help focus attention on these leakage sources.

65. Fuel switching will also reduce pollutants that have local and regional environmental effects, such as SO_x, NO_x CO, particulates, soot, VOC and others. For example, while SO_x emissions are negligible from the combustion of gas, a power plant with a capacity 1000 MWe producing 6000 GWh annually would emit 8,750 t/y of SO_2 with coal, 6,580 t/y of SO_2 with fuel oil (Beukema, 2000). These figures may be conservative, as they assume emission limits of 400 mg/m^3 of SO_2 that may only be achieved with scrubbers of through the use of very low sulphur content fuels (<0.25 per cent).

66. For NO_x, the differences are less impressive, but still large: a coal-fired power plant would emit 4,350 t/y of NO_x, a oil-fired plant 3,300 t/y, and a gas-fired plant 3,190 t/y – and a combined cycle gas-fired only 1,980 t/y. These figures may also be conservative, as they assume an NO_x

emission limit of 200 mg/m^3 that requires low NO_x burners for gas, low NO_x burners with reburning or selective catalytic reduction (SCR) for fuel oil and coal.

67. Environmental advantages are much larger when gas or oil replaces coal in household cooking and heating. Not only do hand-fired coal units emit much larger amounts of carbon monoxide and other pollutants, but they are also difficult to fit with anti-pollution devices.

Current Policies and Trends

68. ***China.*** In March 1999 the Energy Research Institute of China's State Development Planning Commission issued a study entitled "Medium and Long Term Energy Strategies for China". Discussing at length all energy and energy-related environmental issues in China, including climate change, the study states that growing Chinese exports will be able to pay for even very large-scale oil and natural gas imports. These would help China achieve high energy-efficiency levels while addressing a critical local air pollution problem. The study recommends that in 2050, coal consumption not exceed 35 per cent of total energy consumption, with oil and natural gas accounting for 40-50 per cent, and nuclear, hydro, solar and wind accounting for 15-20 per cent.

69. After peaking at 118 million tonnes coal equivalent (Mtce) in 1990, coal consumption in the residential sector has come down to 89 Mtce in 1997 and 66 Mtce in 1998. Oil, and perhaps electricity, seems to have benefited from this reduction rather than gas.

70. The declining share of coal, and increasing share of gas in the policy portfolio was again emphasised in late 1999 at an IEA-China Conference on China's Natural Gas Industry held in Beijing, 9^{th}-10^{th} November 1999, when Minister Zhang Guobao, Vice-Chairman of the State Development Planning Commission, set out a number of gas priorities for the Tenth five-year Plan (2001-2005):

- to actively create markets for gas;
- to boost exploration so that proven natural gas reserves increase;
- to improve gas transportation infrastructure;
- to formulate taxation and investment policies that are attractive to internal and foreign investors;
- to look at and learn from the ways that other countries develop and use natural gas;
- to formulate gas pricing policies that are attractive to investors and gas consumers; and
- to intensify development of the country's substantial coal-bed methane resources.

71. The Asia Pacific Energy Research Center (APERC, 2000) indicates that natural gas utilisation in China grew from 15.8 Gm^3 in 1991 to 17.92 Gm^3 in 1996 (14.66 in Industry, 1.97 in residential, 0.75 for generation, 0.55 for other uses). Supply was 20 Gm^3, with an average annual growth of 4.6 per cent. Natural gas has been used mainly in the industry sector (82 per cent), with the manufacturing sub-sector as the main user. EIA Energy statistics indicates in 1998 a production of natural gas of 1,008 TJ (27.3 Gm^3 on average), plus 0.155, 0.425 and 0.255 TJ of gas from gas works, coke ovens and blast furnaces. Final consumption was only 0.512 TJ or 14 Gm^3, of which 11 Gm^3 in the industry and 2.75 Gm^3 in the residential and commercial sector.

72. The power generation sector uses a small share of natural gas, because cheap coal is readily available. The residential sector also accounts for a small share because of the lack of available supply or transmission and distribution networks. The share of natural gas has remained relatively static at 2 per cent over the last decade – much lower than today's world average of 23.6 per cent. Lack of natural gas supply infrastructure and high capital investment costs for development are largely responsible for the slow growth of natural gas consumption in China.

73. China has huge potential natural gas resources, estimated at 38 trillion cubic metres (38,000 Gm^3), but only 2.9 are classified as proven reserves. More investment in exploration would increase the size of proven reserves of natural gas. China is targeting 70 Gm^3 of domestic production with 30 Gm^3 of imports. In order to do so, China will need huge investment in both upstream and downstream infrastructure.

74. Coal bed methane resources in China have been estimated at 35,000 Gm^3. The use of coal bed methane has been declared a strategic project of the coal industry, demonstration projects have been started and preferential development loans have been earmarked. A publicly owned company has been established which targets 20 Gm^3 (13 Mtoe) in 2010.

75. Most projections for future Chinese gas consumption are within the range indicated in Table 2 below.

Table 2

	2000 (Gm^3)	2010 (Gm^3)	2020 (Gm^3)
Domestic production	25	50-100	60-130
Import Pipeline	0	10-20	20-40
LNG	0	5-10	5-15
Total	25	62-130	85-185

76. WEO 2000 forecasts a growth of gas use in China from 21 Mtoe in 1997 to 110 Mtoe (circa 126 Gm^3) in 2020 – a little more than a five-fold increase in 23 years. These increases seem already impressive. While in contrast the United Kingdom has experienced an almost forty-fold increase over the 18 years between 1980 and 1998, it is, by comparison, a small country close to huge gas fields. Here we have a huge country close to "small" (proven) gas fields – a different picture.

77. As mentioned earlier, the share of oil in China's total primary energy supply is expected to rise at the expense of coal. This is not all "fuel switching", as the bulk of expected oil growing demand will be in the transport sector (although in this sector coal was still in 1997 contributing for 10 per cent and its share is expected to be down to 3 per cent in 2020). However, non-transport uses of oil would grow, according to the WEO 2000, from 2.4 million barrels per day to 6.1 million barrels per day. Some fuel switching from coal to oil will occur in the power sector, the bulk of this will happen at end-user levels in the industry, commercial and residential sectors. While the environmental benefits, both at local and global levels, are much less than those that would occur from switching from coal to gas by unit of energy delivered, on the whole they will be very significant.

78. The new policy focus on switching to gas has begun to be implemented: construction of the LNG import facility at Shenzhen (Pearl River Delta) has started. When completed, it will fuel two

gas-fired power plants and serve end-users in replacement of town (manufactured) gas in China, as well as in new plants in Hong-Kong. Its initial capacity of 3 Mt/y might be further raised to 5 Mt/y. Other similar projects include facilities in Fuzhou, Qingdao and Shanghai. Houston et al. (2000) estimate China's LNG imports in 2010 from 5 to 10 Mt/y.

79. Even more important for gas supply is the March, 2000 decision to construct a massive pipeline that will bring natural gas from Lunnan gas field in the Tarim basin to Shanghai, expected to be completed by 2003. At an anticipated cost of $14.5 billion, it will have an initial capacity of 12 Gm^3/y. About 40 per cent of this gas is expected to be utilised for high-efficiency power generation by 2015. While energy security and environmental improvements are important determinants in that decision, the political will to develop the western part of China appears to have been even more critical in this decision.

80. The emphasis on gas has also extended to the development of new gas turbine technology. The Shanghai Electric Corp and the Shanghai Power Equipment Research Institute have instituted a Gas Turbine Technology Development and Research Centre. The Shanghai Centre is planning to develop 1,000 MW gas turbines immediately, and China is expected to develop gas turbines up to 20,000 GW in the next few years (AEN, 2000).

81. Other projects include the proposed construction of national as well as international gas pipelines and gathering centres and storage capacities. Two potential regional sources of imported pipeline gas are available for China's coastal provinces: Russia (Sakhalin Islands, Sadkha Republic, Irkutsk and Krasnoyarsk), and Central Asia (Kazakhstan, Turkmenistan and Uzbekistan). However, such long-distance projects would only be profitable with very large volumes of gas – that are only likely when the sector has gained an additional 10 to 15 years of maturity (Girdis et al., 2000).

82. Perhaps the more striking change in current Chinese policy is that in order to ensure the building of the east-west pipeline, the Chinese government has proposed to further open its strategic energy sector to foreign investors. Foreign investors are to be allowed to become holding parties in the project without any investment limit. In addition, the range of project types for which foreign co-operation will be allowed has been broadened to include the construction of natural gas pipeline networks in cities (Gas Matters, October 2000).

83. The switch to gas is not only targeted at the power sector. With the national emphasis in part on improving urban air quality, priority has also been placed on replacing coal in household use and in small enterprises.

84. While switching to gas has been a focus of current policy, the future is not as clear. China's abundant coal resources suggest it may rely on coal over the longer term. The 2000 WEO projects that the growth of the gas market will basically depends upon the willingness of end-users to pay for cleaner fuels. However, any future energy development in China will be complicated. Coal resources themselves are "land-locked" in the continental, western parts of the country, and coal transport already accounts for more than one third of all goods transportation. Lack of sufficient rail facilities presents a bottleneck for increased coal consumption.

