

TRADEABLE DISCHARGE PERMITS FOR THE CONTROL OF AIR POLLUTION IN CANADA

by

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INTRODUCTION

Environmental issues have become increasingly important over the last two decades. What had previously been viewed as a local and, at best, national issue, became in the 1980s an international and global one. Environmental problems such as acid rain, smog, global warming and ozone depletion are now serious problems with national and international consequences.

The reduction of pollution levels in the atmosphere is a complex task which requires the development of viable environmental policies at all levels of government. Because of the nature of environmental problems, economic theory is particularly well suited to the development of such policies. Pollution is essentially a problem of externalities. Conventional solutions to the externalities problem, however, are complicated by the fact that the environment is a good for which price (valuation) and ownership claims are ambiguous at best. In formulating environmental policy, the task of regulators is therefore to determine ownership and develop tools to place valuations on environmental assets.

Policy-makers basically have two options for achieving environmental goals: command-and-control regulation and the use of market-based instruments. The use of government regulation requires explicit intervention in the market place. This approach spells out the standards which are to be met and the technologies that are to be used in meeting these standards. Unfortunately, this approach is inflexible and may not be cost-effective in attaining the prescribed environmental standards. The market-based approach, on the other hand, is considered more efficient because it utilizes the flexibility

of markets and the imagination and innovative capacities of market participants. The objective of market-based approaches, such as, taxes, charges, subsidies and marketable permits is to make environmental goals a part of the normal decision-making activity. In this way, the power of the market can be used to reduce compliance costs and encourage innovative strategies to further environmental goals.

One of the more important market-based concepts is the tradeable permit. In themselves, non-tradeable permits to discharge are pure regulation. They are issued to restrict the total volume of pollution within a region and to regulate the volume from each source. Tradeable credits are created by assigning property rights to unused levels of permitted discharge and allowing these to be traded on the market. Firms which find it efficient to reduce discharges below the permitted level can trade the credits they have generated to firms that wish to expand production beyond allowable limits. Under a scheme of tradeable permits, firms are encouraged to find the cheapest way of reducing pollution, including purchasing the unused allocation of other firms. Tradeable permits thus allow the market to sort out a cost effective distribution of permitted pollution.

Canadian environmental policies have traditionally followed a command-and-control approach to regulation and have seldom included the use of market-based instruments, such as marketable permits. The purpose of this paper is to formulate a broad strategy for the successful implementation of marketable permit schemes in Canada. The paper will provide an overview of the issues associated with the use of permits and will discuss how, where and in what capacity permit schemes could be used to achieve prescribed air quality standards in Canada.

1. ENVIRONMENTAL REGULATION: OPTIONS

1.1 DEFINING THE EXTERNALITIES PROBLEM

When the actions of one agent directly affect the environment of another agent, an externality is present. More specifically, an externality is present whenever the actions of one or more individuals impose costs or benefits on others which are not accounted for in the decision-making process of the individuals or, when the agent, whose activity affects the utility or production relationships of others, does not receive (or pay) in compensation for this activity, an amount equal in value to the resulting benefits (or costs) to the others.¹

There are two types of externalities - technological and pecuniary externalities. Technological externalities refer to the indirect effect of a consumption or production activity on the consumption set of a consumer, the utility function of a consumer or the production function of a producer.² Pecuniary externalities refer to externalities that operate through the price system. Technological externalities may be positive or negative. Meade's apple farmer/bee keeper example (1952) illustrates the positive interaction of production activities. Historically, negative externalities such as air, water or noise pollution have attracted substantially more attention than positive externalities. In fact, the discipline of environmental economics is based on the study of negative technological externalities.

SOLUTIONS TO THE EXTERNALITIES PROBLEM

There are three classical solutions to the problem of negative technological externalities in the economics literature. The first class of solutions, associated with Pigou (1920), involves intervention by a regulator who imposes a tax to correct the inefficiencies associated with the externality. The major problem with the Pigouvian framework of corrective taxes is that the regulator generally has no knowledge of the level of tax that will eliminate the externality.

The second class of solutions is associated with Coase (1960). Coase developed an analysis of the social costs of externalities. His paper was basically a criticism of the Pigouvian solution of the externalities problem. Central to Coase's work was the proposition that under the correct circumstances, bargaining between economic agents could achieve an efficient allocation without intervention from a regulator. Although Coase never actually formulated the theorem that carries his name, the basic premise behind his work and the theorem is that all forms of market failure do not require government intervention to correct them. When transactions costs are zero, and property rights well defined, the private voluntary bargaining solution may produce an efficient outcome.³ Through a series of examples, Coase demonstrated that the party affected by the externality should not always have the right to be compensated. It was Coase's belief that such problems could be resolved through the bargaining process and that the concerned parties would reach the efficient outcome through negotiations.

Although Coase's approach makes an interesting case for bargaining, it is not without its problems. It is, first and foremost, an incomplete solution to the problem of externalities because it does not specify a structure from which

negotiations may take place. As well, Coase's conditions for an efficient outcome are very optimistic. There is no valid reason to suppose that transaction costs will be zero. In practice, any type of transaction between individuals usually has a positive cost. As well, bargaining among small numbers of people sometimes breaks down. Bargaining situations are inherently unstable due to strategic behaviour on the part of self-interested negotiators.

The third class of solutions, associated with the work of Dales (1968) and Arrow (1970), involves setting up a market for the externality. If a firm produces pollution that harms another firm then a competitive market for the right to pollute may allow for an efficient outcome. In this case, a competitive market can be thought of as a particular institution that allows agents to negotiate an efficient outcome.

1.2 POLLUTION AS AN EXTERNALITY

Air pollution can be viewed as a technological externality. Pollution, a by-product of production and consumption, may create an external diseconomy because it can cause a loss of welfare for the agents affected by it. In the presence of an externality, an efficient equilibrium usually cannot be achieved. The emissions of a waste products are thus under-priced and cause market failures in the form of excess use.

It is possible, at least theoretically, to solve for the socially efficient level of output - the point at which the marginal costs of producing a given level of output plus the marginal external cost caused by the externality equals the marginal benefits of producing the output. The efficient level of economic

activity, in general, involves a positive amount of externality (pollution).⁴

This can be shown graphically.⁵ Figure 1 shows the level of the polluter's activity, Q , on the horizontal axis. Costs and benefits, in money terms, are shown on the vertical axis. The marginal net private benefits curve (MNPB) shows the extra

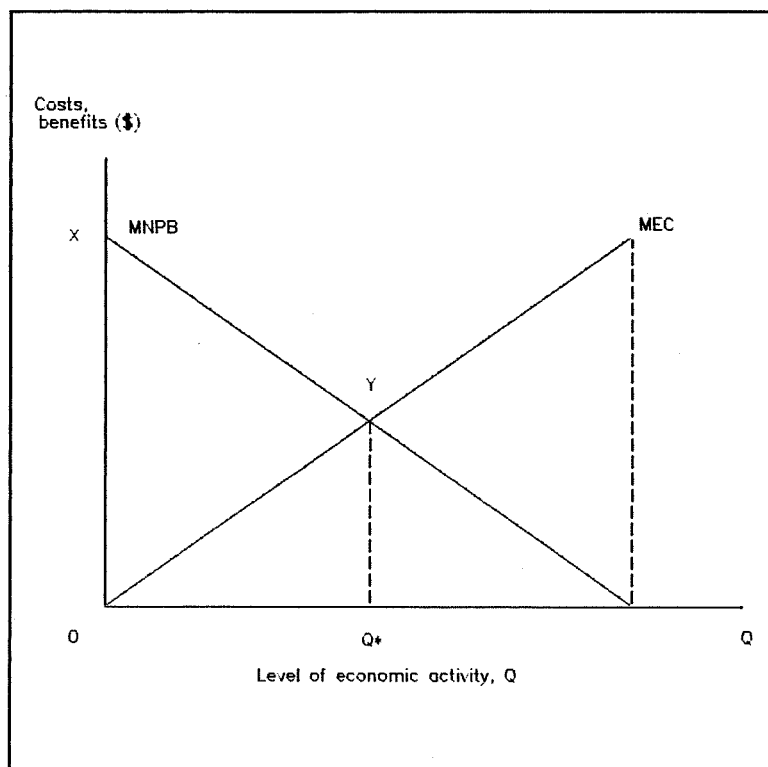


Figure 1 The Optimal Level of Pollution

benefits (profits) of

producing one more unit of good. The MNPB curve is formally equivalent to the marginal profit curve of the firm. The curve is obtained by subtracting marginal cost from price at every level of output Q . The marginal external cost curve (MEC) shows the value of the extra damage done by pollution arising from the activity measured by Q . The efficient level of activity occurs where both curves intersect, i.e., at the point where marginal costs equal marginal benefits. Area OXY is the largest area of net benefit obtainable. Hence, Q^* is the efficient level of activity. It follows that the level of pollution corresponding to this level of activity is the efficient level of pollution. Area OYQ* thus measures the efficient level of economic damage corresponding to the efficient level of pollution at Q^* . It thus represents the total cost of the externality at the efficient level of output.

It is possible to formulate a scenario where the efficient level of output would be zero. Figure 2 illustrates this scenario.

Assume a situation where the external costs of producing a given level of output are very large. Assume further that these costs are greater than any benefit the firm could gain by producing the output.

This situation would be characterized by the MEC and MNPB curves in Figure 2. It is evident, in this case, that the efficient level of production is zero.

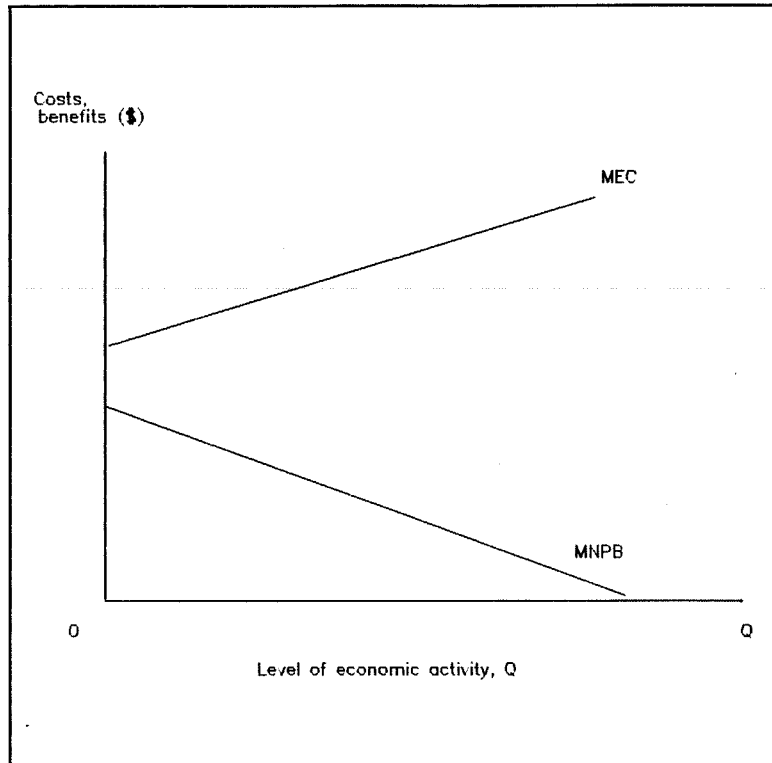


Figure 2 An Efficient Output of Zero

1.3 THE REGULATION OF AIR POLLUTION

Maintaining air quality standards is by no means an easy task for regulators. In addition to the technical difficulties inherent in measuring air quality standards, regulators are faced with the conflicting lobbies of business and environmental groups. In general, environmental regulations mean additional costs and decreased profitability for business firms. Firms are thus resistant to regulation. Environmental activists, on the other hand, demand

strict regulation that will effectively reduce air pollution. To appease both sides of the debate, regulators must therefore set air quality standards in such a way to preserve the environment, without constricting economic growth.

INSTRUMENTS FOR THE REGULATION OF AIR POLLUTION

There are two basic approaches to environmental regulation - the "command and control" approach and the use of economic instruments.⁶ With "command and control" options, regulators set emission standards and attempt to ensure compliance by issuing penalties for non-compliance. Economic instruments, on the other hand, work through the forces of the market to integrate economic and environmental decision-making.

As a means of achieving a specified degree of environmental protection, economic instruments have a number of potential advantages over traditional regulations.⁷ First, economic instruments have the capacity to achieve a specified level of environmental protection at a lower cost. Second, economic instruments provide a continuing economic incentive for firms to abate pollution. Under regulation, there is little or no incentive for firms to go beyond required performance standards but with economic instruments firms can always benefit from further pollution reduction. Third, economic instruments can, in some cases, involve lower administration costs for both government and industry than would be the case under a regulatory approach. For instance, with economic instruments, governments do not need information about abatement technology options of firms to achieve the targets in question. Fourth, the use of economic instruments can eliminate the need for government certification of production

processes and technologies which in some cases can be very costly for regulated firms. Finally, economic instruments can more easily allow the entry of new companies into an industry and the expansion of existing ones, than would be the case under regulation. A brief overview of command and control regulations and various economic instruments is discussed below.

Environmental Standards

The setting of environmental standards is a common regulatory practice. Standard-setting implies the establishment of allowed levels for the pollutant. These standards are usually set with reference to some health related criteria. Standard-setting is closely associated with the imposition of penalties for non-compliance. Under a scheme of environmental standards, a monitoring agency oversees the polluters' activities and is responsible for prosecuting offenders.

