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Creating a global warming implementation regime

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This paper proposes a global warming implementation regime which addresses the issues of equity, flexibility, cost minimization, and population growth. Previously proposed international policy instruments, such as country by country targets, carbon taxes, and tradable permits, face major difficulties as stand alone proposals. The key element of the regime proposed here is to combine annual tradable permits which are allocated based on population in a fixed year with a small carbon tax ($5–10/tonne) on emissions in excess of permits. Both permits and carbon taxes are applied to national level governments, which in turn would use whatever mix of policies desired to reduce national emissions. It is suggested that the initial number of permits correspond to total global emissions in the base year; over time, the number of permits could be reduced and the tax rate increased if improved scientific knowledge so dictates. By allocating permits based on population the equity concerns of developing countries are addressed, while taxing emissions in excess of permit holdings removes the rigidity of a quota system and limits resource transfers by effectively capping the permit trading price, which is a major concern of industrialized countries. To accommodate the difficulties of countries which have not yet achieved the demographic transition, the permit allocation scheme could be subject to a one-time adjustment after 10–15 years based on some weighting of the initial and then-current populations. The proposed scheme is based on the premise that there is a large potential for reducing emissions in developed countries or limiting emission increases in developing countries, and the intention is to create competition between national level governments in implementing cost–effective emission reduction.

In order to deal effectively with the limited capacity of the oceans and biosphere to absorb emissions of carbon dioxide, and of the atmosphere in removing emissions of other greenhouse gases, a global warming regime will need to be formulated. A regime can be defined as a set of implicit or explicit principles, norms, rules, and decision making procedures which tend to govern international relations in a certain area.[1] Regimes require a limited renunciation of national sovereignty in exchange for the benefits of increased international cooperation. Well-known examples include the set of trading relationships codified by GATT (General Agreement on Tariffs and Trade), or arrangements governing international balance of payments financing (centred on the International Monetary Fund).[2] Two prominent atmospheric regimes are those governing ozone depleting substances (as represented by the 1985 Vienna Convention, the 1987 Montreal Protocol, and subsequent strengthening accords) and transboundary air pollution (as represented by the 1979 Geneva Convention on Long Range Transboundary Air Pollution and subsequent agreements governing sulphur oxide, nitrogen oxide, and volatile organic compound emissions).

Regime formation typically evolves through a series of steps.[3] The weakest regime can be described as a *declaratory* regime, which involves declared international norms, principles, or objectives, but no international decision making. This stage had already been reached with respect to a global warming regime by 1990, through declarations such as the Declaration of the Hague and the Noordwijk Declaration of 1989 and the final communiqué of the 1989 G–7 summit, which recognized the seriousness of global warming and of the need to limit or reduce greenhouse gas emissions.

Above the declaratory regime is the *promotional* regime, which includes information exchange, international expert assessments, and action plans. Elements of a promotional regime already exist with respect to global warming through such activities as the World Climate Program, the Intergovernmental Panel on Climatic Change (IPCC), and Agenda 21.[4] The recent United Nations Framework Convention on Climate Change is the latest element of this phase, with its declared goal

of 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system', and its requirement for national inventories of greenhouse gas emissions and for the development of action plans to limit emissions, but with no specific targets or timetables.

The next step in dealing with global warming at the international level would be the creation of an *implementation* regime. This regime would include targets and schedules for greenhouse gas emission control, burden sharing rules, funding mechanisms, technology transfer, policy instruments, and the creation of appropriate international institutions. The strongest regime is the *enforcement* regime, which would include procedures for drawing non-parties into the regime and ensuring compliance.

An important element of any global warming regime is the set of international policy instruments used to allocate permitted greenhouse gas emissions among the participating states. Possible instruments include country by country targets or market based mechanisms such as carbon taxes or tradable permits. The choice of policy instruments at the international level must take into account the need to respond flexibly to changes in the scientific understanding of global warming and its impacts, in the costs of emission reduction, or in value systems; of the need to achieve whatever global emission reductions are agreed at the lowest possible cost; and of the need to address concerns of equity and fairness on the part of both developed and developing countries. However, if a global warming regime does not simultaneously address the issue of population growth and of the ultimate need for population stabilization, efforts to stabilize or at least manage changes in the earth's climate are ultimately doomed to failure. Depending on the technical capabilities of providing human needs efficiently and through renewable energy, it might not be possible to simultaneously stabilize atmospheric composition and significantly improve the living standards of the developing world without stabilizing the human population at a level substantially below current projections of 10–12 billion by the year 2100. Measures to stabilize human population are an essential part of a global warming regime.

In addition to these issues associated with the design of an effective global warming implementation regime is a second set of issues associated with the *process* of creating such a regime. Is the Convention-Protocol model, involving negotiations among all or most states and dependent on widespread agreement, and currently the favoured model, the best way to develop a global warming regime? Or should a global regime evolve from a core founding coalition of like-minded states[5] or from a subset of states which voluntarily adopt targets beyond those agreed by the global community at large (a 'club-within-a-club' model)?[6] Should an implementation regime deliberately start off weak to avoid inciting overwhelming opposition from blocking coalitions, with progressive ratcheting of commitments and obligations?[7]

This paper presents a set of proposals which address the issues raised above concerning both the process of creating an implementation regime and the substance of a regime once in place. A number of key premises concerning the nature of the global warming threat and of the options available for responding to it, are first outlined. This is followed by a critique of international policy instruments proposed as part of a global warming regime. The final section of this paper proposes the structure and initiation mechanism for a global warming implementation regime

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I would like to thank Anita Krajnc for bringing many of the political science papers cited here to my attention and for discussions concerning the application of J Donelly's regime typology to global warming.

[1]S D Krasner, 'Structural causes and regime formation: regimes as intervening variables', in S D Krasner (ed) *International Regimes*, Cornell University Press. Ithaca, 1983, pp 1–21

[2]F Hampson, 'Climate change: building international coalitions of the like-minded'. *International Journal* Vol XLV, 1989, pp 36–74

[3]J Donnelly, 'International human rights: a regime analysis', *International Organization*, Vol 40, 1986, pp 599–642

[4]A Krajnc, 'Rio's global climate convention: A promotional regime', *Alternatives* Vol 19, No 3, 1993, pp 11–12

[5]J Sebenius, 'Designing negotiations toward a new regime: The case of global warming', *International Security*, Vol 15, 1991, pp 110–148

[6]P Sand, 'Lessons learned in global environmental governance', *Boston College Environmental Affairs Law Review*. Vol 18, 1991, pp 213–277

[7]*Op cit*, Ref 5

which addresses the key issues of scientific uncertainty, economic efficiency, equity, multi-gas sources and sinks, and the critical – and largely ignored – need for population stabilization.