85. As an alternative to the development of new rail capacity, China has considered the expansion of its electrical transmission grid – and building power plants at the mine mouth (sometimes called "coal by wire"). While not necessarily reducing total pollution, this system could help relieve

emissions of criteria pollutants (SO_x, NO_x and particulates) and improve air quality in heavily populated consumption areas. However, other considerations also play into the desire to develop the gas infrastructure, including an increased use of oil and gas, in particular LNG, both imported through maritime roads from a large number of potential suppliers. These shifts would increase energy security in these regions.

86. On the other hand, creating a gas market from scratch is not easy. In order to make the large investments to bring the gas (either via pipelines or LNG terminals) less risky and more quickly profitable, it is critical that gas-fired power plants be brought on-line to use resources (see IEA/NMC 2000).

87. However, there is expected to be some competition for investment funds. With China's recent entry into the ranks of oil importers, it has a new set of policies to ensure energy security – including both a wide number of investments abroad as well as inward investments in onshore and offshore oil drilling, transport and refining (see IEA, 2000a). Some experts believe that investments in a large oil pipeline from the Tarim basin to coastal China would yield a higher rate of return than the similar gas pipeline that is now on its way (Fesharaki, 2000) – and funds may not be available for both. With the versatility of oil and petroleum products, and the fact that they do not require large up-front investments, it is possible that existing policies may not lead to as rapid a switch to gas as suggested, or even a more rapid growth in oil. A slower change in fuel switching would then have implications for local and global environment.

88. ***India***. India's policy as expressed in the document "*India Hydrocarbon Vision* – 2025" foresees a growth of the share of gas in future (commercial) energy supply from 7 per cent in 1997 to 15 per cent in 2006 and 20 per cent in 2025. Concomitantly, coal would decline from a 55 per cent share to 50 per cent and oil from 35 per cent to 25 per cent (the document provides proportional shares only – not absolute levels). Natural gas is the preferred fuel for the future in view of both its environmental and economic attractiveness.

89. While 1995 gas consumption in India was close to that of China at 15.7 Mtoe, Indian growth rates are projected to be slightly lower (annual growth rates are forecast to be in the 5-10 per cent range). The share of gas rose from 1 per cent in 1971 to 7 per cent in 1997, reflecting gas discoveries and expanded gas exploitation. These resources have been developed largely for use as petrochemical feedstock and in fertiliser production (IEA, 2000b). In India, even more than in China, domestic gas production is not expected to keep pace with growing demand, so that future consumption levels will depend significantly on the development of gas imports.

90. However, India's gas reserves are relatively small (650 Gm^3), even when its prospects for commercial exploitation of coal bed methane are included (Coal India Ltd and Oil and Natural Gas Corp are to establish a joint venture with such commercial exploration in mind). The main objectives of Indian policy are, therefore, to ensure adequate availability through a mix of gas imports through pipelines and LNG.

91. There are numerous plans to develop LNG import terminals, with more than 15 terminals reported to be under consideration. These include a five million tonne LNG receiving terminal now under construction by Enron; it will supply the 2,144 MW Dabhol power plant in Maharashtra State. LNG purchase contracts have been signed with Abu Dhabi and Oman LNG. Four other terminals are

at an advanced stage of technical design: Dahej (Petronet LNG), Pipavav (BG International), Trombay (Total/GAIL) and Ennore (Tidco).

92. Assuming that not more than two or possibly three LNG import terminals could be operating by 2005, the implied average annual growth rate for gas consumption based on LNG imports alone would be in the 4-7 per cent range over 1996 levels. LNG imports into India could reach 3-8 Mt/y in 2005 and 11-18 Mt/y in 2010, according to Houston et al (2000). The final level of imported LNG quantities will depend mainly on the possibility of finding end users for regasified LNG with sufficient financial strength to allow recourse to project financing for upstream and downstream facilities.

93. International gas imports via pipelines are also being discussed. One has been proposed that would link the Indian gas grid to the gas reserves of Bangladesh. While current proven reserves in Bangladesh are only 310 Gm^3, estimate suggest total supplies of three times that level – in the range of 1000 Gm^3. A proposal has also been made to link India and Iran with an undersea pipeline, but the economics of such a project do not seem favourable.

94. The extent of fuel switching to gas will depend on a number of factors, including the price of oil as well as the extent to which LNG prices could be disconnected from oil price volatility (Houston et al., 2000). Also, crucial in the medium term, are the numbers of vessels and of new liquefaction facilities to be built in exporting countries.

95. As in China, fuel switching in India is likely to involve oil as well as gas – with lesser, but still notable, environmental benefits. However, India is as poor in oil as it is in gas. Dependency on oil imports is now more than 57 per cent and is expected to increase up to 85 per cent in 2010, while consumption would grow from roughly 2 to 5 million barrels per day from 1997 to 2020. In China, the bulk of this growth is in the transport sector, but some fuel switching from coal to oil is anticipated to take place in other sectors – to an extent that largely depends on international oil prices.

96. ***Mexico.*** In recent years Mexico has implemented remarkable structural changes in its economy. However, until recently its energy sector was largely unreformed. This is now changing. In 1995, the Mexican Government introduced legislative changes permitting private sector involvement in natural gas storage, transportation and distribution. Subsequent directives set up a detailed regulatory framework. These developments offer considerable promise, not only for natural gas sector development, but also for growth in the closely linked electricity sector (IEA 1996).

97. The bulk of the expected increase in gas consumption is in the power sector, from 675 TJ (18.3 per cent of total) in 1998 to 3400 (58 per cent) in 2008. An increasingly competitive Mexican energy economy as well as a demand for air quality improvements has motivated this change. A 1994 regulation (NOM-085-ECOL-1994) promotes gas penetration in the power sector in areas suffering critical environmental degradation. Unlike China or India, the gas expansion in Mexico does not seem limited by the availability of local resources and transport facilities.

98. Overall, combined-cycle gas turbines will represent 84 per cent of the new generating capacities and replace 11.5 per cent of current fuel-fired power capacities by 2008. Additionally, existing capacities totalling 4,510 MW will be converted so as to burn gas instead of oil. Perhaps more surprisingly, one existing "dual" power plant is expected to turn to coal – leading to an increase in coal consumption in the power sector from 8.85 million tonnes in 1997 to 14.9 million in 2007

(Secretaría de Energía, 1998). Gas will also substitute for oil in the industry sector, increasing its share to 13 per cent in 2004 and 46 per cent in 2010. The residential sector is expected to see the same annual rate of increase of gas consumption as the power sector: 16.5 per cent. Transport too is engaged: up to 100 000 vehicles are expected to run on gas in Mexico in 2009.

99. The switch to gas is expected to have energy efficiency and CO_2 benefits. Compared to a baseline scenario in which natural gas maintains its current share, switching will reduce total energy consumption by 4.3 per cent and related carbon emissions by 10 per cent in 2010. While CO_2 emissions would still grow from 346 Mt in 1997 to 696 Mt in 2010, the growth is 77 million tonnes less than in the baseline. However, methane emissions from the energy sector would grow faster – at a rate of 2.8 per cent (compared to 0.8 per cent per year in the baseline scenario), reaching 130,000 t in 2010 (compared to 90,000 t in 1996; Betancourt Garcia, 2000).

100. Fuel switching may also reduce NO_x and VOC emissions, therefore reducing ground ozone levels. However, the complex relationship between the levels of different primary pollutants and that of ozone formation make such predictions difficult. At certain atmospheric concentrations of volatile organic compounds (VOC), reducing NO_x concentrations may increase, rather than decrease, ozone formation.

Discussion

101. The general consensus is that fuel switching can provide some of the most immediate and beneficial environmental results of any energy policy. However, assessment of the possible effects of further market reform on fuel switching is not straightforward. In a large number of countries, deregulation has favoured gas-fired combined-cycle power plants over competing technologies, due to high efficiency, low capital costs and rapid construction. However, in India and China, the large-scale infrastructure requirements of pipelines or LNG terminals may ultimately favour oil over coal and gas, rather than gas over other fossil fuels. This suggests that in China and India, switching to gas will require up-front investments in pipelines or LNG facilities that private investors might be reluctant to make without participation from the public sector. While opening this area to foreign investment has provided new funding sources, public intervention may still be needed.

102. The global benefits of fuel switching in these countries may also depend on action by OECD countries to mitigate climate change. For example, it has been suggested that effort to reduce emissions would lead to a decline in global energy demand and thus depress prices, and that these low prices would in turn foster an increase in the energy consumption in developing countries. However, while lower oil prices may foster the demand of transport fuels and thus, increase carbon emissions from this sector, they may also foster fuel switching from coal towards oil (and possibly gas) and thus decrease carbon emissions as well as other pollutants in the power, industry, commercial and household sectors. Assessment of climate benefits then depends on assumption on relative shares of coal and gas displaced by oil.