Standards rarely produce an efficient solution. This is shown in

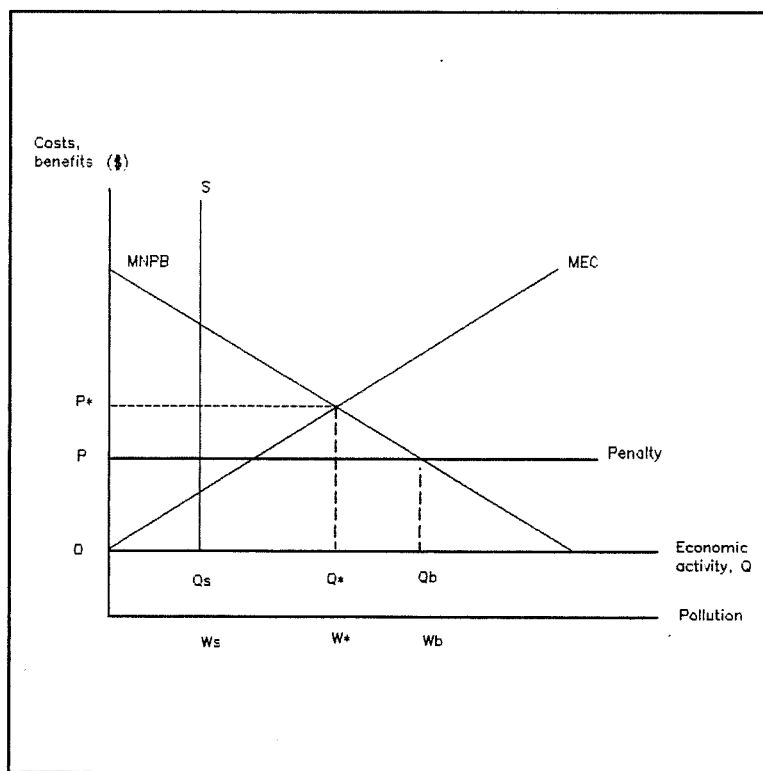


Figure 3 The Inefficiency of Standards

Figure 3.⁸ Figure 3 displays costs and benefits on the vertical axis while economic activity and pollution are on the horizontal axis. The MNPB and MEC curves are identical to the curves in Figure 1. Now assume that the regulator sets a standard S which corresponds to a pollution level W_s and a level of economic activity Q_s . Assume also that a penalty is set at P .

It is obvious from Figure 3 that Q_s is not efficient since it is less than Q^* . Setting the standard at the efficient level is almost impossible because regulators do not have sufficient information about the MNPB and MEC curves. In Figure 3, the penalty P is inefficient because the polluter has an incentive to pollute up to Q_b . This occurs because the total penalty up to Q_b is less than the net private benefits from polluting. In this case, the efficient penalty is P^* , but the regulator does not know this.

A major problem with the use of standards for the control of pollution is that standards are not cost effective for firms. Firms are heterogeneous by nature and thus have different marginal costs of abatement. Achieving the standard will be more costly for firms with a high marginal costs of abatement than for firms with low marginal abatement costs. The fact that regulators do not know the actual shape of the MNPB and MEC curves also creates problems in determining the correct level of the penalty for not adhering to the environmental standards.

The use of standards and penalties pose another important problem for regulators because standards are enforceable (with penalties) only if the polluters are caught by the pollution inspectors. The polluter thus makes his pollution decisions based on the probability of being caught which usually decreases with the number of polluters in the designated region.

Taxation

Price-based instruments, such as taxation, are the simplest form of market-based incentive because they correct for price distortions reflected in the divergence of market and social cost. The imposition, on the polluter, of a tax per unit based on the estimated damage it imposes may lead to an efficient level of pollution. Corrective taxes of this sort are known as Pigouvian taxes. The basic premise of charges is to compel firms to consider the social costs of their production decisions.

To show how Pigouvian taxes would lead to the efficient level of pollution, consider a simplified two firm economy.⁹ Firm 1 produces an output x which it sells in a competitive market. The production of x , however, imposes a cost $e(x)$ on firm 2. Assume that this cost is due to pollution created during production of good x . It may be assumed, as well, that firm 2 receives profits from some production activity, but this profit is ignored for simplicity. Assume further that both cost functions are increasing and convex.

Letting p be the price of output, the profits of the two firms are given by

$$\Pi_1 = px - c(x) \quad (1)$$

$$\Pi_2 = -e(x) \quad (2)$$

The equilibrium amount of output, x_q , is given by $p = c'(x_q)$. This output, however, is too large from a social point of view because firm 1 does not consider the cost it imposes on the other firm.

The efficient amount of output is characterized by price being equal to marginal social cost. It can be determined by internalizing the externality (merging both firms). In this case, the maximization problem of the merged firms would be

$$\max_x \Pi = px - c(x) - e(x),$$

with the first-order condition

$$p = c'(x_e) + e'(x_e),$$

where x_e is the efficient amount of output and $c'(x_e) + e'(x_e)$ represents the marginal social cost of producing good x .

Under a scheme of Pigouvian taxes with two firms, the regulator would set a tax to correct the effects of the externality. By setting $t = e'(x_e)$, the regulator forces firm 1 to acknowledge the external costs of its production. Firm 1 thus chooses to produce the efficient quantity x_e .

Conceptually, Pigouvian taxation is capable of achieving an efficient outcome. There are, however, some practical problems with the implementation of such schemes. The Pigouvian solution requires the taxing authority to know the costs of the polluting firm and the damage function of the polluted firm or consumer, which in general, it does not. The asymmetry of information between the polluter and the regulator thus becomes a major obstacle in the implementation of Pigouvian taxes.

Taxes may alternatively be set at a level which regulates quantity to an acceptable standard, independently of whether this restores the equality of private and social cost. The goal in this case is to keep a particular environmental problem within manageable boundaries. This is an acceptable

approach when the difficulty of applying the polluter-pays principle requires the application of a second-best solution.

Taxes may be applied in several different ways, with quite different effects. First, taxes may be applied to inputs. When an input such as fuel is taxed and the rate set as a function of emission efficiency, higher levels of taxation lead to substitution of more efficient fuels. The problem with this approach is that all users of a particular fuel are treated alike. Users who are more efficient are penalized to the same extent as less efficient users.

Second, taxes may be applied to effluents or emissions. Plants which are most efficient in minimizing emissions will benefit most from this type of taxation.

Third, taxes may be applied to the final product. When a tax is applied to the final product, as is the tire tax of Ontario or British Columbia, for example, the consumer pays for the hazards and costs of tire disposal but there is no incentive for any party to act to reduce the hazards or increase the efficiency of disposal.¹⁰

Subsidies

Compared to taxes, which penalize firms for emitting pollutants, environmental regulation may take the form of subsidies that encourage pollution abatement. These subsidies would be offered to firms which pollute below the allowed level.

The use of subsidies to control pollution may, however, have perverse effects. Although these subsidies may encourage individual firms to pollute

less, they may actually cause the total amount of pollution emitted by the industry to increase. Figure 4 illustrates why this may occur.¹¹ The diagram shows the effects of taxes and subsidies on the output of individual firms and the industry as a whole. The vertical axis measures price or cost while the horizontal axis measures output.

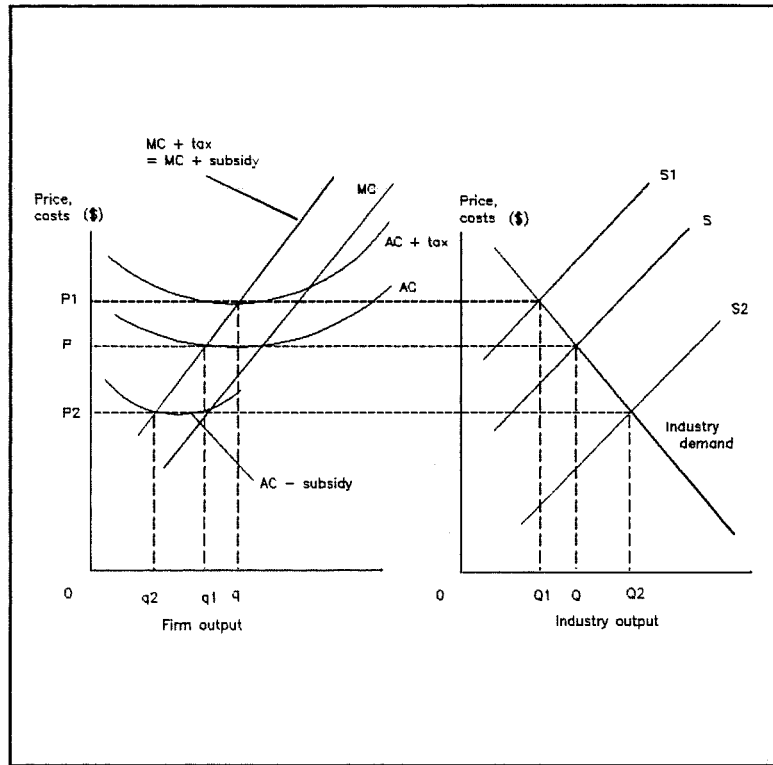


Figure 4 Taxes vs Subsidies for Individual Firms (left) and the Industry (right)

Consider an industry in which there is free entry and exit. The initial equilibrium of the system is characterized by P, q for the firm and P, Q for the industry. A tax imposed by the regulator will have the effect of increasing both the average and marginal costs of the firm - the AC and MC curves shift upward. These shifts lead to a new short-run equilibrium at P, q_1 . This new equilibrium is characterized by a price P which is lower than the new average cost so firms will exit the industry, shifting the industry supply curve left. The new long-run equilibrium is thus P_1, Q_1 for the industry and P_1, q for the firm.

The effects of a subsidy are quite different from the effects of a tax. A subsidy shifts the firm's marginal cost curve upward and shifts the average cost curve downward. The MC curve shifts upward because as the firm expands

output it forgoes a subsidy which it would get by reducing its emissions (foregoing a subsidy is the same as paying a tax). The AC curve shifts downward because it gets a payment for lowering output.

Assuming that the amount of the subsidy equals the tax, the short-run effects of the subsidy are the same as the tax. The long-run equilibrium, however, is characterized by P_2, Q_2 for the industry and P_2, q_2 for the firm. The firm's output has decreased but the industry output has increased. This occurs because the short-run price exceeds the new average cost ($AC - \text{subsidy}$) motivating firms to enter the market. Since pollution levels increase proportionally with output, the level of pollution thus increases with subsidies. Even though individual firms have reduced their emissions, additional firms have entered the industry contributing to greater levels of pollution.

Tradeable Discharge Permits

First discussed by J.H. Dales (1968), the concept of transferable discharge permits (TDPs) for pollution control has been studied extensively over the last few decades and today TDPs are at the forefront of environmental regulation. In themselves, non-tradeable permits or licences to discharge are pure regulation. They are issued to restrict the total volume of pollution within a region and to regulate the volume from each source. Tradeable permits are created by assigning property rights to unused levels of permitted discharge and allowing these to be traded on the market.

TDPs are attractive because they allow regulators to harness the power of the market and channel it toward the achievement of environmental goals.

Tradeable permits have several advantages over other regulatory methods. First, TDPs have the ability to accommodate growth in an industry without compromising environmental quality. They are particularly useful when it is necessary to pursue several related environmental objectives simultaneously. Second, because they deal with quantities rather than prices, they are insensitive to inflation. Third, TDPs have the potential to allow the market to reach the efficient level of pollution at minimum cost.

These advantages can be shown graphically.¹²

Figure 5 illustrates the basic elements of marketable permits as well as the cost-minimization characteristic. On the graph, the horizontal axis shows the level of emissions and the number of permits. The vertical axis shows the price of the permits and costs. MAC is the marginal

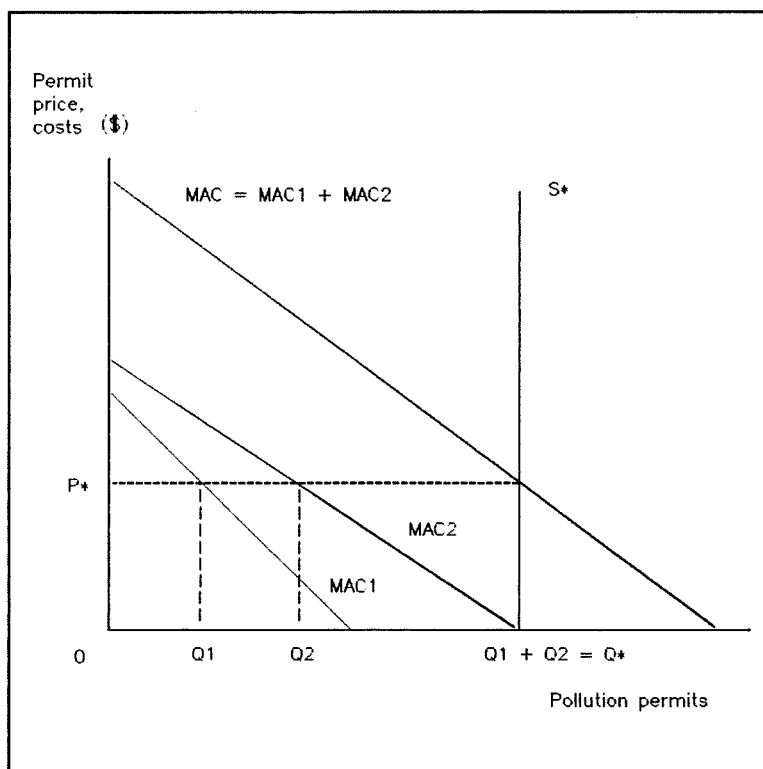


Figure 5 Cost Minimization with TDPs

abatement cost curve. Its

downward slope indicates that abatement becomes more expensive as the quantity of pollution diminishes. The supply of permits, S^* , is vertical because the issue of permits is regulated and is not responsive to price. For simplicity, the example assumes that there are only two polluters. The first firm is assumed to have lower abatement costs (MAC_1) than the second firm (MAC_2). At price P^*

polluter 1 buys OQ_1 permits and polluter 2 buys OQ_2 permits. Note that the higher cost polluter buys more permits. Polluters with low costs of abatement will find it relatively easier to abate pollution rather than buy permits.

Polluters with higher abatement costs will have a greater preference for buying permits than abating. An automatic market is thus created - low-cost polluters selling permits and high-cost polluters buying them. By giving the polluters a chance to trade, the total cost of pollution abatement is minimized compared to the more direct regulatory approach of setting standards.

TDP systems also allow the environmental control agency to alter the environmental standards if necessary. If regulators wish to relax the standard, they can issue new permits. If, on the other hand, a stricter standard is required regulators may enter the market and purchase permits, thereby, reducing the total amount of permits available to polluters.

At the same time, tradeable permits do have some limitations.¹³ The most important is that, in order for them to realize their full potential, the permits must actually be tradeable. In this respect, firms must not behave strategically in the permit market - that is, that they must not seek to gain a competitive advantage by, for example, withholding permits from the market. Another potential difficulty with a tradeable permit system is that the price of the permits (cost of pollution) cannot be predicted in advance because it is determined by market forces. This may cause problems for firms attempting to budget their abatement expenditures.

