KYOTO'S FLEXIBLE MECHANISMS & NUCLEAR POWER

RETHINKING THE OPTIONS

BY HANS-HOLGER ROGNER

Cutting emissions of greenhouse gases is a major aim of the Kyoto Protocol that countries adopted in December 1997. But the cuts won't be easy to achieve -- reductions of the magnitude postulated in the Protocol would involve a substantial restructuring of energy production and use in most industrialized countries. The Protocol states that these countries (referred to as Annex IParties) "shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of greenhouse gases ... do not exceed their assigned amounts ... with a view to reducing their overall emissions by at least 5.2% below 1990 levels in the commitment period 2008 to 2012". *(See box, page 27.)*

Since signing the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, governments have struggled to identify policies that can simultaneously satisfy the demands of domestic politics and meet the needs for global environmental stewardship. Electricity generation is likely to become one of the prime policy targets. For one, electricity generation accounts for about one-third of global carbon dioxide emissions. For another, it is a sector with a relatively small number of actors and emission source points that are easier to regulate and control than, say millions of vehicle tail pipes.

Fossil fuels (coal, oil and gas) supply some 63% of the world's electricity generation, and the percentages in developing countries with large electricity consumption are much higher, more than 80% in China and India. By 1998, annual emissions of carbon from fossil fuel combustion amounted to almost 6.5 Giga-tonnes (Gt) of carbon (C). Although historically the bulk of these emissions have come from the industrialized countries, carbon emissions from developing countries have increased rapidly, by 32% from 1990-98.

To a large extent, this increase is the result of a rapidly growing electricity supply sector which, in future, is expected to outpace growth in Annex I countries. Projections from the International Energy Agency (IEA) show that some 770 GW of the global 1380 GW of net capacity addition between 2000 and 2020 will occur in developing countries. In terms of fuel mix, more than 75% will be fossil based (coal: 348 GW;, natural gas: 210 GW; oil products: 49 GW; nuclear: 30 GW; hydropower: 124 GW; and other renewables: 9 GW). It is in the context of these projections of rapidly growing greenhouse gas (GHG) emissions in developing (or non-Annex I) countries that prompted several Annex I countries to request a "meaningful participation of developing countries".

In addition, experience has shown that allowing economic agents to trade -- in this case national GHG emission reduction units (ERUs) or emission permits -- can substantially lower the costs of meeting an aggregate emission reduction target. The Protocol foresees such a trading provision in Article 17 but clearly states that the acquired permits shall be supplemental to domestic action. Emissions trading implies that if one party wishes to emit more than the assigned amount, it has to acquire the corresponding amount of emission permits from other parties, thereby forcing the selling parties to reduce their domestic emissions beyond the required targets. Given the supplement condition, parties can buy only parts of their emission reductions whereas the maximum amounts have not been specified yet. Obviously, emission trading is restricted to parties subject to emission limitations.

While emission trading introduces flexibility in achieving the emission reduction commitments, it does not create

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a "meaningful participation of developing countries". In addition, non-Annex I parties are very much opposed to the mere thought of embarking on costly GHG mitigation measures which would siphon off scarce financial resources from other vital development projects and thus become an impediment to their economic development aspirations.

KYOTO'S CLEAN DEVELOPMENT MECHANISM

The Clean Development Mechanism (CDM) modeled after the concept of Joint Implementation (JI) was introduced at the eleventh hour during the 1997 Kyoto Conference. The CDM is a vehicle which would allow developing countries to pursue economic development while at the same time provide access to additional resources for the purpose of reducing greenhouse gas emissions.

More precisely, CDM as defined by Article 12 of the Kyoto Protocol is a new cooperative mechanism that involves developing countries with the explicit purpose of assisting these countries in achieving sustainable development and in contributing to the ultimate objective of the Convention while simultaneously assisting industrialized countries in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.

The rationale for CDM (and JI) stems from the fact that GHG mitigation costs differ greatly between regions whereas the impact on climate stability is independent from the geographical location of emissions or emission mitigation. Thus, economic efficiency suggests reducing GHG emissions where the largest mitigation effects can be accomplished at lowest costs. Typically, mitigation costs are lower in regions with aged or inefficient energy plant and equipment with strong energy growth prospects than in regions with modern and highly efficient energy production and use and quasi stagnating energy demand.

