**Marketable Permit Designs for the Methyl Bromide Critical Use Exemption Request in the United States**

Hong Jin Kim
Economist
Office of Pesticide Programs
U.S. Environmental Protection Agency
1200 Pennsylvania Ave. (Mailcode = 7503C)
Washington DC 20460
(703)308-8134 phone; (703)308-6077 fax
Kim.Hong-Jin@epamail.epa.gov

John Faulkner
Economist
Office of Pesticide Programs
U.S. Environmental Protection Agency

David Widawsky
Economist/Branch Chief
Office of Pesticide Programs
U.S. Environmental Protection Agency

Paper prepared for presentation at the American Agricultural Economics Association Annual Meetings, Montreal, Canada, July 27-30, 2003



The findings, results, and opinions expressed in this paper are those of the authors and do not represent policy or regulatory positions of the United States Environmental Protection Agency, real or implied.

**ABSTRACT**

This paper analyzes potential cost savings to the U.S. agricultural sector associated with applying marketable permit designs for methyl bromide critical use exemptions (CUE), under the phase-out of methyl bromide. A necessary condition for an efficient trading system is heterogeneity among methyl bromide users with respect to the costs of switching to potential alternative pest control measures, which would lead to cost savings from trading. Using data on these costs from current methyl bromide users, the authors show that this necessary condition appears to be met, and characterize the potential cost savings that could occur if critical use permits can be traded from methyl bromide users with lower costs to those with higher costs. Several potential mechanisms for implementing these trades are considered, and differ in the extent to which permit for use may be traded within a commodity-use, or traded among methyl bromide users producing different commodities. The total incremental costs of the simulated trading system were higher when permits are traded only among methyl bromide users within a commodity sector, while the costs were lowest when the methyl bromide users are allowed to freely trade their permits across sectors.

## INTRODUCTION

Methyl bromide is a pesticide to control insects, nematodes, weeds, pathogens, and rodents. Methyl bromide is primary used in agriculture for soil fumigation, commodity treatment, and structural fumigation. Methyl bromide is used in the U.S. for soil fumigation prior to planting crops to control a broad spectrum of soil pests. Tomatoes and strawberries account for about 50 percent of the total methyl bromide use in the United States. Others such as perennial crops, pepper, and ornamental and nursery crops widely use methyl bromide to control soil pests and account for about 35 percent of the total methyl bromide use. Methyl bromide is also used for protecting the quality of commodities in storage and for food-processing facilities for pest control. Methyl bromide uses for post-harvest treatments account for about 15 percent of the total methyl bromide use (United States Environmental Protection Agency (US EPA), 2003a).

Under the Clean Air Act Amendments (CAAA) and the Montreal Protocol on Substances that Deplete the Ozone Layer, the production and import of methyl bromide in the United States is scheduled for phase out by January 1, 2005. The Montreal Protocol is an international treaty for protecting the earth's ozone layer by controlling the production and trade of ozone-depleting chemicals (such as chlorofluorocarbons, or CFCs). In 1992, the Parties to the Montreal Protocol listed methyl bromide as an ozone-depleting substances and the Treaty is now phasing out the production and trade of methyl bromide. The United States is committed to implementing the Montreal Protocol to protect the ozone layer, and the CAAA required the general use of methyl bromide in U.S. to be phased out by January 1, 2005, in accordance with the Montreal Protocol.

The Protocol includes a provision for continued use of methyl bromide in cases where technically and economically feasible alternatives are not available, in order to provide additional transition time for methyl bromide users to adopt technically and economically feasible alternative fumigants. Current users of methyl bromide have the option to apply for a critical use exemption (CUE), and the U.S. Environmental Protection Agency invited applications for CUEs from individuals and groups of methyl bromide users. EPA reviewed the submitted CUE applications for their current use of methyl bromide, and paid special attention to the availability of alternatives identified by the Methyl Bromide Technical Options Committee (MBTOC).

Based on the economic analyses of estimating costs and revenues associated with the use of methyl bromide and technically feasible alternatives, the U.S. EPA nominated a set of methyl bromide uses for CUEs, under the Montreal Protocol. These uses, for crop production and structural/storage operation, were deemed critical because available alternative are either technically or economically infeasible. The international parties of the Montreal Protocol are currently reviewing the CUE nominations and are expected to report findings and recommendations by the Fall of 2003. The goal of this paper is to explore the feasibility of implementing the allocation of methyl bromide CUEs with permit trading, by assessing whether the economic conditions exist to support a market-based approach as one option among many. We look at some specific data on costs of production for methyl bromide users, introduce a basic theoretical model for permit trading, simulate some results using the permit trading model, and suggest directions for further work to expand analyses of this option.