Types of TDP systems

There are three basic types of transferable discharge permits defined in the literature - the ambient-permit system, the emission-permit system and the pollution offset system.¹⁴

Ambient-Permit System (APS)

Under the APS, several receptor points are dispersed through the region and environmental (air or water) quality is defined in terms of pollutant concentration at each of these receptor points. The environmental authority issues a fixed number of permits at each receptor point. These permits are defined in terms of an allowed contribution to the pollutant concentration at a receptor point. The APS creates a separate market corresponding to each receptor point. Under this scheme, in order to justify their emissions, pollution sources must obtain a portfolio of permits from the various receptor points at which their emissions contribute to pollution levels.

With an APS, the permits refer to the effects of the emissions and not the emissions themselves. This implies that emissions cannot be traded on a one-for-one basis. A source whose emissions per unit are more damaging to a particular receptor will have to purchase more emission entitlements than the source whose discharges are not as damaging.

The APS has two important properties. First, the APS can achieve the least-cost outcome (minimization of total abatement costs). As well, the least-cost outcome is independent of the initial allocation of the permits. This feature

is quite attractive for regulators since any allocation of permits it decides upon will lead to the least-cost solution. Second, the APS involves high transactions costs for the polluters. Since emissions are not traded on a one-for-one basis but rather on the basis of the damage caused at each receptor point, sources must trade on several separate markets each corresponding to a particular receptor which can be costly. The APS thus has obvious complications for the polluters and may well be administratively difficult for regulators.

Emission Permit System (EPS)

The EPS is much simpler than the APS. Permits are issued on the basis of source emissions and the effects of these emissions on the receptor points are ignored. Under the EPS, the environmental agency divides the region into zones. Sources are assigned to specific zones where they can trade emissions entitlements on a one-for-one basis. By not discriminating according to receptor points, the EPS is unlikely to discriminate between sources on the basis of the damage done. It will, therefore, not be cost effective because the price of permits will not approximate the marginal external cost.

Although this system is obviously less costly in terms of transactions costs for emitting sources, it makes enormous demands on an administering agency seeking to achieve an efficient outcome. Because the EPS cannot, in general, achieve the least cost solutions, the regulators must try to approximate it at tremendous cost. To reach this solution, the administering agency must have not only an air-quality model and a complete emissions inventory, but source-specific abatement cost functions and the capacity to solve the

programming problem.

Another difficulty with the EPS is that one-for-one trades will tend to ignore the differences in pollutant concentration contributed by the various emitters. This situation could result in the formation of "hot spots" - small areas where concentrations of pollution exceed the standard. As well, sources outside the designated EPS zones may contribute to pollution levels within the zone.

The Pollution-Offset System (POS)

The pollution-offset system is a hybrid designed to circumvent the problems incurred with the APS and the EPS. Under a POS, permits are defined in terms of emissions and trades take place within a defined zone but sources cannot trade permits on a one-to-one basis. Transfers of permits under the POS are subject to the restriction that the transfer does not result in a violation of the environmental quality standards at any receptor. The exchange value of the permits is then determined by the effects of the pollutants at the receptor points. Like the APS, the POS leads to the least-cost solution regardless of the initial allocations of permits. As well, it makes only modest demands on regulators because they are not required to know the pollution sources' abatement costs. From the emitting firm's point-of-view, the POS is less costly than the APS because trade does not take place in a multitude of separate permit markets. Instead, firms can purchase emissions permits directly from other sources, which implies substantial savings in transactions costs to sources relative to an APS.

2. TRANSFERABLE DISCHARGE PERMITS FOR THE CONTROL OF AIR POLLUTION

2.1 A BRIEF REVIEW OF THE LITERATURE

The concept of marketable permits for the control of pollution originated with J.H. Dales (1968). Dales proposed the creation of an "artificial" market for the ownership rights to water systems. Once established, the ownership rights could subsequently be traded at prices generated by market forces.

The virtues of this approach are that no person, or agency, has to set the price of permits. If the region experiences demographic or industrial growth the price of rights will automatically rise and induce existing dischargers to reduce their wastes in order to make room for newcomers.

There are, however, some deficiencies with Dales' market-mechanism scheme. Several factors such as, the mapping of water regions, the choice of the allowable amount of pollution and the choice of the time interval during which the number of pollution rights is fixed must still be determined by regulators. As well, the market in pollution rights is not a "true" market. In true markets price creates two-way communication between sources of supply and demand and affects the amounts supplied as well as the amounts demanded. Dales' market provides only for one-way communication. It transmits the government's decision about the use of water to the users of the asset but there is no feedback from the users to the government. A rise in the price of pollution rights signals

that the rights to pollute are becoming more valuable but this does not mean that the supply of permits should be increased. A market of this type is merely an administrative tool that allows regulators to achieve environment policy goals by using economic incentives rather than regulations.

Another important contribution in the study of tradeable discharge permits is that of Montgomery (1972). Montgomery analyzes two systems of marketable pollution permits: a system of pollution licenses that defines allowable emissions in terms of pollutant concentrations at a set of receptor points, and a system of emission licenses that confer directly the right to emit pollutants up to a specified rate.

Montgomery defines the pollution control problem using a mathematical model. According to this model, there are n polluting firms fixed in a defined geographical location. These firms are represented by a set of integers $I = (1, \dots, n)$.

Montgomery models an $m \times n$ matrix of unit diffusion coefficients, denoted as

$$H = \begin{pmatrix} \cdot & & & & \\ \cdot & & & & \\ \cdot & \dots & h_{ij} & \dots & \cdot \\ \cdot & & & & \\ \cdot & & & & \cdot \end{pmatrix}$$

In this matrix, the element h_{ij} indicates the contribution that one unit of emissions from source i makes to the pollution concentration at point j .

The environmental quality standard, which has been pre-determined by the environmental authority, is denoted by the vector $Q^* = (q_1^*, \dots, q_m^*)$, where

q_m^* represents the concentration of the pollutant at the receptor m . Montgomery assumes that all the pollution within the defined region arises from the industrial polluters, each of which emits a single pollutant at a rate e_i . The emission vector $E = (e_1, \dots, e_n)$ is mapped into concentrations by the diffusion matrix H , so that $E \cdot H = Q$. The standard Q^* imposes constraints on allowable emission rates of the form $E \cdot H \leq Q^*$.

The pollution control problem is thus one of attaining the predetermined levels of pollutant concentrations at the minimum aggregate abatement cost. In other words, the problem is to find a vector of emissions $E = (e_1, \dots, e_n)$ that will minimize abatement costs subject to the constraint that the prescribed standards are met at each of the n locations in the region. The abatement costs of the i^{th} source are a function of its level of emissions: $c_i(e_i)$. Thus, in formal terms the problem is to

$$\text{Minimize}_{e_i} \sum_i c_i(e_i)$$

$$\begin{aligned} & \text{s.t.} \\ & EH \leq Q^* \\ & E \geq 0. \end{aligned}$$

Montgomery shows that such a vector exists and, moreover, that, if the sources of pollution are cost-minimizing agents, the emission vector and the shadow prices that emerge from the minimization problem satisfy the same set of conditions as do the vectors of emissions and permit prices for a competitive equilibrium in an air-permits market. In other words, if the environmental authority were to issue the permits up to the predetermined standard, bargaining or trading for these permits would generate an equilibrium solution

that satisfies the condition for the minimization of total abatement costs regardless of the initial allocation of permits among polluters.

Krupnick, Oates and Van De Verg (1983) build upon Montgomery's model and develop a system of pollution offsets. They show that one of the shortcomings of Montgomery's model is the result of the restrictive condition that he imposes on the trading of the licenses. With modifications of this condition, Krupnick et al. find that a "trading equilibrium" exists that coincides with the least-cost pattern of emissions for any initial allocation of emission permits.

McGartland and Oates (1985) rework Krupnick et al.'s system of pollution offsets. They develop a modified system of marketable emission permits that promises both savings in abatement and improved environmental quality relative to an initial command-and-control outcome. They describe a TDP system that can effectively attain the predetermined standards for environmental quality and, at the same time, prevent any deterioration in areas which are already cleaner than the standards. The system calls for redefining the environmental quality standards such that the new standard at each point in the region is equal to the predetermined standard established by the environmental authority or the initial level of environmental quality, whichever is higher. Free trading of permits is allowed provided that no violation of these new air standards takes place.

McGartland and Oates show that the competitive equilibrium of this new permit system exists and that it satisfies the conditions for the least-cost solution. The authors also show that compared to a command-and-control approach, the new competitive equilibrium represents a Pareto improvement for all parties involved, including both environmentalists and polluters.

Roumasset and Smith (1990) approach the issue of tradeable permits from

a different perspective. In traditional models, emissions trading is based on pollutant concentration at various receptor points and trades are based on the implicit assumption that health damages from pollution depend only on the effects of emissions on widespread ambient concentrations. Roumasset and Smith offer the concept of "exposure trading" where exposure is a parameter defined both in terms of pollutant concentration and the length of time exposed to the pollution. Under their system, the damages at each receptor site would be assessed in terms of exposure at the site. By the use of such an "exposure standard" it is possible, according to the authors, to extend emissions trading so that emission permits are exchanged according to "exposure units".

Chichilnisky, Heal and Starrett (1993) investigate the use of marketable emission permits for the abatement of carbon dioxide (CO₂) emissions on an international scale. In contrast to the models discussed above, the authors determine that not all possible distributions of a given total of emission permits are compatible with the attainment of first-best Pareto efficiency. In fact, of the infinitely many ways of distributing a given total of permits between a fixed number of parties, only a finite number can lead to efficiency.

According to the authors, there is an unexpected link between equity and efficiency. The initial distribution of property rights or emission permits determines whether or not a global CO₂ permit market will operate efficiently. The key to understanding this result is to note that the atmospheric concentration of CO₂ is a privately produced global public good. As a result, the equalization of marginal abatement costs across countries is not sufficient for Pareto efficiency. Chichilnisky et al. show that in the absence of policy instruments which can affect unrestricted income redistributions across countries, the only variable available for ensuring that marginal and social

valuations of consumption are equalized across countries is the initial allocation of permits.

2.2 THE U.S. EXPERIENCE WITH TRADEABLE EMISSIONS

A BRIEF HISTORY OF THE U.S. POLICY ON TRADEABLE EMISSIONS

Up to now, practical experience with emissions trading has been limited almost exclusively to the United States. Trading was first introduced in the U.S. in the 1970s to add flexibility to the existing program of pollution control.

Until the mid 1960s, the amount of legislation to control air pollution was minimal. Although the Air Pollution Control Act of 1955 authorized the Secretary of Health, Education and Welfare to spend up to US\$ 5 million¹⁵ a year on research and to help the states in training and technical matters of air pollution, it was not until 1963 that the U.S. government began to actively legislate against air pollution.

The Clean Air Act (CAA) of 1963¹⁶ authorized federal grants to states for the development of state and local air pollution programs. As well, the Act established a conference system to deal with problems of interstate air pollution. The first major amendments of the CAA came in 1970. These amendments established national ambient air-quality standards (NAAQSs) for criteria pollutants and required the establishment of new-car emission standards along with certification programs. As well, states were required to develop state implementation plans (SIPs) to control existing stationary sources of air pollution. In the SIPs, states were required to outline their respective

strategies for attaining and maintaining the NAAQSs and describe how they would implement federal rules locally. As well, as part of the SIPs, states were required to set emission limits for certain source categories and timetables for sources to comply with regulations. In addition, the 1970 CAA amendments charged the EPA with the responsibility of establishing emission standards for major toxic or hazardous pollutants. The EPA was also appointed to establish technology based emission standards for all new sources of the common air pollutants.

Further amendments to the Clean Air Act in 1977 established the goal of "prevention of serious deterioration" (PSD) in areas already cleaner than the national standards. The amendments established three classes of already clean areas:

- Class 1: no additional air quality damage permitted
- Class 2: some air quality deterioration permitted
- Class 3: air quality to be allowed to deteriorate to the level of NAAQSs.

As well, technology standards for the "lowest achievable emission rate" (LAER) for new sources in non-attainment areas, and "best available control technologies" (BACT) for new sources in PSD areas were developed. It is under the amendments of 1977 that the U.S. government began to experiment with emissions trading. Several emissions trading programs were established in the late 1970s. Under these programs, the trading of emission reduction credits (ERCs) was allowed under four specific trading policies; namely the banking, netting, bubble and offset policies.

Trading was subsequently used in the mid-1980s to accelerate the phase-out of lead gasoline. Until 1982, the EPA exercised control by enforcing lead

limits on a refiner-by-refiner basis. In 1982 the EPA allowed trading among refiners and in 1985 it set up a "bank" for lead in which emission reductions that were accomplished ahead of schedule could be banked for use or sale in later years. The lead trading program ended in 1988 when regulators feared that further reductions in lead levels would damage older engines. The program is generally considered to have achieved greater reductions in lead content quickly and at a lower cost than they would have been achieved under traditional command-and-control approaches.

In 1988, a system of fully tradeable chlorofluorocarbons (CFCs) production permits was introduced by the EPA as part of its implementation of the Montreal Protocol. Under the system, permits were allocated to CFC producers and importers on the basis of historical production and import levels. These allowances could be traded freely among producers or other interested parties.

Emissions trading was also an important component of the 1990 Clean Air Act Amendments. The 1990 Amendments set three major goals:

1. A reduction in sulphur dioxide (SO₂) emissions of ten million tons per year below 1980 levels by the year 2000;
2. A nationwide cap on SO₂ emissions, beginning in the year 2000; and
3. A two million ton per year reduction in nitrogen oxide (NO_x) emissions, beginning on the year 2000.

The SO₂ emission reduction program will be achieved in two phases. In Phase I, which was scheduled to begin in January 1994, the SO₂ and NO_x reductions are to be achieved through emission reduction requirements at the largest emitting power plants. Almost all fossil-fuel power plants will be subject to requirements during the second phase of the program which becomes effective in the year 2000.