Biomass

103. Biomass fuels, including wood, constitute by far the largest renewable energy source in use in the world, and especially the developing world. In China, India and Mexico, biomass energies are reported to cover respectively 20-30 per cent, 40 per cent and 6-10 per cent of total primary energy

supply. However, data are scarce and uncertain, as most of these fuels do not pass through energy markets and usage levels seldom finds its way into commonly used energy statistics.

Current Policies

104. The primary use of biomass is in cooking and heating. Thus, policies that focus on improved efficiencies have dominated this energy source. Millions of improved stoves have been disseminated in many developing countries by governmental, intergovernmental or non-governmental organisations in the last decades, with variable successes. China and India are also actively promoting more modern uses of biomass.

105. **China**'s National Improved Stove Programme is said to have led to the adoption of efficient stoves by 142 million farm household – 70 per cent of all rural households – in 1991, leading to annual savings of 1,740 PJ of fuelwood and coal (Zheng Luo, 1998). More than five million small biogas plants are currently operating at farm level.

106. In addition, over seventy biomass gasification systems have been build and tested since 1990, each with a capacity of 1,000 MJ/h or 2,000 MJ/h (respectively 278 and 556 kW thermal). They produce 200 or 400 m^3 of gas per hour with a low heat value of 5.2 MJ/m^3. These systems connect to a network that distributes the gas to households for cooking. As the average family consumes about 6 m^3 of gas per day (in these cases from the gasification of about 3-kg of straw), each system covers the basic energy needs of 800 to 1600 families (Sun & Gu, 1998).

107. **India**'s National Programme on Improved Chulhas has so far led to the installation of more than 28 million chulhas (stoves). with efficiency of 25 to 35 per cent – a substantial improvement over previous traditional chulhas with 5-10 per cent efficiency. In addition, the government has helped install more than 2.7 million small biogas plants, and has set a target of the installation of 168,000 additional biogas systems per year.

108. With respect to modern uses of biomass, India has primarily focussed on biomass gasification systems for power production. A total capacity of 31 MW (electric) has so far been installed, mainly for stand-alone application, under a National Programme launched by the Ministry of Non-conventional Energy Sources (Gupta, 1999).

109. Other elements of the current programme include biomass combustion-only plants for power conversion and biomass-based co-generation. Conservative estimates indicate that about 16,000 MW of distributed power could be generated from biomass residues (estimated at about 150 million tonnes). Of this, bagasse-based co-generation is of particular significance with an estimated possible capacity of 3,500 MW from 430 sugar mills. Projects for 222 MW surplus power capacity have been commissioned and another 280 MW of capacity is under consideration.

110. A major UNDP/GEF project on biomass power generation in India has been formulated which aims to remove the main barriers in the development of biomass in the power sector. The project will fund bagasse or other biomass-based cogeneration projects, large biomass power projects and small-scale gasification engine-based power projects, at a cost of US$ 60 million.

111. In **Mexico**, fuel-wood and bagasse are the main biomass resources. Fuel-wood is essentially limited to use in the household sector in rural areas for cooking and heating; however, it provides 34.6

per cent of the energy needs in these areas. Bagasse is used as an energy complement in the sugar industry.

Environmental Effects

112. While other renewable energy sources can be considered as non-emitting with respect to greenhouse gases (with the exception of hydropower from dams, which is not considered is this paper), the case of biomass is more complex, for two reasons. First, biomass is a “renewable” energy that is not always “renewed”. If biomass fuels are not harvested in a sustainable manner, the CO_2 emissions that occur at the time of its combustion may not be compensated by equivalent uptake of carbon from the atmosphere. Moreover, non-sustainable biomass use may increase deforestation and soil erosion, or deprive the soil of recycled nutrients that would have been available from tree, crop or animal residues. However, the importance of these dimensions might have been exaggerated in the past, and recent analyses (IEA, 1997; RWEDP, 2000) underscore that “*the predicted disaster has not happened*” and the so-called “*fuelwood gap*” has not shown up. FAO experts have suggested that viewing fuelwood use as the main cause of deforestation is a misconception welcomed by illegal loggers as an alibi (Hulscher et al, 2000). Nonetheless, there have been links drawn between encroaching desertification and fuelwood gathering.

113. In spite of these potential concerns, the renewable character of biomass has been confirmed by the IPCC in its Revised 1996 Guidelines for National Greenhouse Gases Inventories, where it is recommended that national inventories not include CO_2 emissions from biomass fuel combustion – assuming that consumption is equal to re-growth. Of course, this methodology also assumes that any departure from this hypothesis would be accounted for in the land use change and forestry part of national inventories. Inasmuch as most of the biomass used in China, India and Mexico could be considered as harvested in a renewable manner, in the remainder of this section, we will consider biomass as “renewable” – although this is probably not always the case, especially in some Indian States.

114. The second complexity arises from the fact that biomass combustion is often incomplete and leads to the emission of a number of gases such as carbon monoxide (CO), methane (CH_4) and a wide number of non-methane organic compounds (NMOC) – as well as soot and particulate. They might be pollutants at local levels, both in-door and out-door, greenhouse gases with higher Global Warming Potential than CO_2, or both. The impacts of these are described below.

Health Effects

115. Low combustion efficiencies in most traditional uses of biomass fuels put a heavy burden on the health of inhabitants in the developing world. Women and children in rural areas and urban slums pay the heaviest price, with acute respiratory infections, chronic obtrusive lung diseases, eye problems and low birth weights; they also suffer the physical tolls from gathering heavy loads of biomass in distant areas.

116. China and India are not very different in this respect from other developing countries. In Africa, according to UNEP (1999), *"indoor air pollution caused by the widespread use of biomass as a cooking fuel is also a major contributor to the high incidence of respiratory diseases because of the exposure to smoke and other pollutants in a confined space."* It is estimated that half of the world's households cook daily with biomass fuels, and that most of this cooking is done indoors with unvented stoves.

117. In India and China, a number of studies have shown a strong and positive correlation between indoor air pollution and morbidity and mortality from acute respiratory infection for children and chronic obstructive lung disease in adults (Pandey, 2000). Acute respiratory infection is the leading cause of deaths in India (13 per cent of all deaths) and creates the largest single contributor to the health burden as measured by the DALY index[1] (Parikh, 2000). Pneumonia in young children causes more than 300,000 premature deaths each year out of a total of 500,000. China's situation seems roughly comparable. It should be noted that these statistics do not easily distinguish between in-door and out-door pollution effects or whether the fuel source is biomass or coal.

118. These reasons alone would justify an extreme caution in promoting policies that could encourage developing countries to "go down the fuel ladder", that is, to switch from cleaner fossil fuels to traditional biomass fuels. One such policy could be a pressure to reduce subsidies to LPG and kerosene, mainly driven by a willingness to reduce CO_2 emissions. As noted by the IEA (WEO 2000), the current shift in China from traditional biomass towards others fuels "*will increase China's greenhouse gas emissions but will reduce local pollution, especially particulate, with significant benefits for public health*".

Biomass and Greenhouse Gases

119. Given the usually low combustion efficiency in traditional uses of biomass, switching from biomass to fossil fuels would not necessarily increase greenhouse gases emissions. Studies in China and India have shown that approximately one-half of biomass stoves, as well as most coal stoves, had substantially greater emissions of products of incomplete combustion (PIC) than liquid and gaseous fuels – from 10 per cent to 25 per cent of carbon being emitted as PIC. Per kilogram of wood, about 100 to 180 g of carbon monoxide is emitted and up to 8 g of particulate matter. Measuring the "global warming commitments" of fuel-stove combinations (including consideration of the global warming potential of the PIC emitted), these studies found that the worst solid biomass fuel-stove combinations might exhibit GWC ten times higher than LPG or kerosene stoves (Smith, 2000).

[1] Disability-Adjusted Life Year is a measure combining years of lost life from deaths and years of lost healthy life from disease adjusted for their severity.

120. Interestingly, the same studies suggest that biogas stoves show GWC ten times lower than LPG or kerosene. Given the fact that burning biogas entails the same low level of polluting emissions as natural gas, that means that the most efficient policy to simultaneously reduce health and climate effects of biomass use in developing countries might be to turn from traditional use toward modern use – rather than promoting fossil fuels – and dividing emissions by one to two orders of magnitude.

121. While traditional biomass use has a greater climate impacts than liquid or gaseous fossil fuel uses, it appears to remain preferable to solid fossil fuel use. Comparison studies performed in China suggest that total greenhouse gas emissions from coal stoves are almost twice as high as those emitted by renewable fuelwood stoves (Zheng Luo, 2000).

Potential for Improvements

122. Technical potentials for improvements include a wide number of options that belong to two distinct categories: improved uses of traditional technologies, and the so-called “modern” uses of biomass.