In the environmental economics literature, traditional direct control approaches have been criticized as more costly than marketable permit systems to achieve environmental quality standards. Theoretically, marketable permit systems could allow polluters with higher costs for emission control to buy permits from polluters with lower costs. Under certain conditions, total aggregate abatement costs can be reduced and pollution abatement achieved at a lower cost to the economy. However, the actual realized benefit from a marketable permit system may not be as big as the theoretically conceivable benefit associated with marketable permit systems due to the difficulties of implementing marketable permit systems.

Marketable permit systems have been used in areas of air quality management, renewable energy, solid waste management, and water resources management. Implementation of such market-based mechanisms depends on meeting well-known theoretical conditions and overcoming practical difficulties. Emission trading in the energy sector is one area where a marketable permit system has received considerable attention (Berry, 2002; Boots, 2003; Nielsen and Jeppesen, 2003). Solid waste management is another area where researchers have examined marketable permit system as an efficient tool to meet minimum recycling targets (Sprenger, 1999; Allen and et al., 1993; Dinan, 1992). The marketable permit system has been extensively studied in water resources management to reduce water pollution in a cost-effective way (Austin, 2001; Morgan and et al., 2001; Stephenson and Shabman, 2001). Many studies (Atkinson and Lewis, 1974; Atkinson and Tietenberg, 1982; Oates, Portney and McGartland, 1989; Tietenberg, 1995; Schmalensee and Joskow, 1998) have found that marketable permit systems can be more cost-effective than fixed allocation approaches in achieving emission reduction targets or air quality objectives.

Pesticide regulatory policy in the U.S. is most commonly directed toward mitigating risk with stipulations on how a pesticide is used (rates, timing, equipment, etc.), which determines risk. Trading of pesticide risk, per se, has not been explored, in part because of the link between use pattern and risk. Hence, no study has been identified to look at potential cost savings of applying marketable permit designs for pesticide uses. Methyl bromide, in its role as an ozone depleting chemical, is different because ozone depletion is almost (but not entirely) separable from use patterns.[1] Therefore, this paper explores the potential of marketable permit systems to provide the methyl bromide users with more flexibility in meeting their required reduction of methyl bromide use in a cost-effective way. An objective of this study is to analyze the potential cost savings of marketable permit systems for methyl bromide under a CUE program.

## DEFINING THE PROBLEM: MARKETABLE PERMIT DESIGN

Through economic analysis of the CUE applications, EPA gathered a substantial body of data on potential losses in revenue and increases in operating costs associated with alternative pest control regimens. These data helped EPA to estimate the incremental costs that might accrue in the absence of methyl bromide. The incremental costs associated with the use of alternatives appeared to have a wide range among the

[1] There are other risk from methyl bromide beyond ozone depletion, and these risk are addressed by EPA in implementing the Federal Fungicide, Rodenticide, and Insecticide Act (FIFRA). For the purposes of a CUE program we focus on ozone depletion in this paper. Site specific factors can also affect the ozone depletion potential of a given methyl bromide use (soil moisture and temperature status, length of contact

CUE applications. For example, the incremental costs for structural/storage uses are mainly from production delays due to a longer treatment time and required capital expenditures with alternatives. Costs of adoption methyl bromide alternatives (per unit of commodity) may be higher in these industries than in crop production systems. Within the CUE applications for crop production, incremental costs varied due to the fact that different methyl bromide alternatives were available for different crops, depending on a range of factors.