Risk minimizing greenhouse gas emission policy

The formulation of a global warming regime must be based on a clear understanding of the risks posed by global warming on the one hand, and of the set of options available for limiting or reducing emissions of greenhouse gases and their costs, risks, and ancillary benefits on the other hand. A rational global strategy with respect to greenhouse gas emissions will seek to minimize the sum of the risks of negative impacts due to climatic change associated with a given level of emissions, and the risks associated with the process of achieving that emission level. Both sets of risks have been comprehensively and critically reviewed elsewhere,[8] where stabilization of global fossil fuel CO_2 emissions (along with reduction of net deforestation to zero) is suggested as an interim target likely to come close to minimizing long-term risk. This suggestion follows in part from the conclusions, adopted here, that there is a large potential (25–50%) for reducing CO_2 emissions relative to current emissions in OECD countries with no adverse economic effects if phased with normal rates of equipment and power plant turnover; that the projected growth in emissions from developing countries can be dramatically reduced through application of advanced end use, generation, and renewable energy technologies; that there are a number of barriers which prevent realization of the full cost effective emission reduction potential; and that national, regional, and local governments can collectively, do much to reduce the barriers to cost effective emission reduction as part of a comprehensive and coordinated programme.

A target of global emission stabilization implies that emissions from industrialized countries will need to be reduced so as to permit emission increases by developing countries as they build a modern infrastructure and increase their standard of living. Further differentiation within both developed and developing country groups is justified. Table 1 gives a breakdown within both groups and an example of a distribution of emission increases and decreases which results in stabilization of global CO_2 emissions at the 1989 amount (further details are given elsewhere[9]). Note that simply stabilizing emissions at the present global level with only a 60% increase in emissions from developing countries implies

[8]L D D Harvey, 'Risk minimizing CO_2 emission policy, Part I: Risks associated with unrestrained emissions', *Manuscript in preparation*, 1995; L D D Harvey, 'Risk minimizing CO_2 emission policy, Part II: Risks associated with measures to limit emissions, synthesis and conclusions'. *Manuscript in preparation*, 1995

[9]Harvey, *op cit.* Ref 8, Part II

Table 1. Hypothetical distribution of fossil fuel carbon dioxide emission changes[a]

Country group[b]	1989 Emissions (Mt C)	Emission Change (%)
Industrialized countries	3921.7	−27
Economically strong high	1521.0	−50
Economically strong low	947.0	−20
Economically less strong	93.8	0
Economically weak	1359.0	−10
Rapidly developing countries	178.2	+20
Arab oil producing	127.0	−0
Other developing countries	1730.3	+60
World total	5957.2	−0

[a]The distribution is relative to 1989 emissions which is constant with global emission stabilization, third world development, and a possible distribution of economic and technical potentials for emission limitation

[b]Economically strong, high emitting countries are USA, Canada, and Australia; economically strong, low emitting countries are Japan and those countries in Western Europe not listed as economically less strong; economically less strong countries are Spain, Greece, Portugal, and Ireland; economically weak countries are the former Soviet Union and Eastern Europe (except former East Germany); rapidly developing countries are South Korea, Thailand, Singapore, and Mexico. Emission totals were summed from data given by the World Resources Institute. (*World Resources 1992–93*, Oxford University Press, Oxford 1992, 385pp)

emission reductions on the order of 50% for economically strong, high emitting countries such as the USA, Canada and Australia. Scenarios have been developed by which emission reductions of this magnitude could be achieved for Canada[10] and the USA[11] at low or no net cost.

Stabilization of global CO_2 emissions eventually leads to CO_2 concentrations far in excess of a doubling of the pre-industrial value of 280 ppmv, so that a stabilization target is unlikely to be acceptable indefinitely. Global emission stabilization is very unlikely to be too strong a target, however. Policy makers can therefore begin now to establish domestic policy instruments and international institutional arrangements to stabilize global CO_2 emissions with the knowledge that this target will most likely be strengthened as scientific knowledge improves.

Policy analysis and discussion presented elsewhere[12] indicate that local governments and community based organizations have important roles to play in cost effective CO_2 emission reduction – roles that have been largely overlooked. The primary role of national and regional governments in developed countries would then be a supportive role, involving national efficiency regulations, elimination of energy subsidies (where present), elimination of regulatory and institutional barriers to efficient energy use (where present), and implementation of a modest carbon tax or some other instrument to generate revenues for use in research, development, and demonstration of new technologies and in assisting local governments in building new rapid transit and where appropriate, district heating and/or cooling infrastructure.

Given that there is a large economically attractive potential for reducing or limiting CO_2 emission, but that achieving a large fraction of this potential will require coordinated action between national, regional, and local levels of government, there is a need to create incentives at the international level to implement the internal domestic policies needed to achieve significant CO_2 emission reductions. The remainder of this paper will deal with techniques for creating competition between national level governments in least cost CO_2 emission reduction, recognizing that the magnitude of emission reduction achieved depends critically on the effectiveness of domestic policy instruments and on coordination with lower levels of government. Global instruments must be established which create this competition while addressing the aforementioned issues of economic efficiency, flexibility, equity, and population stabilization.

Critique of proposed international policy instruments

Given a global agreement on limitations regarding the total global emissions of various greenhouse gases, the task still remains of allocating the necessary emission reductions among different nations. Possible allocation mechanisms include country by country targets, tradable permits, and carbon or greenhouse taxes. Strengths and weaknesses of each of these approaches are discussed below.

Country by country targets

Development of country by country targets requires some agreed criteria for allocating emission reductions or constraints. These criteria could include past emissions, current emissions, population, land area, GNP, or economic strength and debt status.[13] Different criteria lead to different allocation schemes. Given the enormous disparities in economic

[10] L D D Harvey, R Torrie and R Skinner, 'Achieving Ecologically-Motivated Reductions of Canadian CO_2 Emissions', *Energy Policy* (submitted)

[11] Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, Union of Concerned Scientists, *America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, Union of Concerned Scientists, Cambridge, 1991. 124 pp

[12] L D D Harvey, 'Implementation of Mitigation at the local level: The role of municipalities', in S K Majumdar, L S Kalkstein, B Yarnal, E W Miller and L M Rosenfeld (eds) *Global Climate Change: Implications, Challenges, and Mitigation Measures*, Pennsylvania Academy of Science, 1992, pp 423–438; L D D Harvey, 'Tackling urban CO_2 emissions in Toronto', *Environment*, Vol 35, 1993, pp 16–20 and 38–44; and L D D Harvey, 'Local actions to reduce greenhouse gas emissions in the context of national action plans', in *National Action to Mitigate Global Climate Change, Proceedings*, 7–9 June 1994, Copenhagen. The latter reference discusses innovative concepts to reduce transaction costs and other barriers to energy efficiency improvements as part of comprehensive, city wide building energy and water retrofit programme planned by the City of Toronto

[13] B D Solomon and D R Ahuja, 'International reductions of greenhouse-gas emissions', *Global Environmental Change*, Vol 1, 1991, pp 343–350, discuss different allocation criteria.

development and energy resources available, equal percentage emission reductions are infeasible, even among industrialized countries, so differentiated targets would need to be negotiated.

