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Energy Demand and CO_2 Emissions

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Introduction and Summary

The question of how much global warming will be generated by anthropogenic Carbon Dioxide (CO_2) emissions in the next century and what impact it will have on the future quality of life is still under debate. What is not debatable is that absent radical extraneous intervention in the consumption and selection of fuels, global CO_2 emissions will keep rising for the foreseeable future. This report explores the emissions projections from available forecasts and discusses the role of energy consumption and growth in planning least-cost abatement procedures.

The more distant projections are obviously more speculative than those for the first two decades of the 21st century. We have seen how changes in technology, science and/or economic and political factors can invalidate basic long term forecasts over time. We all remember the Club of Rome's widely accepted 1972 forecast of resource constraints on world oil demand towards the end of the 20th century, requiring sharp price increases to bring about the necessary adjustments. Obviously, the forecast proved wrong, even directionally, for a variety of reasons. However, in the 1970's and early 1980's it was a major factor in long-term energy policy planning. Given these growing uncertainties in the more distant forecasts we will limit our discussions to the period 1995-2020.

An examination of all available forecasts supports the conclusion of the World Energy Council/ International Institute for Applied Systems Analysis (IIASA) Report that "at least through 2020 the world will have to rely largely upon fossil fuel with relatively few alternatives."[1] Each of the forecasts projects long term CO_2 growth in its base (or reference) case scenario, and most also show increases in their other scenarios. The just-released *Annual Energy Outlook 1997* by the US Energy Information Administration (EIA) projects an increase in CO_2 emissions in the US, ranging from 19% to 36% from 1995 to 2015 in its five cases. The International Energy Agency's (IEA) 1996 *World Energy Outlook* projects a 49% and a 37% increase respectively in CO_2 emissions from 1990 to 2010 in its two scenarios, with the growth continuing throughout the period. A joint report by the World Energy Council and IIASA, published in 1995, has six global scenarios for the period 1990 to 2020, with increases in CO_2 emissions ranging from 5% to 66%. Their "Middle Course" Case projects a 40% increase by 2020. (The report projects further emission increases to 2050 in all but its "Ecologically Driven" Case.) The forecast growth applies both to the industrial nations (members of the Organization of Economic Cooperation and Development or OECD) and the developing countries.

Even while the scientific community is still debating the atmospheric consequences of greenhouse gas emissions, including the central question of whether global warming is a manifest, measurable phenomenon, the industrial nations are embarking on a program to reduce output of carbon dioxide and other so-called greenhouse gases.

The industrial nations are continuing to work toward a plan for these reductions without obtaining or requesting the participation of developing nations. Achievement of a universal consensus for action would of necessity involve a highly political and contentious global debate. The nations with the largest emissions of greenhouse gases are the industrial countries, but the fastest growth in

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[1] World Energy Council and International Institute for Applied Systems Analysis, *Global Energy Perspectives to 2050 and Beyond,* 1995, p. IV

greenhouse gas emissions comes from the developing nations, a natural outgrowth of economic development that mirrors the earlier pattern of the industrial nations. The OECD currently accounts for 50% of global carbon emissions, and the developing countries for 33%. (The remainder of emissions come from the Former Soviet Union and Eastern Europe.) Between 1990 and 1995, however, CO_2 emissions grew by 4% per year in the OECD and by more than five times that rate, 21%, in the developing countries. The Energy Information Administration forecasts that OECD emissions will rise by a total of 26% or 0.8 billion tons between 1995 and 2015, and developing countries' carbon emissions will double, rising by 2 billion tons over the same period.

These disparities in emissions growth between the industrial and developing countries reflect their different phases of economic and technological development as well as their difference in population growth. Thus, the faster growth in the developing countries' CO_2 emissions may, at least in part, be viewed as a positive indicator of their economic growth and rising standard of living. Hence, their argument that they should be as free of emission restrictions in pursuing this phase of their economic development as were the industrial nations during their industrialization phase is valid and recognized by the OECD.