A permit trading system is intended to reduce the total control costs (across methyl bromide users) of meeting the target for emissions. In the case of emission trading for power plants, this may mean minimizing the cost of expenditures on equipment. In the case of methyl bromide, the "cost" may include changes in expenditures, as well as changes in gross revenue because methyl bromide is a productive input, rather than simply an undesirable output. Assume that methyl bromide trading occurs on a one-for-one basis, that is, reduction in use of one pound in one place is offset by an identical increase in another place. This assumption is generally valid because there is no spatial dispersion effect of methyl bromide use; nearly and all emissions can be considered to have the same effects on the ozone layer. This objective can be represented as finding the set of individual methyl bromide uses, $X_i^{MeBr}$, that minimize the total cost of meeting (or exceeding) a target in use reduction:

$$Min \sum_{i=1}^{m} C_i(X_i^{MeBr}) \quad subject\,to \sum_{i=1}^{m} X_i^{MeBr} \geq E, \quad i = 1,....,m \tag{1}$$

where,

time with soil), but these factors do not change the basic conclusions of this paper, and are not explicitly

$C_i$ : total incremental costs of switching to methyl bromide alternatives for $i^{th}$ methyl bromide users

$X_i^{MeBr}$ : the number of kilograms of methyl bromide to be replaced with alternatives for $i^{th}$ methyl bromide user

E: the total reduction of methyl bromide in kilograms required for the United States

This is equivalent to minimizing the following Lagrangian:

$$\sum_{i=1}^{m} C_i(X_i^{MeBr}) + \lambda \left(E - \sum_{i=1}^{m} X_i^{MeBr}\right), \quad i = 1,\ldots, m \tag{2}$$

where,

$\lambda$: the Lagrangian multiplier

From the first-order condition (FOC), a solution satisfies:

$$C_i'(X_i^{MeBr}) = \lambda \tag{3}$$

Equation 3 implies that when the cost is minimized for reducing methyl bromide use, then the marginal costs of replacing methyl bromide with alternatives are the same across all methyl bromide users. The equation above also shows that the marginal cost for each methyl bromide user should be equal to the Lagrangian multiplier, which reflects the value of changing (increasing or decreasing) the target for methyl bromide use reduction. In other words, it represents the change in the total incremental costs associated with a change in the total reduction of methyl bromide required for the United States. The total costs of meeting the reduction of methyl bromide required for

---

addressed.

the United States would be minimized if each methyl bromide user reduced the use of methyl bromide such that its marginal cost is equal to its contribution to the total costs.

However, this condition may not hold because the marginal costs may be constant and different across all CUE applicants. In practice, the total costs of switching to alternatives for all CUE applicants are more likely to be minimized when applicants with lower costs switch to alternatives first, until the total required reduction in the United States is attained. The marginal cost for the last user applicant switching to methyl bromide alternatives should be equal to the estimated Lagrangian multiplier.

This study analyzes the potential efficiency improvement associated with implementation of two different marketable permit designs to the U.S. agricultural production sectors: 1) a Sectoral Marketable Permit System (SMPS) that allows one-to-one permit trading only for methyl bromide in the same sector (e.g., tomatoes, peppers), and 2) Uniform Marketable Permit System (UMPS) in which all the methyl bromide users freely trade their methyl bromide permits. The incremental costs accounted for in this study are the sum of economic losses from reduced yields and increased production costs associated with the use of alternatives.[2] Therefore, the cost savings indicated in this study represent the differences between the total costs of marketable permit systems to the U.S. agricultural production sectors and those of a system whereby CUEs are fixed based on historical methyl bromide use or production output.

## DATA

The methyl bromide users considered for this study represent individual growers, consortia, and industries using methyl bromide for crop production such as tomatoes and strawberry, and for fumigation of stored commodities and structural fumigation (e.g., flour mills). The U.S. Environmental Protection Agency (EPA) received fifty-six critical use exemption (CUE) applications for 2002. These applications were aggregated into16 sectors for the purpose of the U.S. nomination of CUEs to the International Parties of the Montreal Protocol. Table 1 lists the sectors (and the amount of methyl bromide requested) in the U.S. nomination: tomatoes, strawberries, cucurbits, peppers, orchard replant, food processing, turfgrass, sweet potatoes, forest seedlings, commodity uses, eggplant, strawberry nursery, orchard seedlings, ornamental nurseries, ginger, and tobacco. The U.S. nomination for each crop/use was based on the economic and technical evaluation of the use of methyl bromide and alternatives, and also other factors such as regulatory constraints (buffer zones and township caps) and environmental considerations (groundwater contamination, historic use rate, and etc.). The total amount of 9,920,965 kilograms for 2005 was nominated for the sixteen sectors by the United States, which comprises 39 percent of the 1991 baseline (US EPA, 2003b).