Under these mechanisms, a GHG-emitting firm from an Annex I country seeking least-cost mitigation options may invest in a developing country or in another Annex I country, possibly in economies in transition, if the specific mitigation costs in US dollars per ton of carbon equivalent ($/t C equivalent) of GHG emission avoided are cheaper than domestic mitigation. The recipient country obtains modern technology at lower cost than otherwise while the investing firm receives certified GHG emission credits (CERs) which can be applied against its domestic reduction commitment.

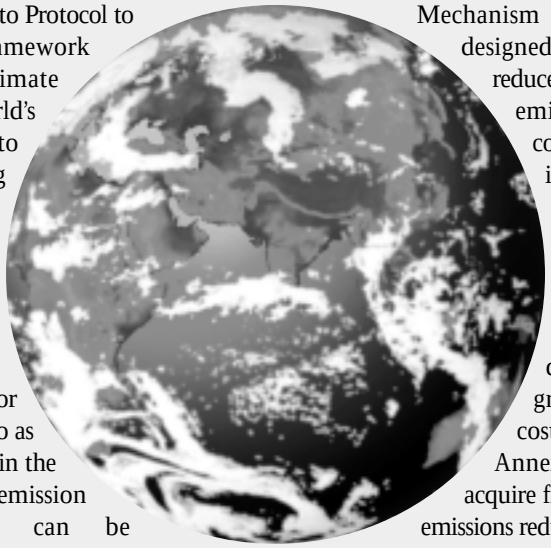
The rules and regulations governing this mechanism (CDM) and its implementation (JI) are under negotiation by the Parties to FCCC. While their exact nature is unlikely to be decided before the end of 2000, several principles are manifest:

- Additionality. The CDM/JI project must constitute an investment that would not otherwise be made by the host country, e.g., for reasons of costs or capital availability. This requires the definition and/or specification of a baseline project against which the CDM/JI project can be compared. The emission reductions must be additional to any that would have occurred in the absence of the CDM/JI project.
- Reality. The project must result in measurable, real and long-term GHG reduction benefits. The emission reductions must be realized, accountable, monitorable and verifiable.
- Sustainability. The project must contribute to sustainable development for the recipient country.

Under these mechanisms, an Annex-I Party would invest in a clean technology project in a country, which it might not be able to afford on its own, but which produces fewer GHG emissions than the affordable technology that would have been used instead. In the power generation sector, the baseline technology for most non-Annex-I countries is probably low to medium efficient coal-fired generation, often with less than state-of-the-art pollution control and hence with significant pollutant emission levels. Nuclear power or wind power plants might qualify as candidate technologies, given their higher capital costs, and their negligible GHG and other pollutant emissions. Coal plants with high conversion efficiency and emissions controls might also qualify. Substituting natural gas fired plants for coal or efficiency improvements throughput the energy system are other mitigation options.

The Annex I country sponsor, say an electric utility that is obliged to curb domestic emissions, now has to assess these CER/ERU values with the domestic GHG mitigation options and costs. If the

THE KYOTO PROTOCOL AT A GLANCE



Adopted in 1997, the Kyoto Protocol to the United Nations Framework Convention on Climate Change commits the world's industrialized countries to individual, legally-binding targets to reduce their greenhouse gas emissions by the period 2008-2012, adding up to a total cut of at least 5% from 1990 levels.

The individual targets for these countries (referred to as Annex I Parties) are listed in the Protocol's Annex B. The emission reduction obligations can be summarized as follows: Western European countries accepted an 8% reduction relative to 1990 emissions, with the exception of Iceland and Norway which were allowed 110% and 101% of 1990 emissions respectively. Countries of the European Union may arrange different emission reduction levels among themselves as long as their combined total emissions remain 8% below 1990 levels.

Eastern European nations generally have the same obligations as Western European nations with some exceptions: Croatia stands at 95%, and Hungary and Poland at 94% of base year emissions. The base year for the countries in this region need not be 1990, but could be a later date, e.g., 1995. The Russian Federation and Ukraine were allowed to maintain 1990 emission levels. Japan and Canada agreed to a 6% reduction from 1990 emission levels. The United States agreed to reduce emissions 7% below 1990 levels; Australia was allowed to increase emissions 8% above 1990 levels; and New Zealand was allowed to emit up to 1990 levels.