Hence we have conflicting forces. On the one hand, given the developing countries' far greater current contribution to the global growth of carbon emissions, their participation in any abatement process is essential. On the other hand, the developing countries cannot be expected to carry the cost of these reductions in their current phase of economic development. The industrial nations have recognized these financial exigencies in moving forward with their own multilateral program. However, since they have already reduced their own emissions growth substantially with their advanced technology, they might actually find it more efficient per unit of incremental investment to help reduce CO_2 emission in the developing countries than in their own.

Thus, the better route to any CO_2 reduction strategy is a host of market-based measures, especially ones that may meet OECD goals by providing incentives for investments in energy efficiency or emissions abatement in developing countries. Such market-based mechanisms would achieve emissions reductions at the lowest cost and accelerate investment for development in emerging economies. Another important benefit for developing countries is that these investments would directly and unambiguously reduce the ground level pollution that has become a critical problem in some of the most populous and fastest growing nations.

Whatever route is taken, CO_2 Greenhouse gas emissions are growing so much faster in the developing than in the industrial countries, both percentage-wise and volumetrically, that the global growth of these emissions will not be arrested, much less reversed, without the active participation of the developing countries.

The report also finds that any significant substitution of oil to curb CO_2 emissions requires a change in the infrastructure of the transportation sector, oil's principal market. However, substitution of coal by fuels emitting less CO_2 can be done within the existing infrastructure of coal's principal market, the electric power and industrial sector.

Emissions Follow Economic Growth and Energy Use

As pointed out, the OECD accounted for 50% of global CO_2 emission, and developing countries for 33% in 1995. The differences are a reflection of the stages of development. The industrial countries

have already moved through the more intensive period of economic growth accompanied by even faster energy use increases. Many developing countries have entered an analogous phase of growth. Thus, while the industrial countries dominate historical and current global CO_2 emissions, their growth rate has recently been, and will continue to be, much slower than that of the developing countries. From 1971 to 1993 the OECD countries' emissions grew at an annual rate of 0.8% while the developing countries' growth rate was 5.2%.

As noted, the differential reflects partly the different annual growth rates in energy consumption during this period -- 1.5% for the OECD group and 5.5% for the developing countries -- and partly the differential in CO_2 emissions per unit of energy consumption. The developing countries' energy consumption mix has a higher CO_2 content, as the following table illustrates.

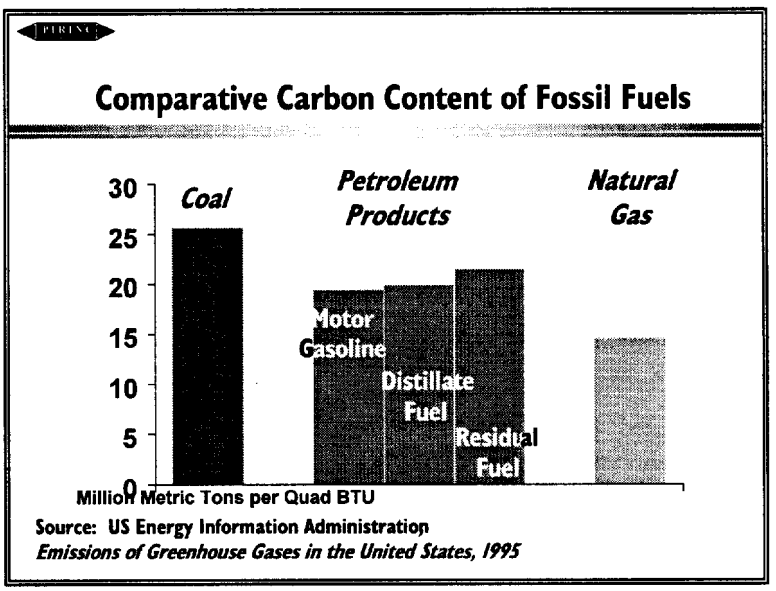
Table I
The 1993 Fuel Mix

	Coal	Oil	Gas	Nuclear	Hydro	Total	MTOE
	----------	----------	----------	---------- % ----------	----------	----------	
OECD	23	42	21	11	2	100	4393
FSU & East. Europe	28	27	39	5	2	100	1354
Rest of the World*	40	42	13	1	4	100	2207

* mainly developing countries
Source: International Energy Agency, *World Energy Outlook, 1996 Edition*, Tables A6-A13

Of the three fossil fuels, gas has the lowest CO_2 emission per unit, followed by oil. The carbon content of different oil products varies, with the transportation fuels at the lower end and heavy fuel oil at the higher end. Coal has the highest carbon content of the fuels, as shown in Figure 1.