123. Several evaluation studies conducted in India have suggested that the new chulhas, widely distributed through official programmes, do not perform as expected due to construction and installation defects. Not only do these stoves rarely last for three years, but the average efficiency of working improved chulhas was observed to be only 30 per cent higher than that of traditional ones, although they were built to be three times more efficient (Natarajan, 2000). Finally, these improved stoves have not substantially prevented health damages or reduced GHG emissions. In the face of such drawbacks, many users have returned to using traditional stoves – perhaps unsurprising given the low value assigned to the time for fuelwood collection, and the somewhat higher capital investment costs for new stoves.

124. This led a recent international expert workshop on this issue to conclude that “*priority should be attached to the development of household stoves with improved combustion characteristics (rather than enhanced thermal efficiency only) in order to reduce indoor pollution and health risks for users.*” (RWEDP, 2000). Efficient and clean wood-fuelled stoves already exist in industrialised countries. The “Thermo kitchen” provides cooking, space heating and utility hot water with an overall efficiency of 75 to 80 per cent. A two stage stove could be made of local materials or by modifying existing popular commercial models and might reach a 65 per cent overall efficiency and a 100 per cent combustion efficiency (Grover, 2000).

125. A special mention must be made of charcoal. Charcoal, with double the heat value of fuelwood per unit of weight, is widely used in developing countries to ease transport from forests to end use locations. However, while actual charcoal conversion rates vary widely, the average conversion ratio is five to one, meaning that the production of 1 kg of charcoal necessitates 5 kg of air-dried fuelwood. A part of this energy loss might be recovered during end use, given the higher average energy efficiency of charcoal stoves. A large part of charcoal use takes place in rural industry sectors that need its higher heat value (Bhattarai, 1998)

126. While losing a share of the heat energy of fuelwood, the use of charcoal does reduce particulate emissions – although not carbon monoxide emissions (probably a factor in the low birth weights and other adverse pregnancy outcomes in many charcoal using regions). Further, even if the wood is harvested renewably, the GWC of the charcoal fuel cycle is still two to four times greater

than produced by burning an equivalent energy content of liquid or gaseous fossil fuel. This calculation rest upon an efficient conversion of wood carbon into charcoal. Therefore, charcoal fuel cycles might be considered "among the most greenhouse-gas-intensive in the world" (Smith, 2000). While some improvements might be made, from slightly enhancing the efficiency of the production process to reducing the associated emissions (Why Kong, 2000), they do not appear very promising and substitution of charcoal by other, modern uses of biomass or even by fossil fuels would reduce climate impacts.

127. Hulscher et al (2000) evaluated the costs of using improved efficiency fuelwood stoves under a variety of conditions. In a case of fuelwood scarcity (considered in the case of India), improved stoves would cost 1.2 US$/t in CO_2 reduction costs. If the focus were on maintaining sustainable fuelwood use (again in India), CO_2 reduction costs would be 1.7 US$/t (this is CO_2 equivalent, as all benefits accrue from reduction in other GHG). In China, the case is different: substitution of coal by sustainable fuelwood would have a benefit for CO_2 reduction of 4.8 US$/t because wood is cheaper than coal. These calculations take into account the costs of improved stoves, but not that of programmes that would disseminate them.

128. A much broader and more environmentally friendly series of options emerge from the consideration of "modern uses of biomass". These modern uses include biomass-fired co-generation, biogas production and gasification, and can be used to provide heat and power at almost all scales, from villages to power grids. They make use of a large number of biomass fuels from animal dung, to crop residues and fuelwood. Moreover, further improvements in the efficiency in the use of biomass fuels at household level could leave available large new resources for more modern uses.

129. There are considerable unused biomass sources in both China and India. The largest available resource is composed of all kinds of agricultural residues, especially crop straws and stalks (of which there are approximately 600 million tonnes in China; Sun & Gu, 1998) and 320 million tonnes in India. Currently most of them are burnt directly in the field at each harvesting season.

130. In Mexico, studies have show that bagasse based co-generation might provide 100 per cent of the thermal and power needs of the sugar industry, leaving an additional capacity of 20 to 25 MW for sale on the grid. Other biomass projects have been proposed that would use biogas from sanitation in Mexico City or water treatment in Monterrey and add an aggregate capacity on the grid estimated at 15 MW.

131. The large availability of resources and the significant advantages of gasification over more traditional uses of biomass suggest excellent prospects for this technology. However, there are a number of barriers. Among these, perhaps the most critical is the variation in the quality of resources – in terms of nature, quantity, size and moisture content. Such differences require highly skilled operators as well as highly skilled commercial and marketing managers to ensure full, year-round peak plant utilisation. Other barriers include limited access to capital, potentially transaction costs, low customer awareness and direct or indirect subsidies that usually benefit grid power and diesel generators at the expense of biomass alternatives.

132. Biogas is obtained by anaerobic microbiological decomposition of wet organic feedstock such as animal dung. Mostly used at the household level, biogas provides multiple benefits for the environment, health, society, gender equality and economy. A 2.5 m^3 /day biogas plant is reported to save 3,000 kg/household/year of cooking firewood; save 40 litres/household/year of kerosene; reduce

CO_2 equivalent emissions of at least 4.6 tonnes/household/year; reduce the workload for women of 3 hours per day; improve health through air quality improvement and improved sanitation; and improve soil fertility and rural employment (Castro, 2000).

Discussion

133. Biomass options provide significant potential in both energy efficiency and environmental benefits. New combustion technologies as well as overall efficiency improvements may make biomass available for power production and co-generation. However, significant barriers remain. Not least of these is the capital cost associated with some of the se technology improvements. This is particularly critical as potential users of the poorest forms of biomass are likely to be amongst the poorest of rural inhabitants. This suggests that perhaps the most significant question for the policy community will continue to be one of promoting access to capital.

Renewable Energies

134. Although they all have some environmental impacts (see IEA, 1998), renewable energies do not emit greenhouse gases or local pollutants. Wind power, solar power, small-scale hydro and solar heating are the main renewable energy technologies that are anticipated to expand – both globally as well as in China, India and Mexico.[2]

Current Policies

135. **China**'s State Economic and Trade Commission issued a "*2000-2015 New Energy and Renewable Energy Industry Development Plan*". It predicts that by 2015 new and renewable energy sources will provide two per cent of the country's energy needs -- thereby replacing 43 million tons of coal annually. This fairly authoritative government estimate for future renewable energy use is lower than that in some other forecasts, primarily as it excludes the 2-3 per cent of energy supplied by hydroelectric power.

136. In 1982, **India** established a Department of Non-Conventional Energy Sources; in 1992, it became a Ministry. This ministry is currently preparing two major documents, *Renewable Energy Vision – 2010* and *Renewable Energy Vision – 2020*. In a more public announcement of its intentions, India announced in a *Joint Statement on co-operation in energy and environment between the United States and India* (22nd March, 2000) that it intends to achieve by 2012, a 10 per cent share for renewable energy in the capacity-additions of electricity nation-wide.

137. In **Mexico,** the Comisión Nacional para el Ahorro de Energía (CONAE), the government agency responsible for energy efficiency, established a forum in 1997 for promoting renewable

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[2] This paper does not consider large-scale hydro. Hydro has been omitted primarily because, according to the recent findings of the World Commission on Dams (2000), its potential effects on greenhouse gas emissions are still unclear. Dams may produce net greenhouse gas emissions, at levels that depend on time, scale and place. These emissions may offset the advantages that hydroelectricity could offer by comparison with thermal power plants.

energies, the Consejo Consultativo para el Fomento de las Energías Renovables (COFER). It has started working on solar water-heating and photovoltaics.

138. Current policies for specific energy sources (wind, solar energy and small-scale hydro) are detailed below under each topic and by countries.

Wind Power

139. **China.** Wind power has been used most successfully in the Inner Mongolia Autonomous Region where one third of the herdsmen use wind. About 140,000 small wind electric generators – produced locally by about 40 manufacturers – charge batteries to power televisions, radios and lights (Lew, 2000). They total about 17 MW of installed capacity. China has been much less successful using wind capacity to feed on-grid power. With a total installed wind capacity of 246 MW at the end of 1999, China was not on track to reach its target of 1,000 MW at the end of 2000.

140. Notwithstanding current use, Chinese wind potential is enormous – although the area with the highest potential is far from demand centres – Beijing is about 500 km away. Total available wind energy has been estimated at 3.2 TW (Lew, 2000), while exploitable electric potential could be about 500 GW, roughly the size of the total new capacity expected on Chinese grids by 2020. The inner Mongolia region alone could produce about 1,250 TWh/year – roughly the current electricity consumption in China. The World Bank (1999) provides much smaller estimates, with a total potential of 160 GW.