The targeted emission reductions cover the six main greenhouse gases, namely, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), along with some activities in the land-use change and forestry sector that remove carbon dioxide from the atmosphere (carbon "sinks").

The Protocol also establishes three innovative mechanisms, known as Joint Implementation (JI), Emissions Trading and the Clean Development Mechanism (CDM), which are designed to help Annex I Parties reduce the costs of meeting their emissions targets. JI is a cooperative mechanism that involves two or more partners from countries subject to quantified emission limitation and reduction commitments (Annex I Parties) with distinctly different marginal greenhouse gas mitigation costs. Any Party included in Annex I may transfer to, or acquire from, any other such Party emissions reduction units resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in any sector of the economy. The CDM also aims to promote sustainable development in developing countries.

While these so-called "flexibility mechanisms" were agreed in principle in the Protocol, their operational details must now be fleshed out. In addition, Parties must develop the framework compliance system outlined in the Protocol, and further work is also needed on provisions for the land-use change and forestry sector, reporting obligations, and the vulnerability of developing countries to climate change and to mitigation measures. At the fourth Conference of Parties (CoP-4) in 1998, Parties agreed to a programme of work (the "Buenos Aires Plan of Action") to finalize these details, to be completed by CoP-6 in 2000.

The Kyoto Protocol was open for signature between 16 March 1998 and 15 March 1999. Eighty-four countries signed the Protocol during that period, indicating their acceptance of the text and intent to ratify.

In order to enter into force, the Protocol must now be ratified by 55 Parties to the Convention, including Annex I Parties accounting for 55% of carbon dioxide emissions from this group in 1990. Although some countries have already ratified, many more are awaiting the outcome of negotiations on the operational details of the Protocol at CoP-6. Many Parties wish to bring the Protocol into force by 2002, in time for the 10th anniversary of the signing of the Convention.

ILLUSTRATIVE DATA FOR SAMPLE CASE STUDY OF CLEAN DEVELOPMENT MECHANISM (CDM)

Characteristics	Units	Baseline Coal	CDM-Coal	CDM-Nuclear	CDM-Wind	CDM-Gas
Technical						
Plant lifetime	year	25	25	25	15	25
Net Capacity	MWe	600	600	935	12	450
Load factor	%	75	75	80	40	80
Net efficiency	% (LHV*)	33.8	47.5	33	1	55
Sulphur abatement (SO2)	%	0	90	-	-	
Nitrogen oxides (NOx)	%	0	80	-	-	
Particulates	%	99.5	99.5	-	-	
Economics						
Investment costs**	US$/kWe	1,090	1,661	2,432	998	836
Localization	%	100	30	15	15	10
Real discount rate	%	10	10	10	10	10
Fix O&M costs	US$/kWe/yr	21.1	43.9	37.9	27.8	23.71
Variable O&M	US$/MWh					
Fuel costs	$/GJ	1.70	1.70	0.72	0	3.9
Emissions & Wastes						
Ash	g/kWh	57.9	41.4	-	-	-
Sludge from abatement	g/kWh	-	20.5	-	-	-
High-level rad. waste	kg/MWh	-	-	x	x	-
Heavy metals	gHM/kWh	0.038	0.027	-	-	-
Sulphur dioxide SO_2	g/kWh	9.09	0.65	-	-	0.15
Nitrogen oxides NO_x	g/kWh	3.01	0.61	-	-	1.13
Carbon monoxide CO	g/kWh	1.08	0.77	-	-	0.45
Methane	g/kWh	-	-	-	-	0.03
Nitrous oxide N_2O	g/kWh	0.02	0.02	-	-	0.018
Particulates	g/kWh	0.2	0.14	-	-	0.045
Carbon dioxide CO_2	g C/kWh	321	230	-	-	99
Total GHG emissions	**g C/kWh equiv.**	**327**	**236**	**0**	**0**	**106**

*Lower heating value. **Investment costs include interest during construction. Source: IAEA

CDM/JI project offers lower mitigation costs, the utility may choose to pay the investment or generating cost difference between the CDM/JI and the baseline project in return for CERs/ERUs in the amount of avoided emissions. The CERs/ERUs then can be applied against the utility's mitigation commitment.