Figure 1



Another factor in regional emissions is the relatively small combined share of nuclear and hydropower, which have no CO_2 emissions, in the developing countries, i.e. 5% vs. 13% in the OECD group. As a result of all these differences, two-thirds of the *volumetric* increase in global CO_2 emission from 1971 to 1993 came from the developing countries (4553 MT out of a global increase of 6980 MT) even though their primary energy consumption growth accounted for about half of the world's total increase. For oil alone, almost three-quarters of the global increase in consumption and hence, in CO_2 emission, came from the

developing countries from 1971 to 1993. This disproportionate share has been maintained, as the developing countries, particularly in Asia, have remained the drivers in world oil demand.

The OECD's Climate Change Controls: Not Here, but Coming

As is discussed in the main section of this report, the industrial nations have organized a Framework Convention on Climate Change to reduce global CO_2 emissions. The OECD countries have assumed, correctly, that the developing countries will not participate in this process, which is bound to dampen their energy use and hence economic growth, at this stage of their economic development. Thus, the OECD nations have adopted tentative targets for reduction of CO_2 emission in the industrial countries only. Their first target, established at the Rio de Janeiro conference in 1992, was aimed at reducing OECD CO_2 emission by the year 2000 to the level of 1990. As we now know, this target will not even be directionally approached. CO_2 emission in the OECD has increased from 1990 to 1995 at an annual rate of 0.8%. For the period 1995-2000 the US EIA's latest *International Energy Outlook* projects OECD CO_2 growth rates ranging from 1% to nearly 2%.

In recognition of this reality, the participants of the Rio Conference, meeting in Berlin in 1995, postponed the targets; gradual but specific CO_2 reductions are being considered for the 2005-2020 period.

As the following table shows, most forecasts currently project further increases in CO_2 emissions of the industrial countries at least through 2015.

Table 2
OECD Carbon Dioxide Emissions
(Projected Growth Rates p.a.)

	2000-2010	2010-2015
International Energy Agency*		
Capacity Constraint Case	1.2	
Energy Savings Case	0.5	
Energy Information Administration**		
Reference Case	1.1	1.0
Low Growth Case	0.9	0.8
High Growth Case	1.4	1.2

*International Energy Agency, *World Energy Outlook, 1996 Edition*
**Energy Information Administration, *International Energy Outlook 1996*

One forecast, the earlier cited WEC/IIASA "*Global Energy Perspectives*" Report, in its "Ecologically Driven Case" (one of three), does show a 30% reduction in OECD emissions from 1990 to 2020. Since the continuing emissions increase from 1990 to 2000 is a given, the decline from 2000 to 2020 would have to be even larger. Achieving this reduction requires, in IIASA's words, "a broad portfolio in environmental control technologies and policies including incentives, green taxes,... stringent international environmental taxes or incentives... [O]ne option is a carbon tax that gradually increases to $400/ton of carbon in 2100..." As this quote makes clear, the only way to achieve significant reductions in OECD CO_2 emissions by 2020 is through large-scale government intervention in the form of restrictions and incentives.