***Why does switching to methyl bromide alternatives lead to costs?***

Economic analyses were only conducted for pre-plant and post-harvest uses when EPA and USDA identified an alternative to be technically feasible in the CUE review process. For pre-plant uses, economic impacts arise due to potential losses in

[2] This doesn't include transaction costs, R&D for adopting new alternatives, etc. Depending on who would incur the costs, sellers or buyers of permits, not including these costs could over or underestimate the

revenue, both from yield declines (when alternatives are less efficient) and increases in operating costs. For example, supplementary weed control or additional irrigation may be required when adopting methyl bromide alternatives. CUE reviewers analyzed crop budgets for pre-plant sectors to determine the likely economic impact if methyl bromide were unavailable. Efforts were also made to quantify economic impacts to methyl bromide users due to decreases in grade and quality of the crops that lead to changes in the prices producers receive; however, not all potential economic losses were quantifiable.

Economic losses in the post-harvest sectors can be characterized as arising from three contributing factors. First, the direct pest control costs increased in most cases because alternatives such as phosphine and heat treatment are more expensive (increased labor time required for longer treatment time and increased number of treatments. Second, large capital expenditures may be required to adopt an alternative. For example, investments to retrofit a facility may be necessary to make it suitable for heat treatment. Finally, additional production downtimes for the use of alternatives are unavoidable. Many facilities operate at or near full production capacity and alternatives that take longer than methyl bromide or require more frequent application can result in manufacturing slowdowns, shutdowns, and shipping delays. Slowing down production would result in additional costs to the methyl bromide users.

Economic loss was calculated as the additional costs, per kilogram of methyl bromide, if methyl bromide users had to replace methyl bromide with available alternatives. Comparing these losses provides a rough measure of the loss in economic

---

efficiency gains from trading.

efficiency associated with adoption of methyl bromide alternatives. This measure indicates incremental cost of switching to the available alternatives and was used to estimate potential cost savings to the U.S. agricultural sector through the use of a marketable permit system for methyl bromide. EPA reviewed each CUE application and estimated the incremental costs associated with the use of alternatives for the methyl bromide users represented in each application (US EPA, 2003b).

Table 2 shows technically feasible alternatives and the economic loss per kilogram of methyl bromide for each sector. Economic losses for each sector are presented as a range because different yield losses were estimated for different alternatives and the methyl bromide users within each sector. Variations in price and operating expenses across different methyl bromide users within each sector also contributed to variability in the range of economic losses. Appendix A shows the technically feasible alternative and the estimated economic loss per kilogram of methyl bromide across methyl bromide CUE applicants. These estimates were used to estimate the potential cost savings associated with implementation of a marketable permit system, and are based on methyl bromide users adopting the best available alternatives (lowest cost). This analysis incorporates CUE reviewers' point estimates of the most likely yield and quality losses associated with these alternatives. Different methyl bromide alternatives and point estimates of yield changes would lead to different estimates of the potential cost savings of a methyl bromide marketable permit system.

The economic loss of replacing methyl bromide with alternatives ranged from $6 to $607 per kilogram of methyl bromide, depending on the methyl bromide use.

The economic losses per kilogram of methyl bromide show a wide range across the sectors and also among users within the same sector. The economic loss for structural/storage uses of methyl bromide appear to be much higher than those to crop producers. Wide variation in economic losses among methyl bromide users would provide users with more flexibility in meeting their required reduction of methyl bromide with marketable permit system.

**EMPIRICAL RESULTS**

The potential cost savings were measured as differences between the total costs of marketable permit systems to the U.S. agricultural production sectors and those of a direct and fixed allocation of CUEs according to historical methyl bromide use or commodity production. The potential cost savings of marketable permit systems were estimated using the assumption that 39% of the 1991 U.S. baseline (reflecting the size of the U.S. nomination) would be exempted for critical needs for methyl bromide use after the phase-out. Three different schemes for initial allocation were analyzed to estimate the potential maximum and minimum cost savings associated with the use of marketable permit systems. They are: (1) high-cost scenario where all the permits are given to the applicants with lower costs in each sector, (2) low-cost scenario where all the permits are given to the applicants with higher costs in each sector, and (3) average-cost scenario where all the users in each sector are required to have the same percentage reduction in their uses of methyl bromide. The maximum cost savings would occur when all the permits in each sector are distributed to the applicants with lower adjustment costs, while minimum cost saving would be associated with the case when the applicants with higher adjustment costs in each sector are given the permits to use methyl bromide.