However, the Protocol states that the flexible mechanisms applied for the purpose of meeting commitments under Article 3 must be supplemental to domestic mitigation action. This is to say, nations can only partly buy their way out of domestic emission reductions (the allowable amounts have yet to be negotiated by FCCC Parties).

SAMPLE CASE STUDY OF CDM OPTIONS

A hypothetical generic case study may illustrate the evaluation of CDM/JI projects. The point of departure is a typical coal-fired power plant, i.e., the least-cost capacity increment option in a non-Annex-I country; in other words, the baseline project. Against this baseline project, an advanced coal-fired power station, a standard commercially available nuclear power plant, a wind energy park, and a modern combined cycle gas turbine (CCGT) are proposed as CDM/JI options.

The following steps need to be carried out in the evaluation:

- Determining the baseline technology; i.e., the technology that would be chosen in a business-as-usual situation (without climate change considerations);
- Calculating generating costs and GHG emissions for the baseline plant;
- Selecting the CDM/JI options;
- Evaluating the incremental investment requirements and levelized electricity generation costs for each CDM/JI option;
- Determining the avoided GHG emissions for each CDM/JI option versus the baseline; and
- Determining the specific abatement costs for each CDM/JI option based on both investment costs and

GENERIC COMPARISON OF COSTS FOR MITIGATION OF GREENHOUSE GASES

	Units	Baseline Coal	CDM-Coal	CDM-Nuclear	CDM-Wind	CDM-Gas
Based on Investment Cost Differences						
Total plant capital costs	Million US$	654	997	2274	12	376
Corrected for difference in capacities and availabilities	Million US$	1087	1657	2274	1866	782
CDM investment	Million US$	-	569	1187	1087	-305
GHG emissions	Million tC /year	2.14	1.55	0	0	0.69
GHG emissions avoided	Million tC /year	-	0.60	2.14	2.14	1.45
Mitigation costs based on levelized capital costs only	$/tC equivalent	-	101	57	48	-25
Based on Levelized Generating Cost Differences						
Total generating costs	mills/kWh	39.60	46.39	49.25	45.38	42.93
Total GHG emissions	g C/kWh equiv.	327	236	0	0	106
GHG emissions	Million tC /year	1.290	0.931	0	0	0.333
GHG abated	g C/kWh equiv.	-	91	327	327	221
GHG emissions avoided	Million tC /year	-	0.359	1.290	1.290	0.956
Mitigation costs	$/t C equivalent	-	74.6	29.5	17.7-77.0	15.1

Notes: CDM = Clean Development Mechanism; GHG = Greenhouse gases. Source: IAEA

total levelized generating costs.

GHG Mitigation Based on Investment Costs. Based on the data used in the case study, total investment requirements are corrected for the different capacity and availability characteristics of the various CDM/JI options including the baseline technology. *(See table.)*

The evaluation of GHG emissions shows that all CDM/JI options generate real, measurable and long-term GHG emission benefits. Except the CCGT, all CDM/JI options would qualify on grounds of their financial additionality, their GHG benefits; and their support of sustainable development (lower pollutant emissions affecting air quality and regional acidification). The CCGT option happens to be a least-cost option with negative GHG mitigation costs, i.e., it should be the actual baseline technology rather than the coal-fired plant. The mitigation costs (in terms of $/t C equivalent avoided) are US $101/tC for the advanced coal option, US $57/tC for the nuclear option and US $48/tC for the wind option. However, this calculation considers capital costs only and ignores O&M as well as fuel costs, which can account for a significant share of total generating costs.

GHG Mitigation Based on Total Generating Costs. Levelized generating costs are calculated from the illustrative data assuming no fuel price escalation. Only actual plant data are used, i.e., no correction is made for different plant capacities and availability factors. All CDM/JI options have higher generating costs than the baseline technology of US-mills 39.60 per kWh.

Coal-fired CDM Option. Since the advanced coal-fired power plant emits annually some 0.931 million tonnes of carbon, it avoids the emission of some 0.359 million tonnes of carbon each year compared to the baseline coal-fired plant. The total emission offset or emissions avoided over the lifetime of the CDM/JI project is some 9 million tonnes of carbon. The costs of avoided carbon emissions then is US $74.6/tC. Put differently, the project would generate CERs/ERUs at a value of US $85/tC.