141. While imported wind turbines are not cost-competitive with coal power in China, it is possible that local, mass production of wind turbines in China could become competitive with coal. This will be all the more true if the environmental advantages of wind power over coal power generation were reflected in relative prices – either through taxes on coal or subsidies for wind. Short-term economics look more promising for coastal wind resources, closer to the demand centres, according to Lew (2000). However, the World Bank notes that new wind farm at Huitengxile in the Inner Mongolia Region would provide wind at prices as low as 42.2 fen/kWh for the period 1999-2006 and 49.2 fen/kWh for 2007-2020; these prices are very close to the projected average tariffs of new conventional power plants on the Northern China grid (45.8 fen/kWh for Tuoketuo).

142. According to Lew (2000), a number of factors have hindered the development of large-scale wind power in China. Of these, the lack of domestic technology and the absence of a clear, fixed policy for wind power sales are perhaps the most important. More surprisingly, the availability of concessional foreign financing is said to have limited the development of wind power in China by eroding the Chinese willingness to pay full cost. Foreign investment has also been limited by an unofficial Chinese 15 per cent restriction on returns on investments for foreign companies. This limit has reduced incentives for investors to increase their return by improving siting or by turbine efficiencies.

143. The World Bank and the Global Environment Facility have a common project to foster the development of renewable energy sources in China with a loan of US$ 100 million and a GEF grant of US$ 35 million. Leveraging a total investment of US$ 444 million, this project would have a wind farm component – building 190 MW of new capacities; a PV component – with an estimated 300-400,000 systems with a 10 MW aggregate capacity; and a technology improvement component. Interestingly, the loan would go entirely to the wind farms, while most of the GEF grant would go

into the PV. Beyond the immediate benefits of these projects (in form of clean power), the funding is particularly aimed aims at increasing at making renewables more commercial. To this end, specific components address corporate governance of wind farm and PV companies, the promotion of internationally accepted power purchase agreements, the diversification of sources of financing, and the encouragement of private investments in wind farm projects. The World Bank expects clearly additional results from the project: By 2004, 440 MW of new construction are expected with the funds – compared to only 150 MW without these new resources.

144. **India**. With an installed wind capacity of over 1,000 MW (mainly in Tamil Nadu State), India ranks fifth in the world after Germany, United States, Denmark and Spain. Potential, initially estimated at 20,000 MW, has been recently scaled up to 45,000 MW at 50-meter hub height. However, the performance of existing projects have been highly variable – ranging from relatively good to poor due to miscalculations of the resource, and poor project design. As a result (as well as because of political uncertainties and an economic slowdown), there have been few new installations since 1997.

145. India has recently moved away from large investment incentives and towards production incentives (Lew, 2000; Jagadeesh, 2000). The government has decided to involve the private sector in establishing wind energy estates and has identified about 192 potential sites in eleven states. Plans are being developed for 80 sites. An autonomous *Centre for Wind Energy Technology* has been established, and the government has sought to establish a market by calling for state governments to pay at least Rs2.25 ($0.05) per kWh for wind power.

146. **Mexico.** In Mexico, the wind energy potential is estimated at 3,000-5,000 MW, while current capacities total only 1,5 MW. Only a few projects, with an aggregate capacity 30 MW, are currently under consideration. There is no current plan to tap a larger share of the potential.

Solar Energy

147. Two different solar power options are most common: photovoltaics (PV) and solar thermal power (STP). Niche markets for PV are primarily in stand-alone applications and in small grids at remote locations. Solar thermal power is much closer to competitiveness for large on-grid applications – provided direct insolation is sufficient. Such conditions, frequently associated with semi-arid land areas, can be found in diverse places around the world, including parts of Mexico, India and China. Solar thermal power plants may also be used in combination with other energy sources, improving both continuity and reliability.

148. In China, current PV capacity is 5 MW (entirely off-grid), and the government plans to install an additional 30 MW by 2000. India is the third largest market in the world for photovoltaics, and new capacity is constantly being installed. In the past year, fifteen projects have been commissioned and ten projects of 500 kW are being installed. In Mexico, 50,000 PV system for 1,300 communities have an aggregate capacity of 11 MW and there is an additional yearly production of 19.3 GWh (CICC, 2000).

149. As costs of PV continue their downward trend, niche markets have expanded. However, few expect that full competitiveness for input to large-scale grid power will be achieved for at least several decades. Therefore, it is not anticipated that PV projects, although they bring important local benefits, will yield significant reductions in the emissions of local or global pollutants.

150. To date, no large-scale solar power plants have been installed in developing countries. The most significant installations are in California where 354 MW of solar parabolic troughs, backed up by gas-fired boilers, have been generating electricity and selling it to the utility for at least a decade. However, GEF-assisted demonstration solar thermal power projects are currently being developed in Egypt, India, Mexico, and Morocco. All are to be based on the same parabolic trough technology, but with diverse designs for the integration of the solar field in hybrid, fossil-fuel solar power plants.

151. A number of programmes have been designed to help lower costs and increase the penetration rates of solar and other renewables. The Global Environment Facility (GEF) Operational programme N°7 deals with the reduction of the long-term costs of low greenhouse gas emitting technologies. It aims to accelerate market penetration of several large-scale backstop technologies, such as solar thermal power and wind power, that presently are constrained by high capital costs and high commercial risks. More specifically, it aims at helping solar thermal power to become competitive with fossil fuels in 2005, with a price of kWh below US$ 0.09. The SolarPACES Implementing Agreement at the IEA – in which both Mexico and India participate – also aims at developing economically competitive, concentrating solar technologies for electricity generation, in particular through co-operative research and development efforts. It is hoped that cost reductions can be obtained by learning from the lessons of current facilities (in California as well as in yet-to-be-built plants), economies of scale, improved designs and performances.

152. New construction is underway in both India and Mexico. In India, a 140 MW integrated solar combined cycle project with a solar field of 35 MW will be built in Rajasthan. It will be a baseload plant fired by naphtha and gas. With the support of the GEF and KfW of Germany, the project is set for completion by the Rajasthan State Power Corporation Ltd, and should be operational within the next three years. In Mexico, a solar plant partially funded by the GEF will be built, and will be owned and operated by a private sector entity in the valley of Mexicali. The plant will be a hybrid of 300 MW combining a conventional fossil fuel (gas) portion of 271 MW and an input from solar sources of 29 MW with the latter having a cost ranging from $1,650 kW to $2,100 kW.

153. The optimal solar resource needed for concentrating technologies are available in most parts of Mexico as well as the north-west of India and some portions of the south-western part of China. While Chinese locations are distant from primary demand centres, there is no such difficulty in Mexico and India. Land constraints, sometimes considered limiting factors, are unlikely to pose problems: current, proven technology for solar thermal power requires about 1 square kilometre for 35 to 50 MW of capacity. A 1,000 MW power plant would require 20 km^2 and produce about 2 TWh annually – 1 per cent of the expected Mexican consumption in 2005.

154. The possible expansion of solar thermal power in India and Mexico rests upon the success of efforts such as those of the GEF and SolarPACES – which aim to bring this proven technology to market. However, the pace of installations may be slower than these programmes envision, as local institutional difficulties have often compounded technical difficulties in the installation of large new power supply systems. Slowing the installation rate would have a ripple effect as well: a smaller number of projects would limit the rate at which cost reductions would accrue due to economies of scales and accelerated learning-by-doing. The lack of a strong set of developed country advocates could also slow progress – currently only Greece is installing new capacity. Further involvement of the industrialised countries that benefit from high insolation levels (e.g., Australia, United States) could raise awareness of and confidence in solar technology – both for government and private sector sponsors.

155. Tens of thousands of solar home systems have been deployed in China, and solar water heaters warm over 3 millions m^2 . There is considerable new construction of solar heated hot houses, with a surface area of over 350,000 hectares. However, while solar power utilisation this year is about 1,5 million tons of coal-equivalent energy – it is still only 0.1 per cent of total primary energy supply.

156. In India only 500,000 m^2 of solar water heating has been deployed thus far. However, the number of manufacturers has quadrupled since 1996. In addition, the Bureau of Indian Standards has established standards for solar heater manufacturers, and certification is now secured with the help of six Regional Test Centres. Furthermore, purchasers of certified solar collectors can be assisted with soft loans and tax incentives. India has also established a programme for promoting solar architecture (passive design); the initiative provides training, and also may help financing both the design and building of demonstration projects.

Small-scale Hydro

157. China is rich in small-scale hydroelectric resources; these were recently assessed at 76 GW. With a net increase of 3 GW since 1995, total installed capacity was planned to be almost 20 GW at the end of 2000, and annual production is anticipated to exceed 74 TWh. Total hydropower, including small-scale and large hydro, produced 208 TWh in 1998, or 17 per cent to total power production. The State Planning Commission foresees a net increase in installed capacity of 8 GW by 2010. In addition, 60,000 micro-hydro units have been installed in off-grid regions of the country.

158. India is far behind China, both in estimated potential and current production. Estimated small-scale hydro potential in India is 10 GW. Having increased threefold in the last ten years, current capacity is about 217 MW in 271 small plants, while 130 additional projects are under construction with an aggregate capacity of 130 MW.