An important feature of the program is the creation of tradeable SO₂ allowances to facilitate achievement of the emissions targets by regulated sources. An allowance represents one allowable ton of SO₂ in a particular calendar year which can be traded, banked, or used nationwide. Under the provisions of the CAA any entity may own, buy or sell allowances. Designed with some of the experience of ERC, CFC and lead trading in mind, the allowance trading program has a number of factors working in its favour. First, representatives of the diverse interests affected were an integral part of the program-planning process. Second, the program incorporates a market-priming mechanism. Power plants will receive less than their full allocation of allowances, thus prompting emission reductions or allowance purchases to ensure compliance. Third, the market for allowances will be virtually unlimited. Because allowance ownership is not limited to particular sources in particular regions, there will be many opportunities to execute trades.

EMISSIONS REDUCTION CREDITS TRADING UNDER THE CLEAN AIR ACT

Emissions Trading

Until the inception of the SO₂ allowance trading program, most trading programs in the United States revolved around the emissions reduction credit which could be traded openly within the context of the offset, bubble, emissions banking and netting policies. A description of this system is given below.

Emissions Reduction Credit

The emission reduction credit is the currency used in trading among emission points. To participate in any emissions trading alternative, an entity must either create ERCs or acquire them on the open market. Should the source decide to create an ERC, it can apply to the control authority for certification of excess control as an emission reduction credit. Certified credits can be banked or used in the bubble, offset, or netting programs. To receive certification, the emission reduction must be surplus, enforceable, permanent and quantifiable. Certifying emission reductions as ERCs requires considerable interaction with regional regulators. By nature, this interaction is an interdisciplinary process, requiring input from engineers, lawyers and often financial planners.

The Offset Policy

The offset policy was established to resolve the conflict between economic growth and clean air objectives. There was concern that the existing regulations were not compatible with economic growth. The CAA specified that no new emission sources would be allowed in non-attainment areas after the original 1975 deadlines for meeting air quality standards passed. Concern that this prohibition would stifle economic growth in these areas prompted the EPA to institute the offset rule. The offset rule specified that new sources would be allowed to locate in non-attainment areas only if they "offset" their new emissions by reducing emissions from existing sources by even larger amounts.

Offset transactions are required for many companies wishing to build or expand operations in non-attainment areas.¹⁷ A firm planning a new facility that will emit more than the local threshold level of a non-attainment pollutant must acquire ERCs for that pollutant from other permitted sources in the relevant air shed. Typically, offset rules require that a new or expanding emission source secure more than enough ERCs to compensate for the planned emission increase. In general, offset ratios range from 1:1 to 8:1. The farther away the new source is from the ERC provider, the greater the offset ratio tends to be.

By purchasing credits from existing firms, new sources in effect finance emission controls undertaken by existing sources, thereby serving as a vehicle for improved air quality. Since 1976, there have been over 2,500 offset trades and most of these trades have involved new sources. The most active offset trading markets are located in Southern California. The South Coast region has been the site of at least 50% of all trades in the United States from 1985 to the present.

The Bubble Policy

The bubble policy applies only to existing firms. It allows a firm to sum the emission limits from individual sources of a pollutant in a plant, and to adjust the levels of control applied to different sources as long as this aggregate limit is not exceeded. The key issue in the EPA's bubble policy is the regulatory treatment of the term "source". In a bubble, two or more emission points can be treated as if they were under a hypothetical dome, creating a single source.

Using the bubble strategy, firms can "overcontrol" at individual emission points that are inexpensive to control while relaxing controls at more expensive points so long as the net effect is an air quality improvement. Many firms have found that the flexibility to plan emissions control strategies in-house rather than having them specifically imposed by regulators can result in substantial cost savings.

The EPA and several states have approved some 75 bubbles, with several hundred million dollars of savings to applicants. Historically, however, bubbles have been the least common type of emission trading.¹⁸

The Netting Policy

Netting allows sources undergoing modifications or expansion to escape the burden of new source review requirements as long as any net increase in plant-wide emissions is insignificant. Whether an increase is significant or not depends on the threshold set by the regulatory authority. Netting allows emission reduction credits earned elsewhere in the plant to offset the increases expected from the expanded portion.

Many firms feel a strong incentive to use netting to avoid source review requirements and the costs of control equipment. In the past twelve years, thousands of netting transactions have occurred making netting the most common type of emissions trade.

The Banking Policy

Emissions banking is an effort to create continuity and certainty in the markets for ERCs. Banking allows firms to store emission reduction credits for subsequent use in the bubble, offset, or netting programs. Regulations concerning banking policies are the responsibility of the various state regulators. States are authorized to design their own banking programs as long as the rules specify the ownership rights over the banked credits, the sources eligible to bank emission reduction credits and the conditions governing the certification, holding and use of these credits.

Estimated Cost Savings and Trading Activity

Although comprehensive data on the effects of the emissions trading program does not exist, several trends are apparent. First, the program has substantially reduced the costs of complying with the Clean Air Act. As of 1990, the accumulated capital savings is estimated at over \$10 billion.¹⁹ As well, the level of compliance with the basic provisions of the Clean Air Act has increased. Somewhere between 7,000 and 12,000 trading transactions have been consummated - the majority of trades involving large pollution sources trading emissions reduction credits either created by excess control of uniformly mixed pollutant or involving facilities in close proximity to one another.

NEW DIRECTIONS FOR MARKETABLE PERMITS

Clean Air Allowance Market of the Chicago Board of Trade

In accordance with the 1990 Amendments to the Clean Air Act, the Chicago Board of Trade (CBOT) has begun to administer an integrated market for SO₂ allowances. Specifically, the CBOT will:

- Administer the allowance auction and sale
- Operate an allowance cash market
- Operate an active allowance futures market
- Establish allowance information systems

On September 25, 1992 the EPA announced that it had selected the CBOT to administer the annual allowance auctions and direct sales. The CBOT is charged with administering the following functions: collect bids and payments, tabulate the auction, publish the results of the auction, and collect direct sales applications and payments. Policy decisions, money disbursements, and allowance transfers have remained the responsibility of the EPA.

The market first became operational March 29, 1993 when the EPA conducted its first annual auction of allowances. Buyers bought 150,010 allowances at prices from \$122 to \$450 per ton. The biggest buyer was the Carolina Power and Light Company which bought 85,103 allowances. Of the 150,010 allowances sold, 50,010 were "spot" allowances applicable to the 1995-2000 period. The remainder were "advance" allowances for the post-2000 period when more stringent emissions limits will be in effect. The CBOT has announced

plans to hold its own auctions several times per year.²⁰

The RECLAIM Program of the SCAQMD

Another major trading program is the Regional Clean Air Incentive Market (RECLAIM) of the South Coast Air Quality Management District of Southern California. This innovative program was initiated in 1992 and covers trading in SO₂ and NO_x. The RECLAIM program is different from other programs primarily because of its size. RECLAIM will replace as many as 62 present and future command-and-control regulations governing emissions of reactive organic gases (ROGs), NO_x, and sulphur oxides (SO_x) from large stationary sources. This will create an ROG trading market of about 2,000 facilities, an NO_x market of 700 facilities and an SO_x market of about 70 facilities. These markets will eventually be expanded to encompass mobile sources.

When the program was initiated, tradeable permits were issued to 2,700 large polluters in proportion to the pollution emissions they would have produced under full capacity production, assuming compliance with existing regulations. The number of permits issued annually will be reduced 8% annually for NO_x and 6% annually for SO₂ until the entire region is in full compliance with federal ambient standards. The SCAQMD estimates savings of at least \$270 million dollars per year over previous programs intended to achieve compliance.²¹

A REVIEW OF SELECTED TRADING PROGRAMS

A number of ERC trading programs have been initiated all over the United States. This section looks at six of these programs emphasizing the characteristics that have contributed to the success or failure of these programs.²²

South Coast Air Quality Management District (SCAQMD)

The SCAQMD's emissions trading program is the most active program in the United States. Its goal is to allow economic growth in the Los Angeles area and South Coast air basin while attaining national air quality standards in the region.

Under the SCAQMD's trading program ROG_s, NO_x, SO_x, carbon monoxide (CO), and particulate matter (PM) are traded within the air basin. From 1976 through October 1990, over a hundred trades involving more than one firm occurred in the SCAQMD. From 1987 through 1990, another hundred or so trades have taken place with over 75% of trades involving ERCs for ROG_s.²³ Only one carbon monoxide trade occurred during this period. The volume of trades reflects the relative difficulty of reducing emissions below the minimum threshold for each pollutant.

Several factors are critical to the success of emissions trading in the SCAQMD. First, the SCAQMD has established minimum thresholds lower than national threshold levels.²⁴ The minimum threshold level sets the quantity of emissions above which a new emissions source or an expanding existing source

must obtain offsets. The lower the minimum threshold levels, the greater the number of sources required to secure offsets. Second, the SCAQMD has experienced population and economic growth for the duration of the program. Economic growth induces firms to expand their operations and draws new firms to the region. Thus, it creates a demand for emissions reductions credits and stimulates trading. Third, the SCAQMD allows for the creation and use of shutdown-created credits. From 1985 to 1990 over 80% of ERC transfers in offset trades involved shutdown-created credits.²⁵ Shutdown credits are relatively easier to create than other ERCs because they do not involve extensive engineering studies, large amounts of equipment, or process redesign. In addition, it is easier to prove that shutdown credits are permanent, real, surplus, quantifiable and enforceable. Another key element in the success of the SCAQMD emissions trading program is the implementation of a well-defined permit program. With very few exceptions, any stationary source that emitted a non-attainment pollutant is required to obtain a permit. As well, the SCAQMD enforces the permit program and offset requirements rigorously. Fines for not obtaining offsets can be as high as \$25,000 per violation per day. Regular SCAQMD inspections, audits and reporting requirements ensure that violations have a high chance of detection.

San Joaquin County Air Pollution Control District (SJCAPCD)

The SJCAPCD program originated on May 29, 1979. From 1987, when an emissions bank was created, until 1990, 2,275 tons of ERCs have been deposited and 12 offset trades have taken place. Most ERCs in the emissions bank were

created through process modifications or the addition of control equipment rather than through shutdowns. Trades have ranged in size from 1.6 tons per year to over 500 tons per year.

The SJCAPCD is generally considered a successful emissions credit trading program. Of primary importance to its success was the support the program received from the regulatory agency and industry. Another contributing factor to its success is the nature of the ERCs held in the emissions bank. Most facilities that have created emission reductions have done so through the addition of pollution control devices rather than through plant shut-downs. The program thus encourages the introduction of new pollution control techniques that go beyond existing technology and federal and state requirements. As well, the SJCAPCD provides explicit guarantees to the owners of banked emission reduction credits. The SJCAPCD rules require that before any adjustments of banked credits can be made, it must be proven to the public that the necessary emissions reductions cannot be achieved through the imposition of additional controls on existing permitted or unpermitted sources. If adjustments of banked credits are deemed necessary, ERC holders are still entitled to a public hearing to discuss the adjustment. The protection of banked credits was critical in obtaining the support of industry.

Bay Area Air Quality Management District (BAAQMD)

The BAAQMD program was adopted March 7, 1984. It was designed to help sources obtain the offsets they need to comply with the New Source Review regulations.²⁶ It applies to new sources and sources undergoing major

modifications. The program allows active trading of precursor organic compounds, nonprecursor organic compounds, PM, SO₂, NO_x and CO.

This program has received only limited use, primarily because its offset thresholds have been high. Given the high thresholds, most new and modified sources were exempt from the offset requirement. Consequently, there were few buyers and little incentive to create ERCs.

New Jersey

New Jersey's Emission Trading Program applies to new or significantly altered stationary sources whose emissions of a criteria pollutant have increased 50 tons or more since 1976. Pollutants traded include ozone, SO₂, NO_x, CO, volatile organic compounds (VOCs), and lead.

The program is not considered very successful and it is estimated that fewer than ten third party trades have occurred in the history of the program. A number of characteristics have influenced the level of trading activity. These include high offset thresholds, slow economic growth, restrictions on the use of offsets, and uncertainties surrounding banked ERCs.

Jefferson County, Kentucky

The Jefferson County Air Pollution Control District adopted its emissions trading program on April 21, 1982. The goal of the program is to improve air quality and trading includes particulates, SO₂, and VOCs.

Although the program was active in its early years, no trades have taken place recently. On the other hand, Jefferson County is in attainment for most pollutants and consequently has less incentive for promoting the program. The early success of the program has been attributed to the existence of few restrictions on the use of bank credits, an efficient emissions bank and strong support from the EPA.

The Fox and Wisconsin River Effluent Trading Program

The State of Wisconsin initiated a system of tradeable biological oxygen demand (BOD) permits on the Fox River in 1981, later extended to the Wisconsin River. The primary objective of the limited marketable discharge permit trading program is to allow firms greater flexibility in abatement options while still maintaining environmental quality. Several sources are included in the trading program. On the Fox river, 21 parties are involved along a 35 mile segment of the river. On the Wisconsin river, 26 parties are involved over a total distance of 500 miles.²⁷

The program is generally considered a failure. Since its inception, only one trade has taken place on the Fox river and none on the Wisconsin. The lack of trading is blamed on numerous causes. First, the restrictive trading rules of the program may have had a negative impact on potential trading. Second, the pulp and paper plants which are included in the trading program have an oligopolistic structure which inhibits competitive behaviour on the trading market. Third, participating firms have been reluctant to use trading as a means of reducing abatement costs.²⁸

2.3 FACTORS CRITICAL TO A SUCCESSFUL TRADING PROGRAM

Several factors may affect the success of an emissions trading program. Based on the conclusions of several theoretical models and the prior trading experience of the programs discussed above, this section outlines the crucial elements to be included in a trading program.

DEFINING THE EFFICIENCY CRITERION

Before discussing the issues and factors critical to the success of a trading program, it is important to differentiate between two distinct but related concepts - efficiency and cost-effectiveness. Efficiency, is in this case an abstract theoretical concept. Cost-effectiveness, on the other hand, is a more practical notion.

The efficient allocation balances, at the margin, the cost incurred from pollution with the costs of avoiding the damage. The problem with the use of the efficient allocation as a policy goal is that the marginal costs involved are seldom known to the regulator. The costs incurred from the uncontrolled pollution are quite ambiguous and subject to wide variations depending on the criteria used to measure them. As well, information on the abatement costs of the polluters are not likely to be known to regulators given the large number of emitters. The efficiency objective is therefore difficult to achieve.