Energy demand and economic growth are clearly interrelated. Any large scale intervention in their energy sector to achieve the proposed CO_2 reduction targets from 2005 to 2020 will almost inevitably affect economic growth. The relationship is particularly strong in the industrial countries,

where energy efficiency and technology improvements have already pared down their energy use. Further mandates for reduction will come at a high cost. A recent extensive study by the American Council for Capital Formation examined the impact of emission control measures on the US economy. It stated that stringent near-term actions to reduce US emissions will ... "reduce US saving, investment, and economic growth with little or no benefit in terms of global CO_2 emission or concentration in the atmosphere."[2] In other words, there is a high probability that if the CO_2 emission reduction proposed for the period 2005-2020 at the Berlin Conference were to be adopted at the *Framework Convention on Global Climate Change's* conference next December in Kyoto, Japan, the economies of the world's industrial nations will be negatively affected while the beneficial effect of the proposed policy on world climate conditions is still very speculative at this stage.

Still, the industrial nations can be expected to reach some binding agreement, probably in 1997, to reduce CO_2 emissions in the post-2000 period. If the new target is much more moderate, such as progressively reducing the *growth* of CO_2 emissions from 2005 on, hence approaching stabilization of CO_2 emissions after 2010 or 2020, it may be achieved without a significant negative economic impact. It would have the positive additional effect of reducing the growth in ground level pollution which is more sure and observable to the public than the uncertain concept of global warming.

Moving towards Stabilization

An indication of the potential reduction in the OECD CO_2 emission growth rate can be gleaned from a comparison of the growth rates in energy demand and in CO_2 emissions and the changing fuel shares of the major regional OECD groups (North America, Europe and Pacific) in the period 1971-93.

Table 3
OECD Primary Energy Demand and CO_2 Growth Rates, 1971-93
(% p.a.)

	N. America	Europe	Pacific	Total OECD
Primary Energy	1.4	1.3	2.5	1.5
CO_2 Emission	1.0	0.2	1.9	0.8

Source: International Energy Agency, *World Energy Outlook, 1996*

North America (US and Canada) and Europe had about the same annual growth rates in primary energy consumption, 1.4% and 1.3%, respectively, from 1971 to 1993 but North America's annual growth rate in CO_2 emissions was five times as fast as Europe's (1.0% vs. 0.2%). The explanation can be seen in the changing composition of energy fuels. In North America the share of coal, which has the highest CO_2 content of all fossil fuels, increased sharply during this period while it declined substantially in Europe. Similarly, the share of gas, which has the lowest CO_2 content, increased in Europe but decreased in North America. The share of nuclear power (zero CO_2 emission) was much higher in Europe than in North America in 1993.

[2] American Council for Capital Formation Center for Policy Research, *An Economic Perspective on Climate Change Policies,* Washington, DC 1996, p. IX.

For the period 2000-2010 in the IEA's *Energy Savings Case*, which has a faster increase in energy efficiency than the IEA's other case, the OECD's primary energy demand growth rate for the period 2000-2010 is more than cut in half to 0.6% per annum from its historical rate. (The drop is reflected in all regions, but is sharpest in Europe.) As a result of the cut, the OECD CO_2 emissions growth rate drops from its historical 0.8% rate to 0.5% in the 2000-2010 period. Yet, there are no radical changes in the energy mix: coal's share remains about the same and continues to account for about 41% of OECD electric power generation. Gas's share in total energy demand also remains almost unchanged while the OECD's nuclear share declines after 2000. Thus, the role of technology, so often understated in long term forecasts, is critical to the path of emissions.

Table 5
Energy Demand in the OECD: IEA's Energy Savings Case

	------Levels (MTOE)----			Growth Rates (% p.a.)			---Fuel Shares (%)---		
	1993	2000	2010	1993-2000	2000-2010	1992-2010	1993	2000	2010
Primary Energy	**4393**	**4733**	**5042**	**1.1**	**0.6**	**0.8**	**100**	**100**	**100**
Solids	1025	1072	1069	0.6	-0.0	0.2	23.3	22.7	21.2
Oil	1856	2008	2179	1.1	0.8	0.9	42.2	42.4	43.2
Gas	903	983	1066	1.2	0,8	1.0	20.6	20.8	21.1
Nuclear	473	514	516	1.2	0.0	0.5	10.8	10.9	10.2
Hydro	108	114	129	0.9	1.2	1.1	2.4	2.4	2.6
Geo/Others	28	41	82	5.6	7.3	6.6	0.6	0.9	1.6
Carbon Dioxide Emissions (Mt)	**10616**	**11310**	**11831**	**0.9**	**0.5**	**0.6**			
% change since 1990	1.7	8.4	13.4						

Source: International Energy Agency, *World Energy Outlook, 1996 Edition,* p. 258.