Nuclear CDM Option. Since the nuclear power plant has a GHG emission factor of zero, the CDM/JI nuclear power plant avoids the emission of some 1.29 million tonnes of carbon each year compared to the baseline coal-fired plant. The total emission offset over the lifetime of the CDM/JI is 32 million tonnes of carbon. The costs of avoided carbon emissions or the CER/ERU value then is US $29.5/tC.

Wind CDM Option. Like the nuclear power plant, the wind option has an emission factor of zero and the CDM/JI wind plant avoids the emission of some 1.29 million tonnes of carbon each year compared to the baseline coal-fired plant.

The total emission offset over the lifetime of the CDM/JI is 19.2 million tonnes of carbon. The costs of avoided carbon emissions or the CER/ERU value then is US $17.7/tC based on generating costs per kWhe differentials between the coal baseline and the wind option.

However, because of the intermittent nature of its availability, the wind option does not replace coal base-load capacity really. Hence, the mitigation cost calculation must use only the fuel and variable costs of the displaced coal-fired electricity and not the full generating cost difference. Doing so increases the CER/EUR value of the wind option to US $77/tC.

Gas CDM Option. The CCGT plant emits some 0.333 million tonnes of carbon each year and avoids 0.956 million tonnes of carbon compared to the baseline coal-fired plant. The total emission offset over the lifetime of the CCGT CDM/JI project is 23.9 million tonnes of carbon. The costs of avoided carbon emissions or the CER/ERU value is US $15.1/tC. However, this example assumes the existence of a gas supply infrastructure, which is not usually the case in developing countries. Hence, although the economics of this gas CDM project appears attractive, this option is not available to regions lacking the necessary infrastructure. The inclusion of the development costs for such infrastructures may in itself be a potential CDM project.

The Annex I sponsor, say an electric utility, now has to assess these CER/ERU values with the domestic GHG mitigation options and costs. If CDM/JI projects offer lower mitigation costs, the utility may choose to pay the investment or generating cost difference between the CDM/JI and the baseline project in return for CERs/ERUs in the amount of avoided emissions. The CERs/ERUs then can be applied against the utility's mitigation commitment.

The market value of the CERs/ERUs may be higher or lower than the carbon mitigation costs calculated in this example, depending on the economic performance and market volume of competing CDM/JI or trading projects elsewhere. Moreover, the allocation of emission credits between host and investor would be subject to negotiation. Other negotiable elements could include project duration, the question of baseline dynamics, penalties for defaulting, etc. all of which may tilt the balance in favor or against the viability of a CDM/JI project. The economic benefits to the non-Annex-I country partner include lower technology costs, sometimes lower fuel costs (as in the cases of the advanced coal, nuclear and wind options), technology, capital and know-how transfer as well as substantially lower local and regional pollutant emissions.

In this generic case study all the options qualify under the additionality criterion. They represent investment decisions that would not happen in a purely economics-driven decision environment but demonstrate clear and long-term GHG benefits. In addition, all projects would contribute to sustainable development by way of reduced local air pollutants and other health and environmental benefits.

RETHINKING THE OPTIONS

In November this year, the Sixth Conference of Parties (CoP-6) will continue negotiating the rules and regulations for the flexible mechanisms. Previous CoPs avoided a formal debate about a nuclear role. It remains to be seen whether nuclear power will be included as a clean and sustainable technology. The role of nuclear power needs to be reconsidered, given the potential risk of climate change, and the very few technically and economically feasible means of drastically mitigating GHG emissions in the short run. At least there should be no additional constraints imposed on countries wishing to include nuclear power in their sustainable development plans.

Nuclear energy can generate cost-effective tradable emissions credits among Annex I countries. It would be highly discriminatory, and without basis in international law, to not allow developing countries to exercise similar options, e.g., as offered by the CDM/JI.

The CDM reinforces the key role developing countries can play in solving the problem of limiting future emissions of carbon dioxide and other greenhouse gases, while meeting their justifiable needs for economic development. Financing nuclear power projects in developing countries in exchange for emission credits meets both goals. ❐