159. In Mexico, about one-third of total installed power capacity – 10,000 MW – is hydroelectricity. However, substantial under-utilisation rates mean that hydro only produces 7 per cent of the country's total electricity. Mexico already has tapped nearly half of its potential: the remaining resource has been estimated at 11,000 to 17,000 MW, within which small-scale hydro is estimated at 3,250 MW for an annual production of 3,570 GWh.

Discussion

160. A number of factors are critical for the successful development of renewable energy sources. These include not only the appropriate natural circumstances (e.g., constant wind, or high levels of insolation) but also institutional interests, capital availability and technical capacity. Of the three countries studied here, natural resources do not seem to be a constraining factor overall – although certain regions in each country are not suited to all forms of renewables. However, each of these countries does appear to be making significant efforts on the institutional side, with the establishment of specialised bodies or agencies at a high government level to oversee the development of new capacity.

161. Part of the emphasis of these institutions has been the development of a framework of fiscal and other economic incentives and tools – including micro-credit facilities – to promote new construction. It is clear that apart from small niche markets, renewables will need significant amounts

of new funding to expand. While this support needs continuity and predictability, it also needs, to evolve over time in order to foster continuous improvements in the development and management of renewables, as suggests the case of Indian wind power development.

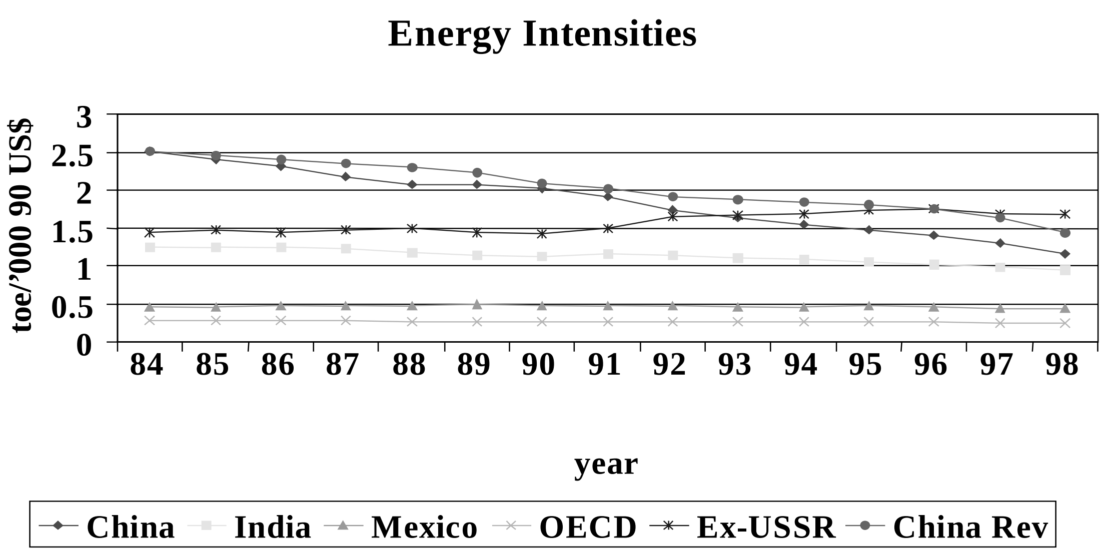
162. Industrialised countries have several roles to play in the renewables effort – and not only in the provision of grants or loans to promote new construction or demonstration projects. It is perhaps equally important that new technologies be developed and construction be undertaken in the developed countries – both to push the limits of the technical potential (thus lowering prices) and building confidence in the markets, critical for securing commercial loans for further construction.

Energy Efficiency

163. Energy intensities are profoundly different in China, India and Mexico. While commercial energy intensity has been slightly increasing in India, it has decreased sharply in China. However, the inclusion of non-commercial energies – always difficult due to the poor quality of data – changes this picture significantly. Present differences have historic antecedents: in 1978, energy intensities, expressed in tonnes oil equivalent per 1000 US$ (1990) were 3.67 in China, 1.26 in India and 0.39 in Mexico. While there has been some convergence, wide differences still remain: in 1995, purchasing power parity figures, the intensities are now 0.83 in China, 0.42 in India and 0.19 Mexico. Energy intensity in India now appears slightly declining (see Figure 1).

164. Assessing energy intensities is not straightforward. A first difficulty arises in the measurement of GDP. For example, OECD estimates for GDP and GDP growth in China differ significantly from official figures. However, this difference does not explain the rapid increase in Chinese energy intensity: Using revised figures (as in Figure 1) reduces the trend – but still leaves Chinese energy intensity decreasing at a faster rate than in any other country in the world – close to 4 per cent per year.

Figure 1



Note: This figure includes biomass fuel for China and India, not for Mexico

165. Other difficulties arise from the energy statistics themselves. For example, the statistics often do not record coal quality – yet better quality coal may lead to an enhanced heat value combustion, which in turn allows for a reduction in coal consumption while maintaining the same energy output. However, official statistics, which use an average figure for coal heat value, will show enhanced energy efficiency and reduced CO_2 emissions – while neither necessarily happen.

166. ***China.*** As noted above, China's primary energy intensity decreased at a rate of almost 4 per cent per year from 1984 to 1998 – a very rapid pace which is almost unprecedented in developing countries. According to Sinton et al. (1998), if energy intensity had remained at the 1987 levels, China would have consumed 2.2 times the actual level in 1996. Perhaps even more surprising are the most recent numbers: since 1997, total energy consumption in China seems to have declined in absolute figures, in spite of a continuing rise in GDP -- although statistical inaccuracies might be invoked to explain this surprising trend (see IEA 2000c).

167. China's very high historic energy intensity levels provide one explanation. The combined inefficiencies of a centrally-planned economy, the strong emphasis on energy-intensive heavy industries and the building of a great number of small factories throughout the country at the time of the "Great Leap Forward" all led to high energy consumption. Undergoing economic reforms could have hardly left this picture unchanged. This was perhaps most strongly pushed by price reform – which have led energy prices over the past decade to come closer to global market prices, although the process has been slow and tortuous.

168. Changes in structure of the economy are also commonly identified as a major factor in China's declining energy intensity. However, economic output of heavy industries like steel, cement, and chemicals have grown at rates similar to the high value-added light industrial sectors (see Sinton and Fridley, 2000). Furthermore, while services have expanded, this has occurred mainly at the expense of growth in the agricultural sector. Thus, the major changes in energy intensity have to be sought within the heavy industry sectors. Here, changes in the product mix, in physical energy intensity, and turnover of equipment and enterprises have all occurred. Growth has come mainly from middle- and large-size plants at the expense of small inefficient (and polluting) producers. While this might be a result of a policy called "15 small" that intends to close the smallest, less efficient plants, one factor fostering these changes might have been the strong environmental policy "two targets at one stroke" currently underway (see above, paragraphs 30 and 32).

169. Since the early 1980s, China has adopted a series of policies and programmes to promote greater efficiency in energy end uses. Financial supports for efficiency investments were made available, and efficiency standards and regulations were designed and adopted. Simultaneously, a nation-wide network of technical service centres was established. One major challenge facing China today is to maintain these policies and programmes in a rapidly changing context – that of, a market economy.

170. Another challenge is to continue the removal of energy subsidies. According to a recent IEA study (1999a), estimated subsidy rates are 73 per cent for coking coal, 38.2 per cent for electricity, 18.7 for natural gas and 8.3 per cent for steam coal. There has been some progress. For both environmental reasons and market liberalisation objectives, coal mine subsidies have been largely phased out between 1992 and 1996. Market prices of coal products are now largely determined by supply and demand, with the exception of coal earmarked for power generation (OECD, 1999). However, large subsidies remain in the power sector and coal industry, through company loss

subsidies, interest discounts on loans and tax refunds. In the oil sector, state-controlled prices have substantially risen between 1991 and 1995, while subsidies have been focused on oil and gas field exploration and development. However, domestic oil prices remain lower than on international market, by 13 per cent to 24 per cent. Removing these subsidies would yield energy savings of 40 per cent, 21.4 per cent, 12.8 per cent and 14.8 per cent respectively, while amounting at a total of 9.4 per cent of the total primary energy supply. CO_2 emissions would be reduced by 13 per cent.

The Potential of Efficiency Improvements: A Thought Experiment

171. Energy intensity can play a major role in total energy demand. A simple example illustrates this point. In China, the WEO 2000 foresees an energy intensity decline of 1.8 per cent on average over the Outlook period, leading to a doubling of energy consumption by 2020, However, if the energy intensity were to decline at a higher rate – say 3 per cent per year on average – total final demand would only grow about 1.7 times. It should be noted that at 3 per cent per year, intensity improvements would still be slower than those observed of the past several decades. Conversely, suppose energy intensity were to improve only at a rate similar to more standard "autonomous energy efficiency improvements" – say, 1 per cent per year. In this case, final energy consumption would multiply by 2.58 between 1998 and 2020. The difference between the two cases is stark: it is almost equal to current total consumption.