Table 4
OECD Fuel Shares
(%)

	N. America		Europe		Pacific		Total OECD	
	1971	1993	1971	1993	1971	1993	1971	1993
Coal	19	25	30	21	25	22	24	23
Oil	46	39	59	43	70	52	53	42
Gas	32	24	7	18	2	12	20	21
Nuclear	1	8	1	15	1	12	8	11
Hydro/Other	2	3	3	3	3	3	2	3

International Energy Agency, *World Energy Outlook, 1996 Edition*

OECD Implementation Strategies: Not All Equal

The successful implementation of any goals adopted by the OECD will require the choice of strategies from a menu of possibilities ranked on cost/benefit. It is accepted that large scale intervention in the energy sector will negatively impact the economies of the participating countries. Thus, it is imperative to minimize the economic cost of any required reduction. One program under consideration is an international carbon trading market, similar to emissions trading markets already in place in the U.S. Also, as noted earlier, the developing countries have argued that if they participate in the emissions reductions, the program will impose a brake on their economies while they are catching up with the industrial countries. Their argument has been accepted for the current round of negotiations. However, their emissions grow at a faster rate and in larger volume than the industrialized countries'. In addition, their energy infrastructure and fuel use are less efficient than those of the industrialized countries. Hence, the strategy for meeting industrialized country targets for emissions reductions with the least cost, greatest global benefit, and greatest *local* benefit may be underwriting efficiency investment and technology improvements *outside* the OECD, i.e. those regions that are most rapidly developing and most polluting, as discussed in a later section of this Chapter.

Even within the OECD, not all implementation plans will require the same intervention level. Any change in the fuel mix of electric power plants -- a move to limit or replace coal, for instance -- affects only the plant itself, not the transportation, distribution or consumption of its end product. Such changes are possible over time without major market intervention because they do not require any change in the existing infrastructure of energy production, transportation or utilization. Furthermore, combined-cycle gas turbines, the prime equipment for incremental power production, are more efficient and cause less atmospheric emissions than coal burning equipment. Of course, the reason for coal's consistent growth as an electric power fuel in the US is its low price relative to other fuels. This has to be considered in any energy policy since electric power is a key factor in economic growth. However, the US and Canada have a very large resource potential in natural gas, and new technology to develop it, particularly in the Gulf Coast Outer Continental Shelf, at declining cost of production.

The EIA projects gas's share in US electric power production to rise from 10% in 1995 to 28% in 2015 in its latest Reference Case Forecast. However, coal generation will also rise during this period, maintaining its 50% share of total power generation. (All of the decline is projected to take place in nuclear power from about 2000 on).

We may be able to increase North American gas production more rapidly than projected and perhaps arrest the growth in power generation by coal in the post-2010 period. Certainly gas's resource base and the infrastructure for such a development is there.

Why Oil Is Unique

For oil, the situation is quite different. About 60% of OECD oil consumption is used for transportation. Transportation is traditionally oil's primary growth market. In the OECD countries it grew at an annual rate of 2.2% from 1971 to 1992 while total OECD oil consumption grew at 0.6%. All forecasts project that the transportation sector will continue to be oil's only major growth market for the foreseeable future. Approximately 80% of oil's transportation fuels consist of gasoline and diesel oil for road and rail transportation.

The world's largest automotive fuel market is the US, where CO_2 emissions from oil used in road transportation amounted to about 350 million metric tons in 1995, compared to coal's 441 million for electric power generation. In the EIA's Reference Case both fuels increase their emission by about 100 million tons by 2015. These projections have led to a strong advocacy among "environmentalists" to reduce CO_2 emissions in the US and other industrialized countries by reducing oil-fueled transportation and replacing it by "zero-emission" electric vehicles. The proposal has much conceptual appeal because it would eventually lower not only all CO_2 emissions from automotive vehicles, but also automotive ground level emissions which are very visible, particularly in urban areas.