The advantage of country by country targets is that uncertainty regarding future emission levels would be reduced since the targets would represent binding obligations. In principle, country by country targets would be flexible over time since the mandated emission levels could be changed as a result of changing social, economic, and technical circumstances and changing scientific evidence. Problems associated with country by country targets include (1) the difficulty in getting all nations of the world to agree to any given set of country by country targets; (2) the great delay that this would pose to international action to address greenhouse gas emissions; and (3) that an incentive might exist to exaggerate the costs of abatement so as to achieve more lax targets.[14]

Greenhouse taxes

Greenhouse taxes could be applied to all fossil fuels in proportion to the CO_2 emissions associated with their use. This would provide an incentive to use less carbon intensive fossil fuels or renewable energy sources, and to use energy more efficiently than at present. Taxes provide an incentive for polluters to reduce emissions as much as they can, and possibly below that which would be required by law.

The level of domestic emission abatement achieved by a given tax level is uncertain, so that it is a crude policy instrument. However, taxation at the international level applied to governments could act as an incentive to institute a whole range of policy options at the domestic level, only one of which might be a domestic tax.

Economic models suggest that, in the absence of other policy measures, carbon taxes on the order of \$100–500/tonne C would be needed to significantly influence CO_2 emissions.[15] If implemented domestically by national governments, carbon taxes of this magnitude could have a negative economic impact, although a greenhouse tax could be offset by reductions in other taxes as part of a move away from income taxes and toward pollution and resource depletion taxes. However, progress on global warming in this case would be tied to the rate of tax reform in the slowest country, since it is unlikely that a nation would simultaneously use a large carbon tax and retain its old tax structure.[16] If also part of an international taxation system, potentially large financial transfers could occur, depending on how the tax was redistributed. On the other hand, a carbon tax small enough to avoid significant international transfers or negative economic impacts would, if unaccompanied by other measures, have little effect on CO_2 emissions because it would have little effect on fossil fuel prices.[17]

Tradable permits

Under a tradable permits scheme, permits to emit CO_2 and possibly other greenhouse gases would be issued to individual national governments (or to individual emitters). Those governments (or emitters) which are short of permits or who find emission reduction to be too costly could purchase permits from those with an excess. If strictly enforced, tradable permits ensure that a given target is reached since the permits amount to a form of rationing.

The advantages of a tradable permit system are (1) only the overall

[14]This concern was raised by M Grubb and J K Sebenius, 'Participation, allocation and adaptability in international tradable emission permit systems for greenhouse gas control', *Proceedings OECD workshop on tradable emission permits to reduce greenhouse gas*. Paris, June 1992

[15]W Cline, *The Economics of Global Warming*, Institute for International Economics, Washington, DC, 1992, for a summary and critical discussion of economic models and the carbon tax calculated to be necessary to achieve varying degrees of CO_2 emission reduction

[16]D G Victor, 'Practical aspects of implementing greenhouse taxes: Issues for OECD countries', in *Fee and charge systems for reducing greenhouse gases*, proceedings of OECD workshop, Paris, 5–6 November 1991, pp 241–272

[17]As a convenient point of reference, a tax of \$100/tonne C corresponds to a price increase of about \$73/tonne of coal or \$2.5/GJ (compared to current prices of \$1.5–2.5/GJ), \$11.4 per barrel of oil (compared to a current price of \$20/barrel), and about \$50 per 1000 m^3 of natural gas or \$1.35/GJ (compared to \$3–5/GJ today)

level of CO_2 emissions needs to be specified, not the country by country distribution of targets (thus giving what Grubb and Sebenius[18] refer to as *negotiating efficiency*); (2) it is theoretically possible to achieve the lowest cost in meeting a given global emission limit with tradable permits, if the cost of permits is passed on to individual emitters and under the assumption of a perfectly operating market; (3) full scope is available for innovation and flexibility in reducing CO_2 emissions, since as economic and technological conditions change, the market may reallocate tradable permits, depending on the extent of market imperfections, without the need for central administrative interference – giving what Grubb and Sebenius[19] refer to as *dynamic flexibility*; and (4) one could create a constituency with an interest in gradually reducing the number of permits so as to increase their value – namely, those with excess permits to sell.[20]

Tradable permits have been criticized on the grounds that they create pollution rights, such that pollution is permissible if one is rich. However, CO_2 is in many respects a completely harmless gas and has a number of beneficial effects on plant growth. The problem is not CO_2 emissions *per se*, but rather, emissions in excess of the absorptive capacity of the ocean-biosphere-rock weathering system. It is therefore not reasonable to object to tradable permits on the grounds that they create pollution rights.

Among the issues to be resolved with a tradable permit system are (1) the initial allocation of permits; (2) the lifetime of individual permits; (3) the currency of exchange for permits; (4) which gases to include in the permit trading system; (5) whether to include sinks as well as sources; and (6) how to accommodate the addition of new countries to the permit trading group. These issues are discussed below.

Initial allocation of permits

The problem of permit allocation is analogous to the problem of allocating targets in a country by country approach, except that the stakes are not as high since additional permits can, in principle, be acquired through trading. Equity considerations have played an important role in a number of international environmental agreements[21] and will be important in any global warming regime. Among the criteria proposed as forming the basis for a 'fair' allocation are (1) population; (2) GNP (level of economic development); and (3) current emissions.

Allocation based on population implies that every human being has an equal right to emit CO_2 and thus appears inherently fair. It is strongly supported by developing countries, which have low per capita emissions and would thus receive an excess of permits, but has been vigorously opposed by a number of industrialized countries. Potentially large resource transfers to the developing world would result, and for this reason most political analysts consider per capita allocations to be infeasible.

A critical weakness of allocation based on population is that it would provide an incentive for population growth. To weaken this incentive, Grubb[22] suggested an allocation scheme based on adult population. This proposal risks not providing an adequate incentive for population control. Indeed, some countries might encourage high population growth in the near-term in order to win more permits in the longer-term, when they might be more valuable. Although an allocation based on adult population reduces the imbalance between developed and developing

[18] *Op cit*, Ref 14
[19] *Ibid*
[20] J Sebenius, personal communication, 1991
[21] O Young, 'The politics of international regime formation: managing natural resources and the environment', *International Organization*, Vol 43, 1989, pp 349–376
[22] M Grubb, 'The greenhouse effect: negotiating targets', *International Affairs*, Vol 66, 1990, pp 67–89

countries, it would still be resisted by industrialized countries, who would want to initially 'grandfather' the permits by basing the initial allocation on current emission levels.[23]

An allocation based on current emissions would constrain development in developing countries, would fail to recognize the greater responsibility of the industrialized countries in increasing current greenhouse gas concentrations, and would build in the current inequities between developed and developing countries. Although likely to be supported by industrialized countries, it would be vigorously opposed by developing countries. It stands little chance of being accepted by the global community at large.