For these reasons there has been a reluctant acceptance of the cost-effectiveness criterion. This criterion provides no guidance for choosing the

appropriate policy target, but it provides a good deal of guidance in selecting among the various ways of meeting that target. It suggests that the best allocation is the one which achieves the target at minimum cost.²⁹

THE CRITICAL ELEMENTS OF A TRADING PROGRAM

The main purpose of tradeable permits is to convey to polluters appropriate price signals. Polluters can select a combination of capital investment, operating practices and emission releases that minimize the sum of abatement costs and permit expenses. The economic efficiency of the system depends on firms being able to buy and sell permits relatively easily, with incidental costs, at competitive prices. In practice, however, economic efficiency will rarely be achieved and environmental authorities will settle on the cost-effectiveness criteria.

Although economic efficiency will seldom be realized, regulators must nevertheless strive to achieve it. Several factors should, therefore, be considered when designing a permits market. A permit market should be first and foremost a competitive market. This condition necessitates that the number of firms within the market be quite large.

The basic premise behind the use of tradeable permits for the control of airborne pollutants is that the market mechanism will provide the incentive for firms to reduce their emissions. The underlying assumption is that firms are profit-maximizers or alternatively cost-minimizers. If firms are not cost-minimizers, the market mechanism will not provide the necessary incentive for firms to reduce their emissions.

The efficiency of the permits market also depends on the magnitude of the transactions costs.³⁰ Ideally, transactions costs should be zero for the market to be efficient. In practice however, transaction costs are not zero and may impede the proper functioning of the market if they are sufficiently large. As long as trading-costs are low, trading should not unduly affect the ultimate cost-effective allocation.

The standard efficiency result of TDPs is based on the assumption that emissions are homogeneous. Emissions, however, are heterogenous by nature. A more realistic approach would be to assume uniformly mixed pollutants. Although there is no reason to believe that the emissions will mix uniformly from source to source, this assumption is somewhat superior to the homogeneity assumption because it considers different emissions. Devlin and Grafton (1994), examine the effects of substitutable pollutant technology on the efficiency of permit markets. They conclude that where firms can substitute among pollutants, establishing a market for only one pollutant provides an incentive for firms to substitute to unregulated ones, thereby undermining the efficiency of the permit market. It is therefore important to consider the technology of firms when designing permit markets for one or many pollutants.

In order for a permit market to remain efficient over an extended period of time, the market must be flexible with respect to changes in environmental quality standards.³¹ Because the relationships between emissions and environmental quality and between pollution and health are not well understood, regulators are likely to acquire new knowledge that will cause them to want to change emissions levels. The efficiency of the permits market will therefore depend on the flexibility of the system.

The remainder of this section discusses specific design issues and factors

critical to the successful establishment and operation of an emission trading program. There are fifteen factors to be considered.

1. Clearly Defined Goals

Marketable emission permits were originally intended to be used as a tool to maintain the status quo - sources were allowed to trade emissions so long as environmental standards were not compromised. In recent years, however, regulators have ascribed different goals to trading programs. Emissions trading is now viewed as an effective method to facilitate emission reductions. In order to measure a trading program's performance, it is necessary for regulators to provide a clear statement of these goals. The success or failure of a trading program should be measured against its intended goals and not broader environmental objectives. For example, the fact that the air pollution persists year after year in a specific program area does not necessarily mean that the program has been a failure. If the goal of program is to ensure that new sources do not make air quality worse and the program accomplishes this, then it may be considered successful even if there is an increase in pollution due to emissions from existing sources.

2. Proportional Participation

A critical aspect of a successful air quality management program is that sources participate in the program in proportion to their contribution to the air

quality problem. The sources participating in the trading program should be defined before the program is initiated and should be related to the objectives of the program. For example, if the goal of the program is to accomplish area wide emission reductions, the requirement that a broad sector of polluting sources participate in the program will contribute to its success.

Ideally, from an economic and environmental standpoint, all the sources should be included in the trading program. From an administrative standpoint, however, it could be very costly and impractical to include numerous small sources in a trading program. It may be more cost-effective to include the large, easily identifiable sources in the trading program, while applying other measures, such as regulatory standards, to the sources who cannot practically be included.

3. A Quality Emissions Inventory

The purpose of an emissions inventory is to categorize the emissions of sources within a particular trading area. Successful trading programs are based on emissions inventories that accurately represent all sources within the trading area irrespective of their participation in the program.

The quality of the inventory depends on the availability of information concerning the emissions of the sources. Ideally, the inventory should not exclude any emissions and should be based on actual emissions rather than allowable emissions.

The success of the trading program is dependent on the quality of the emissions inventory. If the data on which the program is founded is inaccurate,

the program's objectives will not be met.

4. Comprehensive Permit System

A permit system is critical to the success of an emissions trading program. The regulator must have a means to bring sources into the system, ensure that new sources secure compensating offsets, and make certain that sources meet their continuing emission objectives. If the program is loosely regulated or only applies to a limited number of sources, the regulator loses a means to control the air quality problem and to manage its solution.

If reduction targets are to be met, the program must also ensure that firms obtain (and maintain) approval before any source is constructed, operated or modified. As well, the failure to meet the prescribed requirements must be punishable by the revocation of permits, fines, penalties or other sanctions.

5. Credible Enforcement Threat

The mechanism by which compliance with program standards is enforced must be significant to the firms. The penalty for non-compliance with the pre-set standards should, therefore, exceed the cost of obtaining emission permits in the open market.

For a program to be successful, the regulator must have the ability to determine or measure non-compliance. Ideally, a trading program should have two types of monitoring; the monitoring of emissions and the monitoring of

trades. Annual emissions reporting, facility inspections and source testing, as well as review mechanisms for trades should, therefore, be included in the permit program.

The integrity of the system also requires the establishment and enforcement of penalties for exceeding the emission levels allowed by permits. The penalties should be large enough to be an effective deterrent to wilful violations over an extended period, but not so high as to impose an unfair burden on the companies that produce excess emissions in a given period for reasons beyond their control. The absence of these elements will leave the door open for non-compliance and will undermine the trading program.

6. Consistent Rules

Clear and unchanging rules, consistent decisions, predictable time requirements and adherence to the timelines and schedules prescribed in the regulations will contribute to the success of an emissions trading program. To ensure success, regulators must acquire the confidence of participating firms. This can be accomplished if regulators provide firms with prompt, efficient, simple, and low-cost administration of programs.

7. Effective Emissions Bank

An emissions bank is an administrative mechanism that allows sources to create emission reductions, gain recognition for them, and store them for later

use or sale. To be effective, an emissions banking program must have a clear application process, a predictable review process, a long shelf life for ERCs, protection from the discounting associated with rules that are passed after an ERC is created, protection from confiscation and an understandable transfer process. Failure to include these elements in an emissions bank will reduce the industry's willingness to participate in the trading program.

8. Self-Supporting

The trading program should be financially self-supporting. The program should levy fees on the users which are sufficiently large to support its ongoing activities. A trading program that lacks the resources for proper implementation will almost always fail regardless of how elegant its design, well-intentioned its regulators or enthusiastic its industry users.

9. Trading Program and Air Quality Program Under the Control of One Entity

The existence of multiple agencies with different levels of control can result in the implementation of programs with conflicting goals and thus create lapses in the regulator's control of the program. For this reason, the administration of both air quality rules and the emissions trading program should be under the control of the same agency.

10. Input from All the Stakeholders

The emissions trading program must have the full support of those that will be affected by it. These stakeholders include, those within the legislature, the regulatory agency, industry and the public. Failure to gain support from these stakeholders will likely result in a system that is either unused, fails to accomplish its goals, or does not serve its intended users.

11. Appropriate Definition of Trading Zones

A trading zone is the geographical area within which sources of a given pollutant are allowed to buy and sell permits. The size and shape of an appropriate trading zone should vary according to the environmental problem. For example, in the case of ground-level ozone (smog), the appropriate trading area should encompass only the small area affected by the localized ground-level accumulation. On the other hand, an appropriate trading zone for greenhouse gas emissions should encompass the entire world because global warming has a worldwide impact.

12. Seasonal and Episodic Controls

Some environmental problems vary greatly by season. For example, ground-level ozone which results from the interaction of nitrogen oxides and

volatile organic compounds at warm temperatures is mainly a summer problem. In order to deal with seasonality problems, it may be appropriate to implement a permit system which allows for supplementary controls when pollution levels reach extreme levels. Another solution would be to issue permits and allow trading only in the season when the problem arises.

13. Interpollutant Trading

In some cases, more than one pollutant may be responsible for an environmental problem. One issue, in such a case, would be whether to include sources of emissions for the pollutants in the trading program. Another would be to allow trading between the emissions of the pollutants.

From an economic perspective, cross-pollutant trading is desirable because it could increase the number of sources in the trading scheme, thereby allowing for greater flexibility and cost savings. From an administrative perspective, however, cross-pollutant trading requires the establishment of appropriate trading ratios which correspond to damage caused. The determination of these relationships could be a difficult.

14. Initial Allocation of Permits

When a trading program is launched, the total number of permits must be initially allocated among the sources of pollution included in the program. Two

options for the initial distribution should be considered. One is to allocate the permits to the existing emissions sources based on historical emissions. Firms with historically larger emissions would be allocated more permits than firms emitting less pollution. The other option is to hold an auction, in effect leaving the distribution to the market.

As part of its SO₂ allowance trading program, the EPA has allocated permits according to historical emissions. It uses the following formula to allocate permits among sources:

$$\text{Number of permits} = \frac{\text{Average BTUs of fuel used 1985-1987 (millions)}}{\text{per million BTUs}} \times \frac{2.5 \text{ pounds of SO}_2}{\text{per million BTUs}}$$

The formula gives more permits to larger plants, as measured by the average quantity of fuel used during the base period 1985-1987. It is not exactly an equiproportionate system but it moves in that direction by using a common sulphur conversion factor - 2.5 pounds of SO₂ per million British Thermal units (BTUs) of fuel - to calculate initial allowances. More recently, however, auctions have been used to issue new allowances.

Although from the standpoint of realizing the potential economic benefits of a trading program, there is little difference between the two options, the method of permit allocation may have significant distributional impacts. The method of initial allocation may affect the structure of the market thereby affecting the efficiency of the market.³² For instance, if large firms are initially allowed to purchase large quantities of emission permits at the expense of smaller firms, a monopolistically competitive market may result. As well, if the permits are allocated on a historical basis, firms which receive the allocations may profit substantially from the sale of permits. Under an auction

scheme, the government would essentially capture the economic gains that would otherwise be captured by the firms. In addition, firms would bear more of a financial burden under the auction scheme.

15. Length of Permit Life

The length of permit life is an important factor for the success of a trading program. Regulators may choose from a variety of permit lengths depending on their objectives. For example, permits may be valid until a formal regulatory procedure declares them invalid or changes the amount of emissions allowed by a single permit. Alternatively, permits may be finite or perpetual, requiring regulators to buy them back to reduce total emissions. Recently, regulators have opted for permits of finite lengths because they are relatively easier to administer than permits of infinite lengths. As part of its SO₂ allowance trading program, the EPA now issues one year allowances which permit the emission of one ton of SO₂ per allowance.

3. EMISSIONS TRADING IN CANADA

Tradeable permit schemes could be an important component of Canadian environmental regulations in the near future. The use of these schemes, however, is a complicated issue and has several policy implications. The objective of this section is to bring together the theoretical knowledge and practical experience with tradeable permits to formulate a framework for assessing the implementation of tradeable permit schemes in Canada. Before proceeding with this analysis, however, current environmental regulations in Canada will be reviewed.

3.1 ENVIRONMENTAL CONTROL IN CANADA

THE CANADIAN ENVIRONMENTAL PROTECTION ACT

The Canadian Environmental Protection Act (CEPA) is the new federal legislation that gives the government power to protect human health and the environment from the risks associated with the use of chemicals and from exposure to toxic substances. The Act is the result of an extensive public consultation which began in 1982. It combines several pieces of environmental legislation to create a comprehensive approach to environmental protection in Canada. The basic premise behind the legislation is that "the protection of the environment is essential to the well-being of Canada".³³ The Act has the

following elements:

- authority to control the introduction into Canadian commerce of substances that are new to Canada;
- authority to obtain information on and to require testing of both new substances and substances already existing in Canadian commerce;
- provisions to control all aspects of the life cycle of toxic substances from their development, manufacture or importation, transport, distribution, storage and use, their release into the environment as emissions at various phases of their life-cycle, and their ultimate disposal as waste;
- authority to regulate fuels and component fuels;
- authority to regulate emissions and effluents, as well as waste handling and disposal practices of the federal departments, boards, agencies and Crown corporations;
- provisions to regulate federal works, undertakings and federal lands and waters, where existing legislation administered by the responsible federal department or agency does not provide for the making of regulations to protect the environment;
- provisions to create guidelines and codes for environmentally sound practices as well as objectives setting desirable levels of environmental quality;
- provisions to control sources of air pollution in Canada where a violation of an international agreement would otherwise result, or where the air pollution affects another country and reciprocal legislation to control the sources of pollution;
- provisions to control nutrients, such as phosphates, in water conditioners or cleaning products, including detergents, which can interfere with the use of waters by humans, animals, fish or plants;
- provisions to issue permits to control dumping at sea from ships, barges, aircraft and man-made structures (excluding normal discharges from off-shore facilities involved in exploration for,

exploitation and processing of seabed mineral resources); and

- authority to sign agreements with provincial governments regarding administration of the Act.³⁴

Two federal government departments share the responsibility of implementing and administering CEPA. Health and Welfare Canada is responsible for assessing substances for their potential impact on human health and for recommending appropriate controls on their use. Environment Canada is responsible for assessing substances for their impact on the environment and for recommending appropriate restrictions or limits on their use to prevent harm to the environment. As well, Environment Canada has developed a comprehensive enforcement and compliance policy for CEPA. This policy emphasizes preventing environmental damage before it occurs and ensuring consistent and fair enforcement across Canada. As part of this compliance policy, the government has developed an inspection and monitoring program for all regions of Canada.

Compliance means the state of conformity with the law. Environment Canada secures compliance with CEPA through two types of activity: promotion and enforcement. Measures to promote compliance include communication and publication of information, consultation with parties affected by the Act, technical assistance and technology development. Enforcement activities include:

- inspection and monitoring to verify compliance;
- investigations of violations;
- measures to compel compliance without resorting to formal court action, such as directions by inspectors, ticketing, and Ministerial orders; and

- measures to compel compliance through court action, such as injunctions, prosecution, court orders upon conviction, and civil suit for recovery of costs.