However, there are some basic flaws in this concept and the societal cost of switching is likely to be extremely high. The first problem is that, unlike a switch from coal to gas in the electric power sector which is not even noticed by end users, the switch to electric vehicles (EV) would require the establishment of a new infrastructure to service these vehicles, such as recharging or replacing their electric batteries. The EV infrastructure would have to be built while maintaining the existing infrastructure for oil-fueled vehicles for a very long period. If the electric vehicle infrastructure is not generally accessible, car buyers are unlikely to purchase EVs on a broad scale while oil fueled vehicles are readily available. However, investment in such an alternative fuel infrastructure is risky and unattractive for an extended period. Even in California, where there are mandated requirements for a growing share of new zero emissions vehicles from 2002 on, these vehicles will account for only 5-6% of California's total motor vehicle pool by 2020. Most of them are likely to be light trucks and vans, such as post office trucks, which can be fueled from a central source.

Electric vehicles are more expensive than similar type conventional vehicles, have a shorter driving range and will be more difficult to refuel. A 1993 study on EVs by the IEA found that "recent cost comparisons between EVs and internal combustion engine vehicles indicate that the current life-cycle costs of EVs are more than double those of gasoline vehicles". Hence, the market for EVs will be largely a function of government coercion or incentives without a technological breakthrough. Such government intervention never comes free. Either transportation costs will rise, or taxes will rise, or a combination of both.

The question then is what is accomplished by this intervention. The justification given is of course to reduce CO_2 emissions. But actually it would largely transfer the emission source from the vehicle to the electric power plant providing the fuel. To the extent the power is coal-generated there may be no reduction in CO_2 emissions, particularly if one includes the transmission loss in electricity from plant to end user in the calculation. If the power is generated by gas, there may be some reduction but, after accounting for the transmission loss, it is quite small.

A more benign and probably more effective means of arresting the growth in automotive CO_2 emissions is to improve the fuel efficiency of vehicles. As the Energy Information Agency Report points out, current fuel efficiency for new cars is 28 miles/gal. In its Reference Case the Energy Information Administration projects the efficiency to increase to 33 miles/gal in 2015. However, the Report makes it clear that technically a 39 miles/gal efficiency is achievable by 2015. This would reduce gasoline CO_2 emission by 50 million tons in 2015 below the Reference Case. Furthermore, more aggressive efficiency improvements are under exploration. If this is achieved in part through a policy of accelerating the existing trend towards higher automotive fuel efficiency, it could benefit both the economy and public health because it would reduce transportation costs and cut local pollution and improve local air quality.

A recent OECD Secretariat study, entitled *Towards Clean Transport* also reaches the conclusion that it is better to improve the existing system than to replace it by an untried new one. The study

concludes that "the analysis shows that conditions allowing a significant reduction of fuel consumption could be reached, without developing new technologies, by acting in three related directions" (reducing the weight of vehicles, installing a smaller and less powerful engine, and theoretical speed limits). It concludes "these objectives could be reached without much difficulties."

Continuing Surge in Developing Country Emissions

We have so far focused primarily on the CO_2 emissions of the industrial countries because, as already mentioned, the developing countries have not been asked, and have not offered, to participate in any international program to curb CO_2 emissions. Yet, their CO_2 emissions are growing so rapidly, both percentage wise and volumetrically, as to completely overtake the OECD countries. From 1990 to 1995, the developing countries' CO_2 emissions grew at a multiple of that of the OECD countries, as Table 6 shows.