An allocation based on GNP will tend to reward the rich and/or major emitters, is plagued by problems of measurement and conversion, and only crudely reflects economic activity. As well, it fails to recognize ecological and food security limits to climatic change, since permitted total emissions would increase as total economic activity increases unless the permit: GNP ratio is continuously renegotiated downward, which might be difficult.

Attempts at piecemeal, country by country allocation based on 'special circumstances' are likely to become hopelessly mired in disagreements. Cold countries might claim a need for more permits to account for heating requirements, while warm countries could make the same claim for air conditioning. Large, low density countries might claim a need for greater permits for transportation energy use, although the high transportation energy demand in countries such as Canada, the USA, and Australia is more related to the low *urban* density and to lifestyle.[24]

Lifetime of individual permits

Under some proposed permit trading schemes, emission permits would have a lifetime of several decades so as to permit long-term planning by industry. To prevent rich countries from being able to 'buy up' the market for decades, Grubb and Sebenius[25] propose that permits be overlapping: for 20–30-year permits, a tenth would be withdrawn every 2–3 years and replaced with a new issue according to the agreed and current allocation algorithm. Partially 'used' permits could be traded at any time, carrying with them an entitlement to emit the 'unused' portion during the remaining permit lifetime.

An alternative, and simpler, procedure would be to reissue permits each year which would be valid only for the coming year. This would make it impossible for rich countries to buy up or hoard the permits on a long-term basis. Industry would not be guaranteed a long-term supply of permits corresponding to a given emission level, a situation one would in any case want to avoid in the event that improved science requires a downward revision in the total number of permits, or a more rapid downward revision than initially anticipated. The risk of reduced permit levels in the future is one of the factors that industry would have to take into account when choosing particular energy investments.

Currency of exchange for permits

An unrestricted cash flow could be spent on import based consumerism or military spending; hence, some restrictions on the use of funds from traded permits (or carbon taxes) might be required. Conversely, it has been suggested that permits could be obtained through non-financial transactions, such as technological transfer or technical assistance in

[23]D Pearce, 'Economics and the global environmental challenge', *Millennium*, Vol 19, 1990, pp 365–387

[24]See P W G Newman and J R Kenworthy (*Cities and Automobile Dependence*, Gower Technical, Aldershot, 1989, 388 pp), who compare per capita gasoline energy use, urban density, and other urban attributes for a number of cities in North America, Europe and Australia

[25]*Op cit*, Ref 14

limiting growth of energy demand.[26] However, this suggestion seems to unnecessarily complicate the scheme, since strong incentives would already exist to use the funds from the sale of permits to limit long-term CO_2 emissions and thereby secure an ongoing revenue source.

Gases to be included in the permit trading system

In order to be able to trade between greenhouse gases it is necessary (1) that the relative climatic impact of different greenhouse gases can be quantified, (2) that the emission sources of different greenhouse gases are known and (3) that reductions in emissions of all the gases in the trading system can be monitored and verified. Attempts have been made to develop a 'Global Warming Potential' index, whereby the climatic impact of emissions of different greenhouse gases is compared with that of CO_2. As discussed by Harvey,[27] the calculation of GWP's is fraught with enormous conceptual difficulties and scientific uncertainties which preclude their use in an inter-gas emission trading scheme. The only greenhouse gas emission sources known with reasonable accuracy are fossil fuel CO_2 emissions and CFC emissions. However, it appears that the net effect of CFC emissions is close to zero or even one of cooling if the induced stratospheric ozone depletion is taken into account.[28] Difficulties in the monitoring and verification of emissions for other greenhouse gases or for CO_2 emissions from deforestation are so large as to preclude their inclusion in a permit trading scheme, at least initially.[29] Finally, equity problems could arise if 'luxury' emissions in industrialized countries can be traded against 'survival' emissions (ie, methane emissions from rice paddies) in developing countries. Third world governments might attempt to constrain agricultural CH_4 emissions by encouraging or mandating a change in agricultural activities, to the detriment of rural populations, in the same way that land originally used for local food production has been forcibly converted to export oriented cash crop production to help finance external debts, often to the detriment of local populations.

Inclusion of sinks

It has been proposed by some that carbon sinks created through reforestation be allowed as credits against energy related CO_2 emissions. There are several reasons for not including reforestation carbon sinks in an emission permit trading scheme (or allowing it to offset energy related CO_2 emissions under country by country targets):

- many developing world governments regard it as a form of environmental colonialism, with developing countries forced to compensate for continuing excessive energy use in the developed world;
- avoiding a given CO_2 emission is not equivalent to absorbing the same amount through reforestation, because of changes in surface albedo associated with vegetation changes and likely cloud feedbacks;[30]
- estimated reforestation sinks would include the effect of enhanced photosynthesis due to higher atmospheric CO_2 and the effect of climatic change due to greenhouse gas increases. Assuming that these effects could be separated from the effects of management practices, international attribution of that portion of the national biosphere sink (or source) due to CO_2 and climate biosphere feedbacks would involve politically intractable difficulties;

[26] *Op cit*, Ref 5

[27] L D D Harvey, 'A guide to global warming potentials', *Energy Policy*, Vol 21, 1993, pp 24–34

[28] A Lacis, D Wuebbles and J A Logan, 'Radiative forcing of climate by changes in the vertical distribution of ozone', *Journal of Geophysical Research*, Vol 95, 1990, pp 9971–9981

[29] D G Victor 'Limits of market-based strategies for slowing global warming: The case of tradable permits', *Policy Sciences*, Vol 22, 1990, pp 199–220

[30] For deforestation in the Amazon, R E Dickinson and P Kennedy ('Impacts on regional climate of Amazon deforestation', *Geophysical Research Letters*, Vol 19, 1992, pp 1947–1950) compute a surface albedo (reflectivity) increase of 0.07, which causes a decrease in absorbed solar radiation of 16 W/m^2, and a reduction in cloud cover giving an increase in solar radiation absorbed at the surface by 13 W/m^2, for a net decrease in solar radiation absorbed at the surface of 3 W/m^2. The decrease in cloudiness would reduce absorption of solar radiation in the atmosphere by a further 1–2 W/m^2, for a total reduction in the absorption of solar radiation of 4–5 W/m^2. Reforestation of 1 million km^2 of tropical forest at a carbon density of 150 tonnes/ha would sequester 15 Gt C and reduce greenhouse heating by 0.124 W/m^2. Assuming, as an approximation, that the reverse albedo and cloud changes would occur with reforestation as for deforestation, the reduction of surface albedo would increase the global average absorption of solar energy by 0.031 W/m^2, thereby offsetting about 25% of the reduced greenhouse heating, while with cloud feedback the offset would be only 6–8%. These results are highly uncertain and would vary depending on the specific region undergoing reforestation

- allowing reforestation as an offset to continuing CO_2 emissions might create pressure to carry out 'plantation style' reforestation, which may give the largest carbon storage but does not satisfy other important concerns, such as ecological diversity and provision of local services;
- it might direct attention away from measures which are more cost effective in the long run but much less quantifiable, such as measures directed toward removing pressures on existing forests by promoting more efficient agriculture and more efficient use of biomass energy resources;[31]
- reforestation is reversible, either from direct anthropogenic causes or climatic change itself, whereas fossil fuel emissions are not.