172. The potential greenhouse gas implications of these scenarios could vary even more widely. If the fuel mix remains unchanged, the direct effects on emissions would be proportionate to the final consumption. Using the base case identified in the WEO 2000, global and local emissions would be 20 per cent less or 29 per cent more. However, the fuel mix might also change, with new investments disproportionately in renewables or "clean" options. In such a case, both local pollution and global GHG benefits could be substantially larger.

173. ***India***. India's overall energy intensity appears to have levelled off in the 1990s, after rising rapidly (and faster than in most other developed or developing countries) over the preceding two decades (IEA, 2000b). This new trend may reflect an overall improvement in the efficiency of energy use, especially in the industry sector, related to recent changes in the industrial fuel mix (the share of coal in industry also dropped from 60 per cent to 50 per cent in the 1990s). Price effects may have a role as well.

174. According to the *Joint Statement on co-operation in energy and environment between the United States and India* (22^{nd} March, 2000) India intends to achieve approximately a 15 per cent improvement in energy efficiency by 2007-08. The target is to be met in the electric power sector by focussing on renovation and modernisation, including re-powering of old power plants to improve plant load factor, reductions in transmission and distribution losses and the introduction of legislation on energy conservation for promoting end-use energy efficiency. A new "Bureau of Energy Efficiency" will act as the focal point for affecting end-use energy efficiency and formulating goals and objectives in this area.

175. However, additional policies are certainly available. For example, subsidy removal or reform could have a profound effect on efficiency, as well as on government revenues. Estimated subsidy rates in India (IEA, 1999a) are 42.3 per cent for coking coal, 24.2 per cent for electricity, 22.5 per cent for natural gas and 13.1 per cent for steam coal. For kerosene and LPG, subsidy rates are estimated at 52.6 per cent and 31.6 per cent respectively. Removing these subsidies would yield energy savings

ranging from over 15 per cent to nearly 35 per cent, reducing total energy demand by over 7.2 per cent. CO_2 emissions would be reduced by 14.1 per cent. Of course, subsidies currently provide low cost electricity to a poor urban and rural population which would need alternative support mechanisms if they are to continue to receive electric services.

176. ***Mexico.*** The Mexican Energy Department forecasts an annual average increase in GDP of 5.2 per cent with an increase in energy consumption of 5.0 per cent and an increase in energy-related CO_2 emissions of 4.6 per cent for the period 1996 to 2008. These figures indicate a slight decrease in energy intensity (see Figure 1).

177. Since 1993, the Mexican Energy Department, through its National Body for Energy Savings (Comisión Nacional para el Ahorro de Energía, CONAE) has pursued an aggressive policy of mandatory standards promoting energy efficiency in a wide range applications in all sectors (building, housing, appliances, industry). The objectives in setting these standards has been to protect the environment, to reduce consumer expenses, to protect the country's energy resources, to protect the consumers and to promote more efficient technologies. Eighteen such standards have been published, related to: refrigerators, air-conditioning systems, heaters, washing machines, electric motors, pumps, boilers, water-heater, thermal insulation and lightning systems. They apply to more than 6 million producers, are implemented through 49 accredited laboratories and have been estimated to have increased energy efficiency by up to 40 per cent (Pensado, 2000). In 2000 alone, published standards are said to save 6 TWh and avoided the need for an additional installed capacity of 700 MW (Pensado, 2000).

178. Mexico has also experimented with individual project based efficiency programmes – in some cases jointly with other countries or with the Global Environment facility. One such example is the Illumex Project, which was created under the rubric of the UN Climate Convention as an "Activity Implemented Jointly". Focused on the residential sector, the project replaces light bulbs with more efficient ones; in so doing, it is expected to save 1.57 TWh of electricity in 2004 and 1.85 TWh in 2010.

179. As in both India and China, energy is often subsidised. According to the OCED (1996), electricity for households, gas and electricity for agriculture, are subsidised. Fuel prices for transport and industry needs are generally lower than that in the US, and much lower to OECD average. Thus, potential exists through subsidy reform, for additional energy and environmental savings.

Transport

180. Globally, the transport sector is the fastest growing of all energy consuming sectors. While policies have been introduced to seek to provide mobility services with lower impacts, the results have been disappointing – both in developed and developing countries. It is no surprise that transport is challenging the power and industry sectors for the number one ranking source of pollutants in Delhi – and it has long been known that transport-related emissions in Mexico City have annually been the cause of hundreds of fatalities.

181. The difficulty Mexico City has had in controlling emissions – in spite of both a concerted government effort and overall popular support for controls – suggests the difficulty most developing country cities are likely to have in reining in this rapidly growing source of pollution. However, IEA analysis suggests that transport policies focussing on technology improvements in fuels and vehicles

may still have local and global benefits. A life-cycle assessment, however, could be required to accurately assess these. It may be, for example, that removing the sulphur for gasoline or diesel fuel, while decreasing local emissions of SO_2 and other pollutants (by increasing the efficiency of catalytic conversion) would entail an increase in energy consumption and CO_2 emissions at the refinery level. An assessment of all climate impacts would be even more complex, as local pollutants increase the formation of tropospheric ozone – a greenhouse gas.

182. ***China.*** The Chinese transport sector is still a minor source of pollution, in some large cities like Beijing or Guangdong and is now nearly tied with the industry sector as the main source of local pollution. Moreover, in the 1990s oil demand grew on average by 8.4 per cent per year while passenger kilometres doubled.

183. Some policies to reduce the impact of transport on energy consumption and the environment have been enacted. Starting 1st January, 2000, all refineries in China were required to produce unleaded gasoline only – and by 1st July, 2000, no sales of leaded gasoline will be allowed nation-wide. Also starting in 2000, clean unleaded gasoline will be sold in Beijing, which features more strict standards for sulphur, aromatics, olefin, benzene and lead content. (Facts, 2000)

184. The Beijing Municipality has been in the forefront of Chinese transport policy. It recently promulgated the "Light Motor Vehicle Emission Pollution Standard" based on the Euro 1 European emissions standard. Since 1st January, 1999, the Municipality has issued 48,000 green stickers to new motor vehicles that meet this standard. Moreover, 62,000 vehicles, which exceeded the number of permitted years in use, were reported scrapped[3]. At the same time, inspections for existing vehicles began. During 1999, the exhaust emissions of 340,000 vehicles were inspected. Of these, 62 per cent passed – but 110,000 cars were rejected and required to undergo repairs or be removed from the streets. An additional 110,000 vehicles registered after 1995 have been adjusted to meet the new standards and so received the green sticker. Sixteen refuelling stations for natural gas powered vehicles were built, and 16,600 buses and taxis were converted to gasoline/natural gas dual fuel vehicles. Three hundred natural gas busses run up and down Chang An Street in Central Beijing.

185. ***India.*** Between 1970 and 1990, the number of vehicles has grown 11.5 times, from about 1.9 million to more than 21 million. At the same time, the number of vehicles per 1000 population has increased from 3.4 to 25.31, and is expected to exceed 40 by the year 2000. The bulk of this vehicular population is found in urban centres, with about one-third concentrated in the 23 metropolitan areas. Of the total 25 million vehicles registered in 1993, 82 per cent are for personal transport. During the period 1971-1991, the share of 2-wheelers had grown from 30 per cent to 66 per cent of all vehicles, while that of automobiles had fallen from 36.5 per cent to 14 per cent. In 1997 there were 6.7 million cars and 25.7 million two-wheelers in Indian streets. Although 2-wheelers are generally more fuel efficient than passenger cars, they have often not been subject to pollution control measures – and contribute greatly to hydrocarbon emissions.

186. The future of the Indian transport sector seems equally bleak. About two-thirds of the incremental oil demand in India over the WEO Outlook period (IEA, 2000b) will come from transport, with the sector expected to see an accelerated growth of about 5.3 per cent per year, faster than GDP growth and substantially faster than the rise in final energy consumption. This will come

[3] By the US Embassy in Beijing, www.usembassy-china.org.cn

from a continued modal shift towards road for both passengers and freight. However, other modes will also see an increase, albeit not as rapid as road travel. These are not expected to be as rapid as those over the past three decades, when rail passenger kilometres increased from 127 billion to 287 billion, and freight – as measured in tonne-kilometres – increased from 127 billion to 287 billion tonnes over the same period. However, in the rail sector, efficiency improvements have made an enormous difference: in spite of the enormous increases, energy consumption plunged from 8.7 Mtoe to 2.5 Mtoe – an improvement resulting from the shift away from coal to diesel and electricity.

187. A variety of policies have been introduced in India to combat the environmental effects of the rapid demand growth in the transport sector. Emission standards for new vehicles were introduced in 1991 and revised in 1996 and 2000. Since April 2000, these standards have been set at a level equal to European Standards Euro I in most of the country, while in the National Capital Region of Delhi, the Supreme Court of India has ordered that Euro II be the standard. New quality standards for fuels have been established as well, although to date, these standards have only been partially implemented.