Table 6
CO_2 Emissions
(Million Metric Tons)

	1990	1995	Increase Volume	%
OECD	2985	3099	114	3.8
Developing Countries*	1707	2070	363	21.3

***Non-OECD excl. EE/FSU**
Source: Energy Information Agency, *International Energy Outlook, 1996*

For the period 1995-2015 the EIA Reference Case Scenario projects a doubling in CO_2 emission by the developing countries and a 26% increase by OECD. The developing countries' emissions will increase by 2 billion tons and the OECD's by 0.8 billion tons. The IIASA Report to 2020 shows the same pattern. In its "Middle Course" Case, CO_2 emission in the OECD countries rise by 0.5 gigatons (Gt) from 1990 to 2020 while in the developing countries the projected growth is 2.1 Gt. Of course to evaluate these growths in energy demand properly they have to be related to other factors. Thus, while the population in the OECD industrial countries is projected to remain flat at approximately 1 billion, from 1990 to 2020, in the developing countries it is projected to rise from 4 billion to 6.4 billion, or 60%, according to the IIASA Report. Hence, even the sharp increases in carbon emissions in the developing countries do not bring them to the OECD level of CO_2 output on a per capita basis.

The table below shows the current energy composition of the developing countries. Two major differences with the industrial countries are the developing countries' much higher share of coal and lower share of natural gas in their energy composition. Since coal has the maximum fossil fuel emission per unit of output (not only of CO_2 but also of ground level pollution), the projected growth presents a serious problem for these countries in the much nearer future than any possible global warming impact from CO_2 emissions. The situation is particularly serious in Asia where coal's share is 62% and gas's only 7%. In China, which accounts for over half of the energy consumption in Asia's developing countries, coal's share is nearly 80% and gas's less than 2%. The ground level pollution accompanying this energy pattern (which on a smaller scale exists also in India) presents a far more certain and immediate threat to the environment than the Greenhouse Gas effect.

Table 7
Energy Consumption in the Developing Countries, 1995
(million tons of oil equivalent)

	Oil	Gas	Coal	Nuclear	Hydro	Total
Latin America	126.4	98.2	22.5	4.9	42.0	432.8
Middle East	186.5	118.4	5.6		1.2	311.7
Africa	102.7	37.9	87.8	3.1	6.3	237.6
Asia	522.6	117.0	872.0	31.8	33.9	1577.3
	1077.2	**371.5**	**987.9**	**39.8**	**83.4**	**2559.8**
Shares	**42.1%**	**14.5%**	**38.6%**	**1.5%**	**3.3%**	**100.0%**

Source: *BP Statistical Review of World Energy, 1996*

The Example of China

China, with its massive economy, massive population, and growing influence in global matters, presents an excellent example of the competing pressures of pollution versus development. For China alone, the IEA's lower growth ("Energy Savings") Case projects an increase in coal demand of nearly 450 million tons oil equivalent from 1993 to 2010, or 10 times the projected volume growth in total OECD coal demand. EIA shows a similar pattern, with the growth in China's coal use a multiple of the OECD's increase. (Overall, EIA shows a more rapid growth for coal than IEA.) In 2010, EIA shows Chinese coal use surpassing the OECD's. Furthermore, the increase in China's coal consumption accelerates in the 2010-2015 period, suggesting a continuation after 2015 . Both forecasts in all cases show China's carbon emission rising by a substantially larger *volume* in the post-2000 period than total OECD carbon emission.

China's electric power plants and other coal burning facilities are known to be below the existing technical and environmental standard in the OECD countries. Thus, any improvement or replacement of this equipment should lower the CO_2 emissions rate. Presumably, some such improvements are already built into these forecasts. But as of now the potential for more energy efficiency in China and other Asian countries is vast. Thus, according to a 1995 report by the World Bank, *Energy Demand in Five Major Developing Countries*, "high generation losses in the electric power sector reduce electricity by more than 20 percent and sometimes 30 percent in China, India and Indonesia [compared to industrial country norms]." The report also calls attention to energy waste in the industrial sector and in public transportation: in 1990 coal-fired steam locomotives still accounted for 69% of total railway fuel consumption in China. Yet the energy efficiency of steam locomotives is one-quarter that of diesel engines.

If permitted to grow unabated, China's -- and to a lesser extent India's -- rapidly rising coal consumption could cause serious environmental damage from acid rain and various other emissions for all of Southeast Asia, just as would have been the case in the US if electric power and industrial plant emission standards had remained unchanged during the last 50 years.