Accommodating the addition of new countries to the permit trading group

As discussed by Grubb and Sebenius,[32] shocks to the permit system could occur when large emitters are added to the system, even though the number of permits available would increase. If the new participant has disproportionately high emissions it will be short of permits unless the permits are issued in proportion to initial emissions, and so will compete for permits with other parties which are short of permits. If the new entrant is a large country with low per capita emissions, the per capita emission averaged over all participating countries would be reduced, and any allocation formula based on per capita emissions would result in less for *all* the existing participants. On the other hand, if a country with greater than average emissions joins the club, the permit allocation to *all* other participants would increase.

Grubb and Sebenius suggest that participating countries be allowed to 'offset' their emissions by investing in abatement projects in countries *outside* the participating group as a transitional step to bring other countries into the trading system. This is similar to the clearing house mechanism proposed by the Norwegian government,[33] which is essentially the same as the concept of 'joint implementation' promoted by the USA.[34] A simpler alternative would be to allow a transition period for countries whose entry into the trading system would create shocks, with an initially small but increasing proportion of its emissions governed by tradable permits.

A proposal for the creation of a global warming implementation regime

In limiting energy related carbon dioxide emissions, international policy instruments are needed which acknowledge the importance of the precautionary principle, can respond flexibly to improved scientific knowledge, are perceived as fair by both developed and developing countries, which provide incentives for population stabilization, which encourage economic efficiency, and which are as simple as possible. Outlined below is a set of proposals which addresses all of the above concerns by combining elements of tradable permit and carbon tax proposals. These proposals will need to be accompanied by the step by step development of a comprehensive set of individual protocols governing all the other important greenhouse gases and greenhouse gas precursors.

Summary

The proposed global warming implementation regime contains the following elements:

[31]Such measures, to the extent that they improve standards of living, will also tend to reduce long-term population growth rates and thus indirectly lead to lower future greenhouse gas emissions. See World Bank (*World Development Report 1984*, Oxford University Press, 286 pp) on the relationship between development and population growth rates

[32]*Op cit*, Ref 14

[33]*Climate Change Policy Initiatives*, International Energy Agency, Paris, 1992, pp 92–93. The clearing house would receive project proposals from countries with opportunities to inexpensively reduce emissions compared to their agreed limit, would evaluate their effect on greenhouse gas emissions, and would link the projects to investment funding from those countries willing to meet part of their emission reduction commitment outside their borders

[34]*Global Climate Change Digest*, Vol 7, No 6, 1994, p 17

- allocate CO_2 fossil fuel emission permits to national governments based on population in a fixed year, such that total permits equal total base year CO_2 fossil fuel emissions summed over the participating countries;
- make the permits valid for one year and reissuable each year;
- impose a small tax ($5–10/tonne carbon, for example), payable by *governments* to a central fund, on emissions in excess of the number of permits held by a given country, whether acquired through the initial allocation or by subsequent trading;
- establish an effective review process which collects and harmonizes data on national emissions and disseminates information on state of the art energy saving and renewable energy technologies, successful national and local policy measures, and progress being made by countries participating in the permit trading system;
- establish an International Energy Efficiency Agency (IEEA) to perform some of the above functions as well as sponsor joint research, development, and demonstration projects among participating countries and develop efficiency standards for equipment, automobiles, and trucks to be applied uniformly in all participating countries;
- if necessary, gradually reduce the total number of permits and increase the taxation level so that the variation of total CO_2 emissions over time, as projected by economic models with end-use detail and updated by experience, is consistent with requirements for ecological and food security protection based on continuing refinements of ecological, agricultural, climate, and carbon cycle models; and
- renegotiate the allocation of permits, say, 15 years after the initiation of the tradable permit system based on a yet to be determined weighting of the global population distribution during the start-up year and 15 years thereafter.

For reasons discussed above, the emission permit/taxation scheme should be restricted to energy related CO_2 emissions.[35] Restrictions on other greenhouse gases and protection of global forests (both tropical and temperate) should be negotiated as separate conventions and protocols.

Discussion

Country by country targets, tradable permits, and carbon taxes all have major difficulties when viewed as independent proposals and are therefore likely to incite major opposition from one or more nations or transnational groups. Country by country targets are particularly divisive. Market based approaches such as tradable permits and carbon taxes have the advantages of flexibility, economic efficiency, and negotiating efficiency. However, an international carbon tax applied directly to fossil fuels (as most proponents of an international carbon tax envisage) would have to be so large in order to significantly influence consumer behaviour (in the absence of effective complementary policy actions) that serious equity concerns arise regarding poorer countries or the poorer members of individual countries. A large international tax would also seriously impinge on national sovereignty. One can expect vigorous opposition to an international carbon tax by many countries. The stumbling block with tradable permits is getting agreement on the initial allocation of permits; the prospect of finding common ground between nations supporting an allocation based on population and those supporting an allocation based on current emissions seems remote.

[35]The argument for including all major greenhouse gases in an emission trading scheme or in a single target for overall radiative heating is that it would allow different states to concentrate on reducing emissions of those greenhouse gases whose emissions (and associated heating impact) could be reduced at the lowest cost. However, as discussed by M J Grubb, D G Victor and C W Hope 'Pragmatics in the greenhouse', *Nature*, Vol 354, 1991, pp 348–350, the extra growth in CO_2 emissions that can be bought by increasingly stringent controls in CH_4 is limited and subject to diminishing returns, while exponential growth in CH_4 emissions cannot continue no matter how much CO_2 emissions are restricted if global warming is to be limited to 2.5 C to 4 C. Furthermore, as discussed by Harvey, *op cit*, Ref 27, some of the most economically attractive measures to reduce fossil fuel CO_2 emissions by switching from coal to natural gas also reduce CH_4 emissions, so that simultaneous reductions in both greenhouse gases can be achieved

However, the problems associated with both tradable permits and carbon taxes can be avoided if they are *simultaneously* implemented according to the proposals outlined above. By allowing taxable emissions in excess of the permits, the free market price of the permits (and associated financial transfers) would be capped at the taxation rate, since it would be cheaper for governments to pay the tax than to buy permits if the price of permits exceeds the tax. The relative effectiveness of different governments in implementing domestic policies to limit emissions would determine how the reductions are allocated among different nations, thereby eliminating the most contentious and divisive negotiation issue. Because the cost of permits would initially be capped at a low value, the initial allocation of permits would be much less important than country by country targets and therefore easier to agree. Allowing emissions in excess of permit holdings eliminates rigid targets and allows for year to year fluctuations in economic activity and associated CO_2 emissions, which would also make agreement easier.