CEPA is much stiffer than previous environmental legislation. Under the Act, polluters may be fined up to \$1 million a day, or more if they have made profits from their polluting activities. Corporate officials can also be punished if they authorize or participate in activities that violate environmental regulations. These types of penalties are designed to encourage compliance by companies and individuals.

CANADA'S GREEN PLAN

In 1990, the federal government released "Canada's Green Plan" to complement the existing CEPA regulations. The mission of this project is "to make Canada, by the year 2000, the industrial world's most environmentally friendly country" [Government of Canada, The Green Plan: Framework for Discussion of the Environment (1990)]. The Green Plan document addresses questions of both ends and means. It sets out a range of possible goals and methods for achieving them but is careful to underscore that the plan itself is still being formulated, and that it will be shaped by a public consultation process. One of the key messages of the Green Plan is that economic growth and preservation of the environment are fully compatible and reinforceable goals if Canadians as a society build the environment into their choices and their decision-making.³⁵

The Green Plan also recognizes that although environmental science, education and information are necessary for enhancing environmentally

responsible decisions-making, they are not sufficient. More direct measures are also required, specifically regulations and economic instruments. The government of Canada has explored and is currently exploring the use of several types of economic instruments to be used in conjunction with existing regulations. These include:

- tradeable permits;
- user charges;
- deposit-refund schemes;
- environmental charges;
- tax incentives; and
- combined environmental charges and tax incentives.

Of all these economic instruments, tradeable permits have received the most attention in recent years. In order to meet Canada's commitment under the Montreal Protocol on Substances that Deplete the Ozone Layer, Environment Canada is proposing that transferable allowances be used for hydrochlorofluorocarbons (HCFC) phase-out by 2030. A system of transferable allowances for Methyl Bromide production and consumption is also scheduled for implementation on January 1, 1995.³⁶ Several programs under the auspices of CEPA and the Green Plan are also considered strong candidates for the implementation of tradeable permit schemes. These environmental programs are discussed below.

EXISTING ENVIRONMENTAL PROGRAMS

Canadian authorities have traditionally taken a command-and-control approach to environmental regulation. Recently, however, authorities have focused their attention on the use of economic instruments to achieve environmental goals. Since most of these initiatives are still in the design stages, Canada's initial approaches to the problems of acid rain, smog and global warming still take the traditional command-and-control approach.

Acid Rain Control Program

The main cause of acid rain in Canada are emissions of SO_2 released by industrial sources. These emissions cause severe damage to Canada's lakes, rivers and forests when they return to earth as acid rain, snow, fog or dust.

Canada's Acid Rain Control Program was launched in 1985. Under the program, the federal government and the seven provinces east of Saskatchewan agreed to reduce total emissions of SO_2 by 50 per cent³⁷ to 2.3 million tonnes per year by 1994.³⁸ The program was initially very successful as five provinces - Manitoba, New Brunswick, Nova Scotia, Newfoundland and Prince Edward Island - reduced their emissions below the 1994 caps.

To ensure that they meet the 1994 emission caps, the provinces of Ontario, Québec, and Manitoba have set air quality standards for SO_2 . Under no circumstances are sources to release emissions that would exceed these standards. As well, these provinces have issued additional regulations that set emissions ceilings for polluters. In Ontario and Manitoba, the annual emission

ceilings apply to individual companies. In Québec, on the other hand, the ceilings are applicable to different sectors, such as copper or zinc smelting rather than to companies.

Since the inception of this program, SO₂ emissions have decreased dramatically. Although the decrease may be partly attributed to the recession, as of 1994, all the participating provinces had achieved their emission targets and further reductions were proposed. As well, Canada has pledged to establish a permanent national emissions cap of 3.2 million tonnes of SO₂ by the year 2000.

Management Plan for Nitrogen Oxides and Volatile Organic Compounds

The build-up of ground-level ozone is the largest contributing factor to the smog problem that plagues several Canadian cities. Caused by the interaction of NO_x and VOCs in warm temperatures, ground-level ozone accumulation is usually quite severe throughout the summer months. In the Lower Fraser Valley of British Columbia, the Windsor-Québec City corridor and the Southern Atlantic region smog has reached levels harmful to human health and vegetation.

In October 1988, the Canadian Council of Ministers of the Environment (CCME) ordered the drawing up of a management plan to control NO_x and VOC emissions. In 1990, the plan was approved in principle and a target concentration of 82 parts per billion (per hour) for all regions of Canada by the year 2005 was established.³⁹

The Management Plan is a multi-phase program designed to contain

ground-level ozone in areas where the CCME target is met and reduce it in areas of non-attainment. In Phase I, a national prevention program will be introduced to control NO_x and VOC emissions for the period 1990-1994. As well, interim targets will be set for the years 1995 and 2000 for problem areas - Lower Fraser Valley, Windsor-Québec City corridor and the Southern Atlantic region. As part of the national prevention program, Phase I outlines several initiatives for reducing NO_x and VOC emissions. These initiatives are essentially a menu of options for controlling emissions and may be substituted with measures that achieve better results or "environmentally equivalent" ones that are more cost efficient. These initiatives include:

- emission limits for transportation sources;
- energy efficiency standards for equipment and appliances;
- new-source performance standards for stationary sources of NO_x and VOCs; and
- measures to reduce emissions from products containing solvents.

Phase I also specifies additional initiatives which may be implemented in non-attainment areas. These include:

- retrofit programs for existing NO_x and VOC sources;
- the development of environmentally oriented urban transportation systems; and
- ozone episode management plans to deal with peaking problems.

In Phase II (and possibly Phase III if necessary) the final 2000 and 2005 emission targets will be established for the problem areas along with additional measures needed to achieve those targets.

National Action Strategy on Global Warming

The growing concentration of man-made emissions of greenhouse gases, such as carbon dioxide, methane, nitrous oxide and CFCs, is considered the main cause of the "global warming" phenomenon. In a cold country like Canada, global warming may seem like a blessing but there are serious consequences that may arise from an increase in global mean temperatures. Greenhouse gases act as a buffer in the atmosphere, trapping the earth's heat. Thus, rising temperatures could alter climatic patterns and could threaten the existence of some plants and animals.

In order to control this problem, a number of countries, including Canada, have established national targets for greenhouse gas emissions. Developed by the federal, provincial and territorial governments, Canada's proposed approach to the problem of global warming is set out in the National Action Strategy on Global Warming.

There are three main elements to the National Action Strategy:⁴⁰

1. limit greenhouse gas emissions;
2. adapt to potential changes resulting from global warming; and
3. improve scientific understanding of the global warming process.

In addressing the limitation of greenhouse gases, the government of Canada has placed a priority on limiting CO₂ and other gas emissions not controlled under the Montreal protocol.⁴¹ The immediate goal is to stabilize emissions at 1990 levels by the year 2000. In the Green Plan, the federal government announced several measures to begin the stabilization of greenhouse gases, however, the National Action Strategy on Global Warming recognizes that

it may take more than these first steps to achieve the stabilization goal. The Strategy therefore proposes that governments begin studying potential longer-term, wider-scope measures that may become necessary to reduce emissions.

MORE RECENT ENVIRONMENTAL INITIATIVES

As part of its commitment to environmental protection, the current federal government established a task force in July 1994 to find effective ways in which to use economic instruments to protect the environment and to identify barriers and disincentives to sound environmental practices. The "Task Force on Economic Instruments and Disincentives to Sound Environmental Practices" consisted of business leaders, academics, environmentalists and government officials. In its final report the Task Force identified a number of promising short and long-term applications of economic instruments.⁴² Several of the short term proposals (pertaining to air pollution) outlined in the final report are discussed below.

Energy Retrofits - RRSP Financing and Enhanced Financing

To promote energy efficiency while stimulating activity in the residential energy retrofit sector, the Task Force has suggested that individuals be allowed to use capital from their RRSP accounts (up to a specified limit) without tax consequences for residential energy efficient retrofits. The Task Force has also suggested that the federal government should encourage financial institutions to

provide loans for home energy and commercial sector energy and water energy retrofits. These measures were considered to be consistent with government objectives to improve energy efficiency and reduce greenhouse gas emissions.⁴³

Level Playing Field in the Energy Sector

The Task Force has suggested that the federal government should commit itself to ensuring that renewable energy options receive an equitable portion of federal energy research and development and demonstration spending. In the past, expenditure patterns have tended to be weighted to non-renewables.⁴⁴

Tax Exemptions for Transit Passes

The Task Force has suggested that tax exemptions should be provided for employer-provided transit passes. Although this option may seem trivial, the use of public transportation over single occupancy vehicles may reduce energy consumption, atmospheric pollutants and traffic congestion in urban centres.⁴⁵

Over the short term, other measures such as increased gasoline taxes and gas guzzler taxes with rebates were mentioned but the Task Force failed to reach a consensus on these points. Over the longer term, the Task Force proposed several measures which have great potential for achieving economic and

environmental goals. These measures are discussed below.

Incentives for Alternative Transportation Fuels

In order to encourage the use of more environmentally friendly transportation fuels, the federal government should create economic incentives for the use of alternative transportation fuels such as ethanol, methanol, natural gas and propane. Because several alternative fuels offer lower tailpipe emissions than conventional fuels, encouraging their use may mitigate greenhouse gas emissions.⁴⁶

Implementation of Tradeable Permits Schemes

The Task Force supports the use of tradeable allowances for the control of SO₂ emissions in Eastern and Western Canada and tradeable permits for the control of NO_x in Ontario. The implementation of these schemes is discussed in greater detail in Section 3.2. The Task Force also supports the implementation of a tradeable permit for limiting benzene in gasoline. A tradeable permit program for benzene would be similar in structure to the U.S. lead phase-down program. The permit system would set limits on the benzene content in gasoline that refiners could not exceed. Permits would be distributed to each refiner in proportion to their production and subsequently traded between refiners. Such a system would be a cost effective method to limit the benzene content in gasoline.⁴⁷

3.2 THE FEASIBILITY OF TRADING IN CANADA AND RELATED DESIGN ISSUES

The U.S. emissions trading experience has shown that emissions trading can be successfully combined with regulations to achieve environmental goals with appreciable cost savings. Although Canada and the United States are different in many respects, the success of U.S. emissions trading programs provides support for similar programs in Canada.

Emissions trading is well suited to complement existing environmental regulations in the control of acid rain, smog and global warming. Environmental regulators attempting to establish emissions trading schemes in Canada, however, should proceed with caution. Canada is a nation of diverse regions with differing characteristics and environmental problems. Since emissions trading has proven to be more effective in some circumstances than others⁴⁸, it is therefore logical to establish the feasibility of trading on a case by case basis.

EMISSIONS TRADING AND THE CONTROL OF ACID RAIN

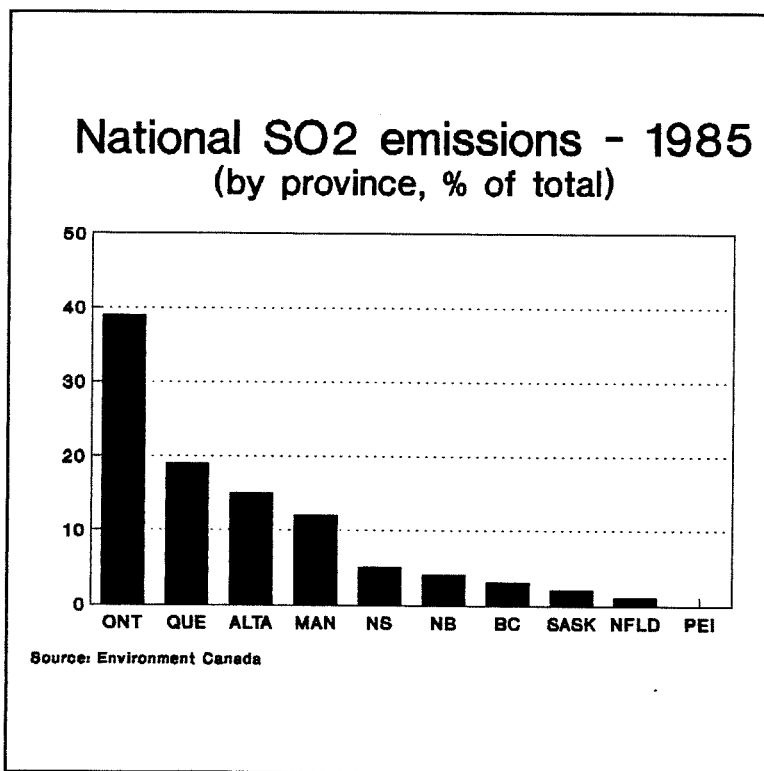
Tradeable permits appear particularly well suited to the problem of controlling SO₂ emissions in Canada for several reasons. First, an overall emissions cap has already been set as part of the existing program. Second, Canada's existing acid rain program has some of the characteristics of a tradeable permit system in that it gives firms some flexibility in how to meet emission limits. Ontario Hydro, for example, is free to shift or "trade" emissions between its various electricity generating stations, provided its total

emissions do not exceed the overall level.⁴⁹ Third, SO₂ emissions from the United States contribute to the acid rain problem in Canada and vice-versa. Since the United States already has an active trading program for SO₂ emissions, a similar trading program in Canada could eventually allow international trading.

Specific issues must be addressed before a trading program for controlling SO₂ emissions is implemented. Regulators must determine which types of permits will be used and how these permits will be distributed. As well, they must select appropriate trading zones and identify the sources to be included in the trading program.

Trading Zones

The severity of Canada's acid rain problem varies considerably from region to region. The distribution of Canada's SO₂ emissions by province is shown in Figure 6.⁵⁰ According to 1985 levels (when Canada's Acid Rain Control Program was launched), emissions from the seven provinces participating in the Acid



Rain Control Program accounted for 80 per cent of total national emissions. The acid rain problem is most severe in Ontario and Québec which accounted for the largest share of total emissions with a combined total of 58 per cent. The problem is considerably less severe in Western Canada and in the Atlantic provinces.