Joint Implementation

The OECD nations might therefore find it economically and environmentally desirable to help finance China's move to slow down its emissions growth by moving towards a clean coal technology, accelerating the phasing out of coal-fired steam locomotives, and encouraging a faster growth in natural gas demand through imports. China is likely to be reluctant on the gas imports issue, since it means replacing part of an abundant, low-cost domestic fuel with a higher-cost, imported fuel. But if the cost is largely borne by foreign lenders or investors it may help to overcome China's reluctance since its policy makers must be concerned about the measurable and noticeable effect of its existing energy composition on its environment. The concept of this assistance is specifically referred to in the Rio Framework Convention on Climate Change as "joint implementation policies and measures."

Joint implementation is based on the indisputable fact that any given reduction of greenhouse gas emission anywhere has the same effect on the global climate everywhere. Hence, joint implementation would lower the cost of greenhouse gas abatement by seeking out the least-cost options, regardless of geographic boundaries. Most of these options would be in the developing countries where a larger emissions reduction can be achieved than in the industrial countries, since the latter have already drastically reduced their emissions per unit of energy. As has been pointed out, the developing countries can not be expected to underwrite all or most of the cost of their global emissions reductions, both because of their much lower per capita economic wealth than the industrial countries', and because they are now in an economic phase where current domestic growth has priority over long-term global welfare considerations. Hence, the industrial countries are now actively considering a program under which they would contribute to the cost of reducing greenhouse gas emissions in the developing countries. As pointed out earlier, emissions reductions in developing countries will have the highly beneficial secondary effect of reducing these countries' ground level pollution which has become grossly excessive by industrial country standards.

There are a variety of benefits, at least conceptually, to the joint implementation strategy. Most important, its incentives for energy efficiency and improved technology will accelerate technology transfer, not hinder development. Details of such a system are only now beginning to be fleshed out. An OECD-based company, for instance, already required by its home country to reduce emissions, could get credit for a qualifying investment -- one with higher efficiency or more benign fuel choice -- in a developing country. The developing host country would have gotten what it wanted, a new power plant, for example, and the incremental cost of choosing a power plant with lower emissions potential will have been financed by a foreign enterprise. This enterprise will receive credit at home for investing abroad to reduce global greenhouse gas emissions. The central banks and international lending institutions in the OECD could likewise provide a preferential loan rate for investments in equipment with lower greenhouse gas emissions. Again, the developing host country would not bear the incremental cost.

Of course, any such joint implementation policy between sovereign nations requires compatible policies and legislation in both countries as well as international inspections, controls and verification procedures. Some OECD business organizations have expressed concern over these prospects, fearing that they might unduly curb their countries' national jurisdiction over emissions policies. Such fears are realistic and understandable. While they do not invalidate the concept of "joint implementation," they must be addressed by policy makers in the forthcoming negotiations. Presumably, the growing number of joint implementation pilot projects will furnish some of the answers to these legitimate questions. The decision to establish a joint implementation pilot project program was made at the Berlin climate Conference in April 1995. By October 1996 there were 28 active joint implementation pilot projects in

13 host countries. Meanwhile, the World Bank has also embarked on an initiative to study the financing of joint implementation greenhouse gas reduction projects.

Conclusion: Global Problems → Global Solutions

To conclude, under all realistic scenarios and assumptions, CO_2 emissions of the OECD countries will be higher in 2020 than in 1995. However, the principal contribution to global CO_2 emissions has shifted from the industrial countries to the developing countries. In the period to 2020 the latter will not only show a much faster growth rate but also a much higher volume increase in emissions than the industrial countries. This is due to several factors: population growth, rising standard of living, obsolete or inefficient energy producing/distribution systems, and growing use of fuels with relatively high emissions rates.

Thus, those wishing to abate the growth in global CO_2 emissions would reasonably explore investments to limit emissions in developing countries. Minimizing the economic impact that accompanies emissions control will be a key to successful implementation, hence driving the search for least cost, market-based implementation strategies.