Permits would be valid for one year only and reissued each year, thereby eliminating potential problems of hoarding. Since developing countries have lower than average per capita carbon dioxide emissions, a population based allocation of permits corresponding to current global emissions would guarantee that developing countries have excess permits which they could sell to finance efficient energy use and other development needs. The tax on excess emissions could be earmarked for energy efficiency and renewable energy projects in the Third World only, or in all countries paying the tax.[36]

Thus, the proposals presented here avoid divisive deliberations over country by country targets, allow for the efficiencies of a market based mechanism (where the players are individual governments), address the equity concerns of the developing world and the need for financial transfers both for energy projects and for general development, and address the concerns of developed countries over the magnitude of resource transfers. Equity concerns are addressed by allocating permits based on population, but initially setting the number of permits at current emissions and levying a small tax on emissions would limit the magnitude of the resource transfer, thereby satisfying the major objection of developed countries to population based allocation schemes. There would be no need for recourse to grandfathering schemes, which are unlikely to ever be acceptable to the developing world.

Table 2 shows the international financial transfers that would result assuming that permits corresponding to total 1990 emissions are allocated based on 1990 population and that the permit price is $10/tonne. Transfers are given both for the 1990 distribution of emissions and after the emission changes given in Table 1. Present official development assistance (ODA) is also given for comparison. The additional financial transfers from OECD countries resulting from permits trading at $10/tonne are generally much less than current ODA, with the exception of the USA, where the additional financial transfer is comparable to current ODA. Note that because the former USSR and other former East-bloc countries have high per capita emissions (an average of 3.3 tonnes C/year), they would have to purchase permits and act as a source of funds to the developing world in a population based allocation. Clearly, special provisions would have to made for the former East-bloc countries.

Also shown in Table 2 are current levels of ODA as a fraction of GNP. Most OECD countries have accepted the UN target of 0.7% of GNP for

[36]Recycling the proceeds of the tax back to countries paying the tax would reduce any negative economic impacts of the tax, although for a small tax these impacts would be negligible. Indeed, the tax could be used to *increase* long-term economic productivity through strategic reinvestment in energy efficient technologies and infrastructure. Net transfers to developing countries would then occur only through sale of tradable permits. Since governments would prefer paying a tax they get back rather than buying permits, the market price of permits would drop below the tax rate in this case. If, on the other hand, the tax revenues are redistributed based on population, this should be done based on population in a fixed year, as in the yearly permit allocation. Even in this case, some of the tax revenues would flow back to developed countries through the purchase of energy efficient technologies and expertise from developed countries

Table 2. Financial transfers to and from selected countries[a]

Country	Financial transfer 1989 emissions	Financial transfer Altered emissions	Official development assistance Amount	Official development assistance As % of GNP
Argentina	+49	−144	+172	0.2
Australia	−508	−156	−955	0.34
Austria	−54	−25	−394	0.25
Belgium	−153	−100	−889	0.45
Brazil	+1166	+827	+164	0.0
Canada	−936	−316	−2430	0.44
China	+6644	+2770	+2076	0.6
Denmark	−69	−44	−1171	0.93
Finland	−83	−55	−846	0.64
France	−328	−133	−9380	0.79
Germany	−877	−526	−6320	0.42
India	+8035	−6969	+1586	0.6
Indonesia	+1744	−1519	+1731	1.6
Italy	−405	−193	−3395	0.32
Japan	−1415	−848	−9069	0.31
Mexico	−148	−331	+140	0.1
Netherlands	169	−100	−2592	0.94
Norway	−77	−52	−1205	1.17
Poland	759	−639	—	—
Spain	115	−115	—	—
Sweden	−63	−31	−2012	0.90
UK	−891	−581	−2638	0.27
USA	10401	−3768	−11394	0.21
Former USSR	−7046	−6010	—	—
Venezuela	−34	−178	+79	0.2

[a]It is assumed that permits corresponding to total 1989 emissions are allocated based on 1990 population and trade for US$10/tonne. Transfers are computed assuming the 1989 emissions and assuming the changes in emissions given in Table 1. Official development transfers in 1990, as tabulated by the World Resources Institute. (*World Resources 1992–93*, Oxford University Press, Oxford, 1992, 385pp), are given for comparison (negative values indicate donor countries). All transfers are in million US$.

ODA, a target reaffirmed by *Agenda 21*,[37] although very few have achieved this target. If current levels of ODA are not reduced to offset the transfers associated with permit trading, all nations except Finland which have not achieved the 0.7% target would still be below the target, while for those nations already providing in excess of 0.7% GNP as ODA, the additional transfer is small compared to current aid levels. For current emissions and permits trading at $10/tonne, the total transfer from OECD countries would be about $16.7 billion per year. This is somewhat less than the $20 billion per year of additional funding estimated by the UNCED Secretariat to be necessary to implement the climatic protection measures listed in *Agenda 21*.[38]

Governments, rather than individuals or corporations, would hold the permits, exchange them, and pay any required carbon taxes in the scheme proposed above. There would therefore be no *direct* price signal to greenhouse gas emitters through the purchase of permits or payment of carbon taxes. However, governments could use whatever domestic policy instruments they wished to send signals directly to emitters within their jurisdiction, and could collect the necessary revenues to purchase permits or pay the international tax in whichever way they choose. Governments which presently subsidize energy would have an additional incentive to end such subsidies,[39] while countries which have already invested in energy efficiency measures would be rewarded.

The magnitude of the carbon tax proposed here ($5–10/tonne) is substantially less than the tax felt to be necessary ($100–500/tonne) to stabilize emissions according to several macroeconomic modelling exercises. This is not of concern for three reasons. First, macroeconomic analyses of options to limit greenhouse gas emissions are based on a number of questionable assumptions and exclude many of the measures that would be taken in response to higher fossil fuel prices (see Harvey[40] for a critique of one such model). Second, macroeconomic analyses assume carbon taxes as the sole tool to achieve emission reduction,

[37]United Nations Conference on Environment and Development (UNCED), *Agenda 21*, Article 33.15, 1992

[38]*Op cit*, Ref 37, Article 9.33

[39]Studies by the OECD and World Bank indicate that the fossil fuel subsidy in non-OECD countries averages $92/tonne carbon (see M Grubb, J Edmonds, P ten Brink and M Morrison, 'The costs of limiting fossil fuel CO_2 emissions: A survey and analysis', *Annual Review of Energy and the Environment*, Vol 18, 1993, pp 397–478)

[40]L D D Harvey, 'Review of "Buying Greenhouse Insurance: The Economic Costs of CO_2 Emission Reduction" by A S Manne and R Richels', *Climatic Change*, Vol 28, 1994, pp 405–410

whereas, here, it is assumed that the primary emphasis will be an attack on the barriers to rational energy use, rational national energy policies, and strategic infrastructure investments combined with appropriate action at the local level. Third, the permit/carbon tax system, because it involves international resource transfers, merely functions as a *stimulus* to national governments to implement the necessary domestic policies and regulatory reforms to achieve more rational energy use and to initiate the necessary dialogue and cooperation with local governments; the premise here is that national governments with excess emissions will want to minimize international resource transfers, while governments with excess permits will want to maintain as large a surplus as possible, and will therefore implement the measures which will directly achieve emission reductions. This could very well include a domestic carbon tax which is larger than the international carbon tax proposed here. In any case, achievement of emission reductions will depend heavily on the active participation of local governments and community groups, as well as trade associations and other groups, in a bottom-up approach to policy implementation.[41]