188. Interestingly, these standards have led to a greater penetration of four-stroke engines with considerable reduction in hydrocarbon emissions. Four-stroke engines are also on average more fuel efficient, with a fuel economy of 65 km/l as opposed to 45 km/l for two-stroke engines. Very recently, a new model based on direct injection has been put on the European market (Tuquoi, 2000). It consumes half as much fuel as earlier two-stroke models, and emits only one fifth of the pollutants – while its cost is comparable to that of less efficient models. As only 12-20 per cent of two- and three-wheelers is currently four-stroke engines, there remains a considerable potential for further improvement either from this or another technology.

189. Within India, Delhi and the National Capital Region (NCR) need special attention, both for the number of vehicles (more than the three other megacities of Mumbai, Calcutta and Chennai combined), and for the policy interventions being proposed. While vehicle ownership is high in this region, diesel buses account for more than 50 per cent of kilometres travelled. The construction of a Mass Rapid Transit System is currently underway, comprising rail corridors, metro corridors and dedicated bus ways. It is expected to increase the share of mass transport to 60 per cent by 2005 and 66 per cent by 2010 – although it will not reduce total annual travel demand, which is still anticipated to grow from 88 billion passenger-kilometres to 143 billion in 2010. Energy demand is expected to grow concomitantly, from 1.08 Mtoe in 2000 to 1.6 Mtoe in 2010, with a corresponding increase in CO_2 emissions. While lead emissions would be reduced and hydrocarbon and CO emissions essentially stabilised, particulate, SO_2 and NO_x emissions would increase by 74 per cent, 30 per cent and 63 per cent respectively, according to Bose (1999).

190. However, researchers at the Tata Energy Research Institute have conceived alternative scenarios, focusing on modal shifting, and cleaner and more efficient technologies (Bose, 1999). While the scenario focusing on technology gives better results on local pollutants, it only slightly decreases energy consumption and CO_2 emissions (as compared to baseline scenario). The alternative scenario that focuses on modal shifting, reduces local polluting emissions less, but is the most efficient for reducing energy consumption. A scenario combining the two types of measures gives the best results on almost all factors – but any of the scenarios is expected to require significant capital investment, and will need to overcome institutional and individual inertia to be implemented.

191. ***Mexico.*** In Mexico City and other large Mexican cities like Guadalajara and Monterrey, the bulk of the air pollution originates from vehicular traffic. The associated health effects have given rise to extensive policy actions to reduce emissions from this sector.

192. Since 1985, large investments have been made to modify refineries so that they can produce higher-quality fuels. All fuels consumed in the Mexico City area must contain 1 to 2 per cent oxygen, which reduces emissions of CO by 15 per cent and of hydrocarbons by 12 per cent. Although one quarter of diesel fuel still contains as much as 500 ppm of sulphur, 75 per cent of the market share is now made by “Diesel Sin” (“Without”) with only 50 ppm of sulphur. Since 2000, all gasoline sold in Mexico City has to be lead-free. Catalytic converters also became mandatory in new cars in 1992. Standards have been adopted in 1997 for the existing fleet – with values typical for cars not yet equipped with catalytic converters. Since 1995, all vehicles are tested biannually for CO emissions (OECD, 1998).

193. Traffic control policies have also been introduced. For example, in an effort to restrain traffic growth in Mexico City, the No Driving Today (“Hoy No Circula”) programme was established which prohibited the use of private cares one day a week, though 1993 or later models can drive every day if they meet more stringent emission standards. However, these measures have not been fully effective – for example, some have bought old second cars to offset or counteract the measure.

IV. MAIN RESULTS AND IMPLICATIONS

194. It is clear that energy (including transport) use in India, China and Mexico are responsible for significant shares of national (and global) emissions and pollutants. However, it is equally clear that energy policy is undergoing a shift in these countries – largely for reasons related to energy supply, but in a growing number of cases, due to local environmental problems inherent in the existing situation. By and large, these case studies suggest that significant technical and cost-effective potentials exist for reductions in local and global emissions. In many cases, improvements at local and global levels go hand by hand – although in others, local benefits may dominate policy choices.

195. The magnitude of the policy effects can be enormous – perhaps much more significant than those apparently available in industrialised countries, and described in the “alternative scenarios” of the WEO 2000. This is in part a result of the rapid growth in the developing world: developing countries are building their infrastructures, notably in the power and industry sectors. As might be expected, this provides a large number of opportunities for improvement, particularly when countries are positioned to benefit from recent technological developments.

196. With respect to the effectiveness of specific policy choices in China, India and Mexico, a number of conclusions can be drawn:

- In the near term, energy efficiency – particularly for end-use – seems to offer the most significant potential to change global and local emissions. End-use efficiency improvements can be made through a variety of policy actions, including market reform (particularly pricing policies and subsidy reform – as well as targeted new subsidies). Additional tools such as standards, direct financing of demonstration projects, awareness and information programmes also play an important role in the countries studied;

- The development and construction of new, cleaner power plant technologies also holds significant potential. Among the most promising options in China and India are the adoption of state-of-the-art coal technologies – which could reduce local and global emissions in the power sector by up to 15 per cent at no increase in operating costs, although requiring significant up-front capital investments. However, other proposed improvements, such as less capital intensive end-of-pipe SO_x and particulate emissions capture and fuel preparation, offer little or no global benefits, instead focusing on the local environment. Clean technology decisions need to carefully balance the array of investment and policy questions – but the global benefits may only be fully incorporated if there is a price on carbon;

- Fuel switching from coal and oil towards gas (and oil) could also bring global and local benefits. However, at least in the near term, these seem likely to be limited by the availability of local resources (e.g., in India), the pace of exploration, exploitation and building of transport facilities (e.g., in China) and the cost of LNG. External investments will be required if the potential for savings is to be realised – although this implies both a growth in the investment market, and a concomitant relaxation in regulations governing foreign investment in the energy sectors in these countries;

- Of the renewable technologies, perhaps the most promising in terms of global potential is biomass. In China and India, the development and diffusion of a new generation of "improved stoves" facilitating a complete combustion of biomass in households would entail major public health benefits. It would also broaden the available basis of biomass fuel for an expansion of new, modern biomass uses for rural industries and power production. Three other renewable energy sources could also make significant contributions to the electricity generation by 2020: small-scale hydro (in China), wind power (in China and India), and solar thermal power (in India and Mexico). However, while their potentials in the long run might be very important, success in introducing these technologies rests on well-designed incentive policies, and on successful technology transfers that require competitive markets. Efficient and cost-effective systems also likely will require further technology development – most probably in the industrialised countries that enjoy the necessary natural resources. In particular, a revival of solar thermal power in the United States and/or Australia would greatly help;

- A variety of aggressive transport policies are needed in each of these countries to avoid further deterioration of local air quality, to provide economic and social mobility benefits, and to slow the growth of CO_2 emissions. Cleaner fuels and cleaner vehicles would provide large local benefits, but small global ones. However, "cleaner scooters" in India may provide great global and local benefits at little cost. Ultimately, new low- or zero-emitting technologies will be required to overcome the effects of a rapidly industrialising and dense urban centre in need of increasing mobility.

197. The rationale for national action – in the three countries studied here, as well as in many other developing countries – is largely one of domestic energy security, access to energy for local (particularly rural and poor urban) populations, and local pollution problems. Within this set of policy drivers, issues such as the up-front capital costs, questions of availability of domestic technological resources to build and maintain infrastructure, and political questions all enter in final decisions. Few of these decisions are changed because of international or global environmental concerns. However, as has been demonstrated in this paper, decisions made at local levels can have significant effects on emissions of greenhouse gases. Furthermore, choices can be made that provide equal levels of energy services (addressing each or even all of the drivers listed above) while reducing global and local pollutants.

198. This in turn suggests that perhaps the pivotal issue for these countries is one of information: if alternatives exist to meet the energy and energy-related needs of the future, the lack of information and analysis to inform the decisions may be the biggest problem. Thus, one area in which OECD countries can help is in the development and exchange of information, including analyses of the advantages and disadvantages of different policy choices. The information chain is extensive. It begins with the development of alternatives (not only in technologies, but also in investment and financing options) and extends to the need to set the example, within the industrial nations, of operating facilities that demonstrate potentials.

199. Even with information, issues of price remain. Many of the "cleaner" alternatives require up-front capital – a commodity in scarce supply n the developing world. However, the construction of new plants is ongoing, so it is more a matter of leveraging or re-directing resources than finding entirely new funds. In addition, international development assistance, including bilateral programmes, as well as multilateral banks, may provide some incremental financing. And ultimately, setting a price on carbon in an international market can help in refocusing financial flows.

200. In the meantime, these countries will continue to develop, and their energy infrastructures will continue to grow. Hopefully, the extensive set of actions described here marks the beginning of an increasingly successful effort to blend energy needs with environmental awareness. If so, these policies, and others like them, could help lead these countries – and by extension the world– to a more sustainable future.

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