Since there is considerable variance from region to region in the gravity of the problem, one trading zone encompassing all affected areas would not be desirable. Such a trading zone could lead to a decrease in overall environmental quality. Three distinct regions, with distinct patterns of emissions, emerge from the data: Ontario and Québec, the Atlantic Provinces, and Western Canada. This suggests that the creation of three separate trading zones would be more appropriate.

Sources to be Included in a Trading Program

In Canada, a very large proportion of the SO₂ emissions comes from a small number of companies. According to 1985 data, six corporations account for approximately half of the SO₂ emissions in Canada. Inco and Hudson Bay Mining and Smelting are responsible for roughly 95 per cent of the SO₂ emissions in Manitoba. In Ontario, four corporations - Inco, Algoma, Falconridge, and Ontario Hydro - contribute 80 per cent of the province's emissions, and Noranda in Québec accounts for half of the province's emissions.⁵¹ In New Brunswick and Nova Scotia, the largest emitters are the provincially owned electric utilities.

Ideally, all SO₂ emitting sources should be included in a trading program.

In practice, however, the inclusion of every contributing source is virtually impossible and quite cumbersome for regulators. To minimize monitoring and administrative costs, the trading programs should initially include only the major offending sources. Once established, the trading programs could be expanded to include relatively minor sources such as pulp and paper mills, refineries and other industrial sources provided these do not lead to excessive administration costs. The major obstacle for SO₂ trading in Canada, however, is that the number of large emitting sources may not be sufficient to support competitive trading in the areas where the acid rain problem is most severe. Although the number of large sources in Ontario/Québec and Western Canada seems to be sufficient to support trading programs, it is doubtful that there are enough large firms in Atlantic Canada to support trading activities.

The case for SO₂ emissions trading in Canada is also complicated by the fact that a relatively small number of sources contribute the majority of emissions in Canada creating the possibility of market domination and strategic behaviour by large firms. To be effective, emissions trading should, therefore, be used in conjunction with other regulatory practices.

SO₂ emission reductions could be achieved with programs combining regulations and the use of tradeable permits. For instance, to prevent the domination of the market by large sources, the large sources (which are easily identifiable) could be subjected to regulations such as emission standards or could also be induced to reduce emission levels with various tax incentives, while the smaller sources could be allowed to participate in a trading program. Another alternative, would be to allow large sources to participate in a competitive trading program that includes U.S. firms and regulate smaller sources. Another solution to the problem is to allow trading between zones.

Trading, however, should not be allowed on a one-for-one basis. Instead, trading ratios, which take into account the emission levels within each zone could be developed.

Permits, Permit Life and Distribution

Tradeable permits may take several shapes and forms. In the United States, trading has traditionally revolved around the ERC which is basically a permit for a continuous stream of emissions that is valid perpetually. More recently, however, the use of allowances which represent an allowable quantity of emissions in a specified time span has been prevalent in U.S. trading programs.

An important distinction should be made between permit systems which use allowances and those which use the ERC. Under the ERC approach, command-and-control measures are mandated for existing, modified and new point sources to achieve the target reduction in emissions. The trading program is intended primarily to offset residual emissions from new and modified sources so that air quality does not deteriorate. Under the tradeable allowances approach, no new command-and-control measures would be instituted for stationary sources. The target reduction in emissions would be achieved by reducing the total quantity of allowances and requiring all existing and new point sources to acquire allowances equal to their total emissions.

Canadian SO₂ emission trading programs could effectively utilize both types of permits systems depending on the goals of the program. However, allowance-type permits would be easier to administrate than ERCs. U.S.

experience with ERCs shows that their use can be quite cumbersome for regulators and sources attempting to secure them. Conversely, allowances are less problematic for participants because they are standardized emission permits.

The distribution of permits is another issue of considerable importance. There are basically two options for the distribution of permits to sources. First, permits could be distributed to existing sources free of charge based on historical levels of emissions. This method is also known as "grandfathering". Second, the government could auction off the permits to the sources. Although both these methods may create distributional imbalances because there will be a tendency for large firms to appropriate large quantities of permits, they are by no means equivalent. Grandfathering will benefit sources because permits will be obtained free of charge. Auctions, on the other hand, will benefit the regulator who will receive the proceeds from the auction.

In order to minimize the disruptive effects of establishing a permit system, the initial allocation of permits should be based on an equiproportionate distribution mechanism which takes previous emissions into consideration. Once the program is established, however, auctions could be held for subsequent permit allocations.

Inter-Pollutant Trading

Another design consideration is whether or not to allow inter-pollutant trading between NO_x and SO_2 . In view of the small number of major sources of SO_2 emissions in Canada, inter-pollutant trading could potentially expand the

market for permits and improve the effectiveness of the trading system. The issue of whether or not trading between NO_x and SO₂ should be allowed must, however, be examined more carefully from an environmental perspective. In some sites, for example, nitrogen is taken up by the ecosystem as a nutrient and therefore does not contribute to the acidity of freshwater ecosystems.⁵² In such cases, inter-pollutant trading is not warranted.

Trading with the U.S.

Allowing trading across international borders makes sense in the case of the United States because each country contributes to the other's acid rain problem. It is estimated that in 1985, 3.2 million tons of U.S. SO₂ emissions ended up in Canada, representing more than 15 per cent of the 21.0 million tons produced in the United States. Meanwhile, 1.35 million tons of Canada's SO₂ emissions ended up in the United States, representing more than one-third of 3.7 million tons emitted in Canada.⁵³ Since Canada imports almost as much SO₂ from the United States as it produces itself, participation of American sources is vital for the success of Canadian trading programs.

Although the environmental effects of cross-border emissions are understood, reliable estimates of source-receptor relationships are difficult to obtain. Recent studies, however, have suggested several tendencies in the patterns of cross-border emissions which must be addressed if cross-border trading is being considered.⁵⁴ These are:

1. The prevailing weather patterns tend to carry pollutants from the south and west to the north and east to a greater degree than they flow in the opposite direction.

2. Sensitive regions in the northeastern United States receive about 70% of their acidic deposition from within 500 kilometres.
3. Sensitive receptors in southeastern Ontario receive about 70% of total acidic deposition from distances further than 500 kilometres.
4. U.S. sources contribute about 50% of total sulphur deposition in southeastern Canada.
5. Sensitive regions of northeastern North America receive from 5% to 25% of total sulphur emissions from Canadian sources.

Due to the nature and size of emission patterns between the United States and Canada, SO₂ emissions trading between the two countries is a logical and realistic possibility. In establishing trading schemes in Canada, it therefore makes sense to create trading programs that will allow the possibility of cross-border trading. As such, these programs should be compatible with the U.S. SO₂ allowance trading program. Of the three areas in Canada capable of supporting trading programs, the Windsor-Québec City corridor has the greatest potential for cross-border trading. Allowing the transfer of discharge permits in an area comprising southern Ontario, southern Québec, northern New England and New York could help the acid-rain problem in southeastern Canada and the northeastern United States. Cross-border trading in this area is also facilitated by the fact that the mechanism for establishing cost-effective transboundary control of acid-gas emissions is already in place, with the acid-rain accord signed by Canada and the United States in March, 1991. In that accord, both countries have committed to meet emission targets they have set for themselves and also to monitor the transboundary flow of SO₂ emissions.

Cost Effectiveness of SO₂ Emissions Trading

Fuel substitution or modification, combustion modifications and cleaning of flue gases are some of the abatement technologies available to emitting firms. As such, control costs can be expected to vary among individual sources according to the technology used. For example, abatement costs range from about \$200/ton for SO₂ removal in smelters to about \$1,500/ton for Ontario Hydro and to a multiple of that amount in some smaller industrial sources like pulp and paper mills and oil refineries.⁵⁵ In Ontario, the average cost across all sources for an additional 10% cutback beyond the 1994 objective ranges from \$270 to \$1,400 per metric ton of SO₂ removed.⁵⁶ The Ontario Ministry of the Environment (1990) estimates potential cost savings on the order of 25-30% if least-cost strategies, such as emissions trading, are followed in apportioning reductions of SO₂ among major sources. Barakat and Chamberlin (1991) also suggest significant cost savings from emissions trading in the Lower Fraser Valley.

Allowing the transfer of discharge permits among pollution sources across borders should also achieve additional cost savings because of the increased trading potential. As the number of sources involved in trading increases, the costs of meeting the pollution control objective will fall because there are more opportunities to transfer control responsibilities to sources with lower abatement costs.

EMISSIONS TRADING AND THE CONTROL OF GROUND-LEVEL OZONE

As mentioned previously, the smog problem in Canada is quite severe in three specific areas: the Lower Fraser Valley, the Windsor-Québec City corridor and the Southern Atlantic region. Emissions trading could play a role in attaining the NO_x and VOC emissions targets in these problem areas.

Although both VOC and NO_x emissions could conceivably be included in one trading program, in effect allowing trading between the two pollutants, emissions trading programs for these pollutants are usually considered separately. Until the impacts of incremental NO_x and VOC emissions on the formation of ozone are better understood by the scientific community, it has been deemed prudent not to trade between pollutants.⁵⁷ For the purposes of this discussion, however, they will be examined together.

Sources to be Included in a Trading Program

Several types of sources contribute to the accumulation of ground-level ozone. Figure 7⁵⁸ shows the sectoral shares of NO_x emissions in Ontario for 1985. Automobiles and other mobile sources are by far the largest source category of NO_x in the province, accounting for 62.5 per cent of the total. The second largest source category is electric power generation, which accounted for 17.5 per cent of emissions. Other types of industrial and commercial fuel combustion accounted for an additional 9.9 per cent, followed by industrial processes at just under 7 per cent.

It may not be feasible, however, to include all these sources in trading

programs. The choice of sources to be included in a trading program should reflect a variety of factors, in particular the tradeoff between the cost-savings advantages of broader coverage and the administrative problems that may arise with a large number of small sources.

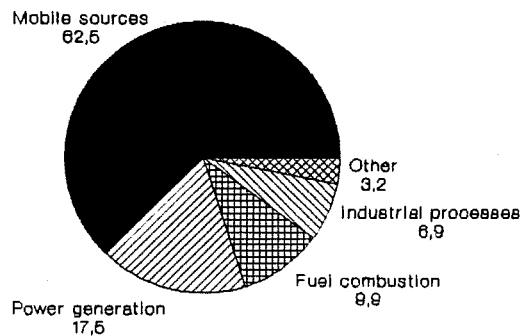
In the transportation sector for instance, because the individual sources of NO_x

are small, numerous and mobile, it would not be practical to include them in regional emissions trading programs. By contrast, large sources such as power generating facilities, and large industrial and commercial fuel combustion facilities should be included in trading programs.

The situation in the Lower Fraser Valley is similar to that of the Windsor-Québec City corridor in that most of NO_x emissions in the area are caused by mobile sources (78.2 %). However, only six large stationary sources account for 62.5 per cent of total point source emissions. These sources include four oil refineries and two cement plants. A limited regional trading program should include these facilities.

Natural sources, such as forests, generate as much as 85 per cent of VOC emissions in Canada as a whole. Since it is virtually impossible to control these

Sectoral Shares of NO_x Emissions (Ontario, 1985, % of total)



Source: Environment Canada

Figure 7

natural sources, control programs must target man-made VOC emissions. Man-made VOC emissions come from a variety of sources: the transportation sector, industrial processes, the evaporation of solvents, the combustion of fossil fuels in all sectors, and the evaporation of liquid fuels during their production, storage, handling, or final use. Figure 8 shows the

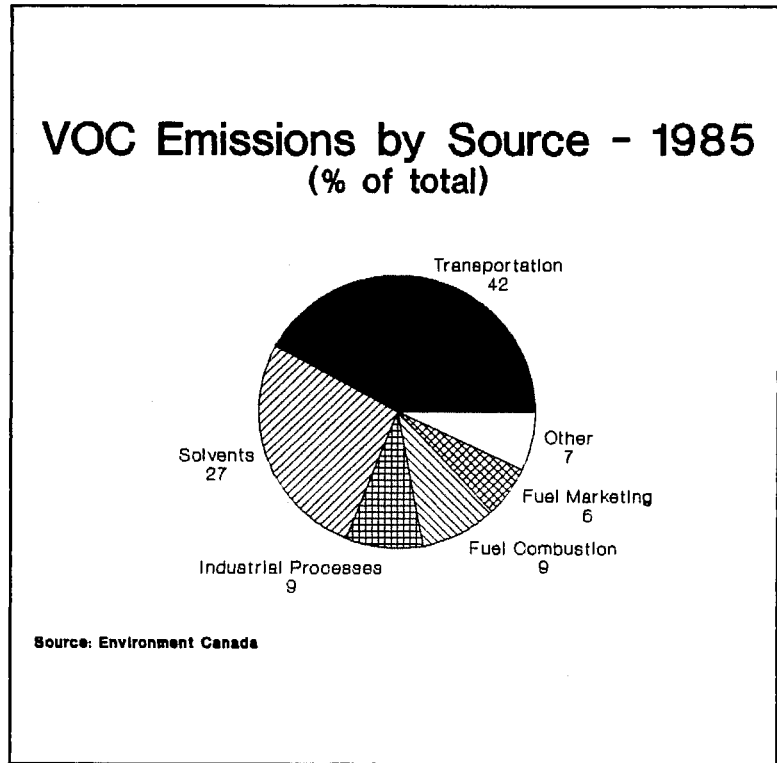


Figure 8

breakdown of VOC emissions by source for 1985.

As in the case of NO_x , it would be difficult to include the transportation sector in emissions trading programs for the three problem areas because of the number and mobility of sources. In the solvent category, large stationary sources could easily be included. Other sources which could easily be included in trading programs are industrial processing facilities including petrochemical plants, petroleum refineries, pulp and paper mills and plastics production installations. It would not be practical, however, to include smaller sources such as consumer and household products.

Trading Zones

An important consideration in designing trading zones is that in order for a trading program to be effective in minimizing the costs of meeting environmental targets, the zone must contain several sources with different abatement costs. Since there are at least 200 large stationary sources of NO_x in Ontario alone, this suggests that the Windsor-Québec City corridor is more than adequate to ensure trading without compromising environmental objectives.

The situation in the Lower Fraser Valley is somewhat different. Although there are at least 100 large stationary sources of NO_x, six of these sources generate at least 60 per cent of total emissions. The entire area should therefore be considered as a single trading zone. The fact that six sources produce most of the emissions in the area, however, somewhat complicates the case for trading in this area. One solution to this problem is to establish emission standards for these six firms and to allow trading among the remaining large sources. Such a scheme would eliminate the possibility of market domination by one of the large firms.