By restricting permit trading to between governments, the proposed scheme would function in a manner similar to the Clearing House/Joint Implementation concept mentioned above, to the extent that financial transfers from industrialized countries are used by developing countries to limit the growth of their own emissions. However, the scheme proposed here would give developing country governments a source of revenue which could be used for general development needs (which is essential for long-term population and hence atmospheric stabilization), whereas Joint Implementation would result in financial transfers only for projects directly reducing CO_2 emissions. In addition to financial transfers through permit trading which could be used for general development needs, further transfers earmarked specifically to the acquisition of the most energy efficient technology available could be provided from the tax on excess emissions. Unlike the Joint Implementation concept, there would be no need to determine what emissions would have been in the absence of energy efficiency investments in developing countries nor to determine the net incremental cost of such investments.

Role of the International Energy Efficiency Agency

The global warming implementation scheme proposed here includes an International Energy Efficiency Agency (IEEA) funded from the carbon tax on excess emissions. As discussed by Geller,[42] the IEEA should:

- collect, compile, and share information about state of the art energy conserving technologies (using uniform test procedures), successful policies and programmes, planning and regulatory techniques, and the status of implementation in different countries;
- sponsor joint R&D and demonstration projects;
- develop and recommend minimum efficiency targets for appliances, automobiles, and industrial processes, and discourage manufacturers from maintaining dual efficiency standards (efficient equipment for developed countries, inefficient equipment for developing countries);
- support energy efficiency in developing and Eastern European countries through institutional development, technical assistance, and training; and

[41] *Op cit*, Ref 12

[42] H S Geller, 'Establishing an international energy efficiency agency - a response to the threat of global climate change', *Energy Policy*, Vol 19, 1991, pp 689–695

- finance energy efficiency improvements in developing and East European countries.

Since formal coercive sanctions will not be part of the global warming regime proposed here, open information on the performance of the parties, compiled and disseminated by the IEEA, would play an important role by generating pressure for improved performance. The process would be consultative, not adversarial or confrontational. By making available reports on what other nations are doing, this will help individual nations to refine their own policies and make it easier to ratchet up the restrictions on greenhouse gas emissions later. The impact of reporting by the International Labour Organization (ILO) has been cited as a good example.[43] Reporting and review would play the important role of building norms without formal commitments.[44] The usual objection to creation of bodies such as an IEEA is that it represents yet another international bureaucracy. However, the proposed IEEA could evolve from the climate related sector of the Global Environment Facility (GEF), which has been adopted as the institution for administering the financial mechanism associated with the UN Climate Convention and for providing limited funding for greenhouse gas emission reduction measures in developing countries,[45] or it could evolve from the International Energy Agency (IEA), which already has programmes for cooperative energy research and development. In any case, an IEEA would perform several important functions which are currently not carried out by existing agencies.

Foremost among these functions would be assistance to developing countries in technological 'leapfrogging'. Two important areas where this is needed are electricity generation from coal and steel making. Currently, electricity is generated from coal with an efficiency of 31–35% in industrialized countries and 24–28% in some developing countries, while fuel cell based technologies nearing commercialization will result in efficiencies of about 50% (giving about a factor of two reduction in CO_2 and CH_4 emissions per unit of electricity in the case of developing countries).[46] Developed countries should be given the means to jump directly from their current low efficiency to an efficiency of 50% as soon as such technology becomes available, something the IEEA could hasten. In the case of steel, advanced technologies could reduce the energy requirements by almost a factor two compared to current best practice and by more than a factor of three compared to the US average,[47] but their development has either been halted or greatly slowed due to the fact that demand for steel is falling in industrialized countries; under such circumstances, the cost for any one country to develop advanced production technologies is not justified. However, with steel demand poised to grow dramatically in developing countries, a case can be made for joint development of advanced technologies and their transfer to the developing world. The chemical industry provides other opportunities for significant energy efficiency gains through technological leapfrogging.[48]

Population growth and per capita emissions: complementary developing and developed world concessions

By basing the initial allocation of permits on population in some fixed reference year, a powerful incentive would be created for population control. However, there is a considerable inertia to population growth

[43]A Chayes and E B Skolnikoff, 'Core institutional arrangements for a global climate change regime' (presented to the Bellagio Conference, 28–30 January, 1992)

[44]D G Victor, A Chayes and E B Skolnikoff, 'Pragmatic approaches to regime building for complex international problems, in N Choucri (ed) *Global Change: Environmental Challenges and International Responses*, MIT Press, 1992, pp 453–474

[45]A Jordon, 'Paying the incremental costs of global environmental protection: The evolving role of GEF', *Environment*, Vol 36, 1994, pp 12–20 and 31–36

[46]For a discussion of fuel cells and other advanced technologies, see L D D Harvey, 'Solar-hydrogen electricity generation in the context of global CO_2 emission reduction', *Climatic Change*, Vol 29, 1995, pp 53–89

[47]J Goldemberg, T B Johansson, A K N Reddy and R H Williams, *Energy for a Sustainable World*, Wiley, New Dehli, p 137

[48]*Op cit*, Ref 47, pp 142–146

and developing countries which have not yet achieved the demographic transition would be at a disadvantage. To partially account for the lag in stabilizing population, it could be agreed to allow a redistribution of permits in 10–15 years based on some weighting of the then-current and initial population distributions.

Thus, both the developed and developing world face penalties and advantages in an allocation scheme based on population during a fixed reference year: the developed countries have high per capita emissions and a lag occurs in the transition to best available technology to reduce emissions, but most have stable or very slowly growing populations, while developing countries have high population growth rates and will experience a lag in reducing population growth, but have significant opportunities for technological 'leapfrogging' as they undergo development. Since both groups of countries would experience both advantages and disadvantages, and both will be seen to be conceding something, acceptance of this allocation will be easier than if one group only has to make concessions.

Long-term limitation of greenhouse gas emissions requires different policy responses in developed and developing countries: in the case of developed countries, per capita emissions must be reduced, while in the case of developing countries it is more important to stabilize population than to limit the near-term increase in per capita emissions. The regime proposed here will provide strong incentives for this asymmetric response.

An exception to the above generalization occurs in the case of Canada, the USA, and Australia, all of which have high per capita emissions and relatively high population growth rates. These countries, like developing countries, will also have to grapple with population policy as part of their response to the need to limit greenhouse gas emissions.

Getting started

Although it is desirable to include all the major and potentially major CO_2 emitters in a global warming implementation regime, this may not be possible initially. In this case, a tradable permits/taxation scheme should be set up among whatever group of nations is prepared to initiate the regime, once a group of sufficient size and diversity to work effectively is identified. If the founding coalition consists only of industrialized nations, for which absolute emissions reductions are readily achievable at a net economic saving, then the number of permits should be set at less than current total emissions so as to provide downward pressure on emission levels.

It is preferable that the founding coalition include at least one major developing world country with a potential for rapid growth in energy related CO_2 emissions so that the mechanics and benefits of resource transfers and permit trading can be more effectively demonstrated. Since tradable permits allocated based on population represent a form of side payment, countries with large populations and low emissions would benefit from joining the emission trading scheme even if they anticipated no harm from global warming.[49]

Once the initial emission trading club is established, the prospect of 'symmetric' expansion through simultaneous accession by one or more developed and developing world emitters may provide the necessary joint gain to get both parties to join when neither party would join unilat-

[49]For a discussion of the role of side payments (or 'selective incentives') in past international environmental agreements, see Sand, *op cit*, Ref 6

erally. For example, suppose that neither the USA nor China are part of the founding coalition. Neither party might see enough gain in terms of avoided climatic change or other benefits to join without the other joining, but might be convinced that the costs of domestic action to limit emissions were justified if the other party were also to limit emissions: the USA would see the benefit of avoiding future Chinese emissions much larger than the reductions it would have to make or could make in its own emissions, while China would see the USA as a ready market for its excess permits and source of funding for technology transfer.

In the absence of joint industrialized/developing country accession, non-participant countries may conclude that they are better off not participating because their own emissions are too small, while benefiting from the emission reductions by other countries. This behaviour is known as 'free-riding'.[50] By negotiating simultaneous accession by industrialized and developing country pairs, the temptation to free-ride could be reduced.

Adjustments for exports, imports, and migration

It can be argued that, in calculating national emission levels for purposes of permit trading and taxation, allowance should be made for exports and imports of carbon intensive products so as not to penalize countries with carbon intensive, export oriented industries. This would include emissions associated with oil refining and oil and gas extraction, when the oil and gas are exported to other countries. Such allowance is not necessary because the cost of the permits associated with these emissions can be passed on to the consumer, and it is not desirable as it would weaken the effectiveness of the regime in reducing CO_2 emissions. Price increases, on the other hand, would have the effect of discouraging consumption of carbon intensive products (although not to a great extent given the initial permit prices and tax levels envisaged here). Countries whose economies are highly dependent on the export of carbon intensive products can be expected to oppose any effective global warming regime, although if the major importers of these products reduce their consumption, such countries will be forced to diversify their economies or find ways of reducing emissions associated with the products they export if they are to remain at their current level of prosperity.

In allocating permits over time, a case can be made for accounting for migration to a given country in excess of migration required to maintain population stability.[51] This could create measurement problems, but net immigration in excess of stability requirements occurs largely in developed countries, where the required data are readily collected.

Responding to changing circumstances

The most important task at this stage is to establish effective and flexible implementation mechanisms for controlling greenhouse gas emissions, even if the initial levels of control fall short of those dictated by the precautionary principle. The implementation regime proposed here allows for an upward 'ratcheting' of the controls in response to either cyclical waves of political concern, new technological developments regarding efficient use of energy and renewable energy, or yet stronger scientific data indicating the need for greenhouse gas emission limitations.[52] Upward ratcheting would occur through a decrease in the number of permits issued coupled with an increase in the taxation level.

[50]For example, Pearce, *op cit*, Ref 23

[51]Given that fertility levels are below the replacement level in many OECD countries, an eventual population decline would occur in the absence of immigration. See *Future Demographic Trends in Europe and North America: What Can we Assume Today?*, International Institute for Applied Systems Analysis, Laxenberg, 1990, 585 pp

[52]Sebenius, *op cit*, Ref 5 for an exposition of the need for built-in ratcheting mechanisms

Indeed, further improvement in the economics of energy efficiency and renewable energy will lead to lower emissions even without changes in the number of permits or taxation level if total emissions exceed total permits.

Concluding comments

There is a strong scientific consensus that unrestricted increases in greenhouse gas concentrations will lead to significant, open-ended climatic warming and that such warming will pose an increasingly severe risk of adverse, and potentially catastrophic, impacts on global agriculture, ecosystems and human welfare. To safeguard future food production and to allow sufficient time for ecosystems to adjust to climatic change requires, as an almost certain minimum, stabilization of energy related CO_2 emissions at the current global total. Current evidence strongly suggests but does not convincingly demonstrate that even greater restrictions will eventually be required.

Given the need for at least stabilization of global CO_2 emissions, the most important task is to establish a framework to achieve this while providing flexibility to respond in a timely manner to improved scientific knowledge. Such a framework must address concerns for equity or 'fairness', must be economically efficient, must provide a means of providing additional funding to developing countries, and must address the imperative need for population stabilization. Carbon taxes and tradable permits, as stand alone proposals, are faced with intractable obstacles. However, these and other problems can be overcome if carbon taxes and tradable permits are combined in the following way:

- allocate CO_2 emission permits to national governments such that (1) the total number of permits equals the total base year emissions by participating countries, (2) permits are allocated according to population in the base year and (3) permits are valid for one year only but are renewable;
- levy a carbon tax of \$5–10/tonne on the governments of countries emitting in excess of the number of permits (whether allocated or acquired through trading), thereby capping the permit trading price and limiting the resource transfers from developed to developing countries;
- establish an International Energy Efficiency Agency, funded by proceeds from the carbon tax, to sponsor critical research, development, and demonstration projects; to disseminate information; and to provide technical assistance;
- gradually reduce the number of permits and increase the carbon tax as required in order to achieve emission stabilization or in response to improved scientific knowledge; and
- readjust the distribution of yearly permits in 10–15 years based on some weighting of the base year and then-current population.

These proposals resolve the conflict between equity and grandfathering principles for the allocation of permits: the allocation is based on population, but the regime is structured such that developed country concerns over a population based allocation (namely, large resource transfers and too large a fund to efficiently administer) are addressed. Rigid targets are avoided while allowing application of any desired degree of downward

pressure on emissions. Full scope is allowed for human creativity and ingenuity in finding ways to reduce emissions. Realization of least cost emission control will require a bottom-up approach with strong involvement of local governments, supported by appropriate policies at the national level. The greenhouse implementation regime proposed here is intended to create competition between national governments in least cost CO_2 emission reduction. Strong incentives for population control are built in while accommodating the difficulties of countries which have not yet achieved the demographic transition. Both developed and developing countries have to make an important compromise from their currently held positions: developed countries in accepting a permit allocation based on population, and developing countries in accepting that this allocation be based on population in a *fixed* year (subject to a one time adjustment). However, because compromise is required on both sides, and both sides will ultimately benefit by limiting global warming, it is conceivable that a core group of industrialized countries and at least one major developing country can be found which would be willing to accept such a compromise. The proposed permit trading/taxation scheme could then begin between these countries. If executed intelligently, significant benefits to all parties involved would quickly become evident, thereby prompting other countries to join the founding coalition until it grew into an effective global regime.