Possible trading zones for VOCs would approximate the trading zones for NO_x, however, the case for VOC trading is complicated by the fact that in all three regions, a few major sources dominate the contingent of large stationary non-solvent sources. In the Lower Fraser Valley, for example, four refineries generate more than 70 per cent of the VOC emissions from large, stationary non-solvent sources.⁵⁹ This suggests that in this area, only one trading zone would be appropriate.

Again, however, the possibility exists that the trading market will be dominated by a few firms. Barakat and Chamberlin (1991) suggest that this is

not necessarily the case. Upon examination of four-firm concentration ratios for the proposed NO_x and VOC allowance markets, Barakat and Chamberlain conclude that although the concern over possible noncompetitive behaviour is valid, the concentration is not so high as to be alarming. Smaller sources will need smaller quantities of allowances if they are buyers, and these can be supplied by other small sources. Hence the small sources are not captive buyers or sellers for the large sources. If, however, market domination by large sources exists, the problem can be resolved quite easily. One solution is to regulate large sources and exclude them from trading programs while allowing medium sized sources to participate in trading.

Permits, Permit Life and Distribution

As mentioned earlier, tradeable permits may take several shapes and forms but the use of standardized permits may facilitate the administration of the program. Both the ERC and tradeable allowance approaches may be suitable for NO_x and VOC reductions in the Lower Fraser Valley.

Regardless of its design, however, the NO_x or VOC emissions trading program must have an initial allocation of permits. For this purpose, an historic emissions level should be established for each stationary source. This level would serve as a base from which emissions credits are calculated or to determine the proportion of allowances allocated to each source.

Most trading programs use the terms "allowances" or "permit" to describe the trading currency used in the programs. The basic trading system devised for stationary sources of NO_x in Ontario takes a different approach. The system

makes use of coupons and shares rather than allowances or permits.⁶⁰ A coupon entitles its holder to emit one tonne of NO_x. Coupons are issued at regular intervals but are valid indefinitely, until used. Coupons are freely tradeable among all sources covered by the plan and may be banked if so desired. In contrast, a share represents a mechanism for allocating coupons among covered sources. Each share entitles its holder to receive a proportionate share of the coupons distributed at a particular time.⁶¹ This system facilitates the distribution of "permits" by linking the allocations to the size of the sources' emissions. Although this method of permit allocation is slightly more complicated than a simple ERC or allowance approach, it provides an alternative to these methods and could easily be implemented in regional trading programs.

Seasonal and Episodic Controls

The need to address seasonal and episodic problems is a design issue specific to the control of ground-level ozone. One way to address this problem is to place an additional cap on emissions during the summer months. Accordingly, each year, two types of permits could be issued. One type would allow NO_x emissions in the summer months and the other would allow emissions the rest of the year.

NO_x/VOC Interpollutant Trading

Interpollutant trading would allow sources in a trading zone to purchase permits for one pollutant in order to satisfy their requirements for the other. In this case, interpollutant trading makes sense because the interaction of both substances causes the accumulation of ground-level ozone. As well, interpollutant trading would increase the number of sources that could trade emissions and ultimately enhance the diversity of sources in an area.

Cost Effectiveness of NO_x/VOC Trading

The basic concept behind the use of tradeable permits is that they are a cost effective method of achieving environmental goals. One NERA study estimates that the province of Ontario can generate savings of \$129 million by utilizing emissions trading instead of standards for the period 1991-2005.⁶² Barakat and Chamberlin (1991) examine the feasibility of NO_x and VOC trading in the Lower Fraser Valley. Although they do not explicitly address the magnitude of cost savings to be realized with emissions trading, their analysis suggests that emissions trading would have substantial economic benefits.

TRADING PROGRAM FOR GREENHOUSE GASES

Canada is currently a net carbon sink. Canadian forests currently naturally absorb or "sequester" more carbon than is produced in the country.

It has been suggested that sequestering additional carbon through increased forestation might be a cost-effective method for Canada to contribute to reduced climate warming. Cost analysis of additional sequestering is unclear, however, because there is no straightforward way to translate carbon sequestering benefits into dollars.⁶³ Regardless, carbon sequestering, can play an important role in reducing CO₂ levels in Canada.

The use of tradeable permits might also be a cost effective method by which Canada could reach its goal of stabilizing CO₂ and other greenhouse gas emissions at 1990 levels by the year 2000. Consistent data on national and international emissions of artificially produced greenhouse gases, however, is only available for carbon dioxide (CO₂) suggesting that only trading programs for CO₂ are feasible at this time.

Trading Zones

The contribution of greenhouse gas emissions to global warming is not related to the location of the source. Greenhouse gas emissions have the same global impacts no matter where they are emitted in the world. For this reason, there is no reason to limit the size of the trading zone. Trading programs for CO₂ could effectively be implemented on a national or international scale. In fact, larger trading zones may improve trading because of the increased number of participants.

Sources to be Included

There are basically three major sources of artificially produced CO₂ emissions in Canada - the energy sector, the non-energy sector and agricultural land. As can be expected, the energy sector is the major emitter. 1990 estimates place total emissions from energy sources at 450 millions tons of CO₂ (or 88 per cent of emissions). Non-energy sources are responsible for emitting 12 million tons of CO₂ per year. Estimates for agricultural land are highly uncertain.⁶⁴

For administrative reasons, it may not be feasible to include small sources in trading programs. This all but eliminates most sources from the transportation sector. It has been suggested, however, that a trading program could be developed specifically for this sector. A trading program could target fuel efficiency by allowing automobile manufacturers to trade permits that are based on the average fuel efficiencies of their fleets. Alternatively a system could be devised to allow trading of permits covering the carbon content of fuel.⁶⁵ These programs, however, are still in the discussion stages.

It is feasible to include sources from the industrial sector and the utility/power generation sector in a nationwide trading program. Industrial sources such as pulp and paper mills, cement factories, chemical and petrochemical plants, iron and steel smelting plants and aluminium plants contribute as much as 20 per cent of total CO₂ emissions.⁶⁶ Utilities, on the other hand, account for at least 23 per cent of total Canadian emissions.⁶⁷ If these sector were combined into one permit trading system, a market of 200-300 sources could be created that would account for over 40 per cent of total Canadian emissions.

SUMMARY AND CONCLUSION

Acid rain, smog and global warming are serious environmental problems which demand immediate attention at national and international levels. As a leader in environmental protection, Canada has traditionally achieved its environmental goals with the use of regulations. Although command-and-control approaches to environmental regulation still have an important role to play, the use of market-based approaches has several advantages.

The basic difference between regulations and economic instruments is that the former directly prescribes behaviour. For example, regulations may specify products, processes and the actual technology to be used by firms. Economic instruments by contrast, use market signals to influence behaviour in a manner which is consistent with environmental goals. With economic instruments, specific decisions about how to achieve an environmental objective are left to the discretion of the firm.

Economic incentives can be effective tools in promoting environmentally sound behaviour. They include tradeable emission permits, user charges, deposit-refund schemes, environmental charges, and tax incentives. Economic instruments are superior to other alternatives in many respects. First, economic instruments are cost effective. Second, they provide continuing economic incentives for firms to abate pollution. Third, in some cases, economic instruments can be less cumbersome for government and business to administer.

The most innovative of the market based approaches is the tradeable emission permit. Under a tradeable permit approach, a cap is placed on the total

quantity of pollutants allowed to be emitted within an airshed. An appropriate share of the total amount of pollutants allowable is then allocated to each participating emission source within the airshed. Participating sources are then allowed to buy or sell their emission shares. Firms with low pollution abatement costs can increase their pollution abatement activities and sell their surplus emission shares to firms with high pollution abatement costs. Because they allow flexibility in the way clean air objectives are met, tradeable permits have the potential to achieve air emission targets at a lower cost to society than command-and-control approaches.

This paper had two main objectives. The first objective was to review the theoretical literature and the practical experience with emissions trading. To this end, several U.S. trading programs were analyzed. Based on this analysis and the study of several theoretical models, several factors critical to the success of a trading program were outlined. To be successful a trading program should have clearly defined goals, input from all stakeholders, proportional participation, a quality emissions inventory, a comprehensive permit system, credible enforcement threat, consistent rules, an effective emissions bank and appropriately defined trading zones. In addition, the program should be self-supporting and allow for seasonal and episodic controls and interpollutant trading. As well, the trading program and the air quality program should be under the control of one entity. The permit system should also address the initial allocation of permits and the length of permit life.

The second objective of the paper was to determine the feasibility of emissions trading in Canada. It was determined that trading could be successful when used in conjunction with existing legislation for limiting SO₂, NO_x, VOC and CO₂ emissions. In the case of SO₂, NO_x and VOC trading, two main areas in

Canada could support trading programs - the Windsor-Québec City corridor and the Lower Fraser Valley. Because of the nature of CO₂ emissions, a national trading zone for CO₂ was considered more appropriate.

Emissions trading in Canada is complicated, however, by the possibility of market dominance by large firms. Uncompetitive market behaviour may result because a small number of firms is responsible for the majority of emissions in several of the proposed trading areas. This problem, however, is not as serious as it seems. The paper proposes several solutions to resolve this problem.

This paper has outlined several issues regarding the implementation of tradeable emission permits in Canada. As well, the paper provides some insights as to the direction of environmental control in Canada. Emissions trading has been successful in the United States - it can also play an important role in Canada.

ENDNOTES

1. Baumol and Oates (1988), p. 18.
2. Laffont (1988), p. 13.
3. Transaction costs refer to costs that arise when individuals exchange ownership rights to economic assets or enforce their exclusive rights to these assets.
4. Although environmental zealots advocate the elimination of air pollution entirely, clearly this proposition does not conform with the concept of an industrialized society.
5. Graph taken from Forsund and Strom (1988), pp. 62-63.
6. Government of Canada (1992), "Economic Instruments for Environmental Protection." p. 13.
7. Ibid., p. 15.
8. Graph taken from Forsund and Strom (1988), p. 103.
9. Example taken from Varian (1992), p.433.
10. Hull and St-Pierre (1990), p. 15.
11. Graph taken from Forsund and Strom (1988), p. 108.
12. Graph taken from Forsund and Strom (1988), p. 111.
13. Government of Canada (1992), "Economic Instruments for Environmental Protection", p. 23.
14. Baumol and Oates (1988)
15. In the discussion which pertains to U.S. programs and policies all monetary figures are denominated in U.S. dollars.
16. Information regarding the Clean Air Act and the U.S. emissions trading program was obtained from Tietenberg (1980, 1991, 1992), Field (1994), and Barakat and Chamberlin (1991).
17. A non-attainment area is a region which has not met a specified ambient standard.

18. Barakat and Chamberlin (1991), p. 16.
19. Tietenberg (1991), pp. 19-20, p. 24.
20. Howe (1994), p. 156.
21. Ibid., p. 156.
22. Information on the trading programs was obtained from Barakat and Chamberlin (1991).
23. Barakat and Chamberlin (1991), table III-1, p. 25.
24. The October 1990 revisions to the SCAQMD regulations lowered the thresholds to zero for all pollutants. Now all non-exempt new and modified sources must offset all emissions increases through the acquisition of emission reduction credits.
25. Barakat and Chamberlin (1991), p. 27.
26. Ibid., p. C-1.
27. Howe (1994), p. 157.
28. Hahn (1989), p. 98.
29. Tietenberg (1980), p. 247.
30. Tietenberg (1991), p. 22.
31. Noll (1982), p. 121.
32. Ibid., p. 120.
33. Declaration of the Canadian Environmental Protection Act. The full title of the legislation is "An Act respecting the protection of the environment and of human life and health".
34. Government of Canada (1992), "Canadian Environmental Protection Act, Enforcement and Compliance Policy", pp. 13-14.
35. Government of Canada (1992), "Economic Instruments for Environmental Protection", p. 1.
36. Task Force on Economic Instruments and Disincentives to Sound Environmental Practices - Final Report (1994), p. 24.
37. Using 1980 levels as the base levels.
38. Government of Canada (1992), "Economic Instruments for Environmental Protection", p. 27.

39. Ibid., p. 30.
40. Ibid., p. 31.
41. The Montreal Protocol allows trading between countries through an industrialization provision which allows the transfer of CFC production rights between countries. Canada and the U.S. have made use of these provisions.
42. Task Force on Economic Instruments and Disincentives to Sound Environmental Practices - Final Report (1994), p. 1.
The Task Force has outlined roughly twenty short-term proposals and fourteen measures for longer term consideration. Only the measures relevant to this paper will be discussed here.
43. Ibid, p. 9.
44. Ibid, p. 10.
45. Ibid., p.15.
46. Ibid., p. 32.
47. Ibid., p. 37.
48. These circumstances were discussed in Section 2.
49. Government of Canada (1992), "Economic Instruments for Environmental Protection", p. 29.
50. Ibid., p. 28.
51. Ibid, p. 29.
52. Ibid, p. 30.
53. Menz (1992), p. 1.
54. Ibid., p. 10.
55. Ibid., p. 8.
56. Donnan and Deshpande (1991).
These figures represent average costs of controlling emissions and, therefore, mask significant differences in costs among individual sources.
57. Government of Canada (1992), Economic Instruments for Environmental Protection, p. 32.
58. NERA (1992), "Emission Trading Program for Stationary Sources of NO_x in Ontario", p. 3.

59. Government of Canada (1992), "Economic Instruments for Environmental Protection", p. 34.
60. NERA (1992), "Emissions Trading Program for Stationary Sources of NO_x in Ontario", p. 25.
61. For example, if 1,000 shares are outstanding, then the holder of 10 shares is entitled to 10/1000, or 1 per cent of the coupons issued that period.
62. NERA (1992), "Emission Trading Program for Stationary Sources of NO_x in Ontario", p. S-7.
63. Van Kooten, Arthur and Wilson (1992).
64. Government of Canada (1992), "Economic Instruments for Environmental Protection", p. 37.
65. Ibid., p. 39.
66. CER, Emissions Permit Trading: A Policy Tool to Reduce the Atmospheric Concentration of Green House Gases (1991).
67. Government of Canada (1992), Economic Instruments for Environmental Protection, p. 39.

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