This study does not address trading for sectors in which no technically feasible alternatives have been identified or all the 2005 requested amounts of methyl bromide were included in the U.S. nomination. The sectors in this category are cucurbits, turfgrass, sweet potatoes, eggplant, strawberry nursery, and tobacco. Therefore, this study incorporates for 81% of the total requests by sectors in 2005, for the purposes of estimating potential efficiency gains from trading. The cost savings of marketable permit system estimated in this study would be smaller than the case that all 16 sectors were allowed to trade their permits.[3]

Table 3 shows the potential cost savings of marketable permit systems. If critical use exemptions were allocated to users with higher incremental costs under a fixed allocation system, then a marketable permit design would provide the smallest cost savings. This is because there is not much of need for permit trading. At the same time, identifying and allocating methyl bromide to users with high incremental switching costs could require substantial transaction costs and would not be uncontroversial. On the other hand, the more the applicants with lower incremental switching costs are given the critical use exemptions, the higher the potential cost savings could be. If 39% of the 1991 baseline were exempted for critical needs for methyl bromide, we estimated the total incremental cost under a fixed allocation system ranges from $55 to $177 million depending on the allocation of the critical use exemption among methyl bromide users. If methyl bromide critical use exemptions

[3] This may also lead to an overstatement of benefits because the total 2005 requested amount may be greater than the current methyl bromide use.

were allocated among all users, reducing methyl bromide use by the same proportion for each user, then the estimate of the total cost of adjustment is $120 million.

Under a permit system, where trading occurs only among users in a given sector, the total incremental cost was estimated at $55 million. Under this Sectoral Marketable Permit System (SMPS), some sectors have minimal cost savings because there is little variation in economic losses per kilogram of methyl bromide. These sectors include forest seedling, orchard replant, ornamental nurseries, and ginger. The SMPS did not provide significant cost savings to these sectors in our simulation, while tomato, strawberry, pepper, commodity, and food processing sectors enjoyed significant cost savings. In particular, the food-processing sector reduced its cost from $42 to $5.5 million and tomato sector from $52 to $14.5 million, a result of trading between users with high costs and those with low costs of adopting alternatives to methyl bromide.

Table 3 also illustrates the incremental costs under a Uniform Marketable Permit System (UMPS), when trading occurs across sectors and the permit price is assumed to be the marginal cost for the last user switching to methyl bromide alternatives in order to sell the permit. The permit price was $14.49, which corresponds to the economic loss per kilogram of methyl bromide measured for the representative user in the forest seedling sector. This marketable permit system is most cost-effective, at $35.5 million, when methyl bromide users are allowed to trade freely across sectors. The total adjustment cost of the UMPS is less than one-third that of a fixed allocation system based on proportional reductions among methyl bromide users (average cost scenario in Table 3). The potential cost savings of marketable permit systems could range from 36% to 80%, depending on the trading system and initial allocation of CUEs

Payment and receipt of marketable permits among methyl bromide users would affect individual income. Buyers of permits would incur additional costs to purchase permits, but this would be more than offset by avoiding costs of adjusting to alternatives, so they would realize a net gain from trade. Users who sell marketable permits would enjoy more income because their cost of adjusting to alternatives would be less than that value of the permit they sold. The total costs of meeting a required reduction of methyl bromide to the economy as a whole may be minimized using a marketable permit system, but it is also important to bear in mind that the initial distribution of permits can affect the distribution of gains and losses, and these equity considerations may be an important factor in designing a trading system.

The potential cost savings estimated in this study were based on the assumption that the price of methyl bromide remains at the 2001 price, which was \$8.8 to \$11 per kilogram. However, it is unlikely that the price of methyl bromide in 2005 will be the same as that in 2001. The price of methyl bromide in United States has increased approximately 300 percent over the seven-year period from 1995 to 2001 (US EPA, 2003a). The price of methyl bromide has increased due to the decreased production levels and the price policies of suppliers. The potential cost savings associated with marketable permit systems will be smaller if the price of methyl bromide increases and more growers switch to the alternatives, so the price assumption may lead to overestimates of savings from trading. The cost-effectiveness of a marketable permit design also depends on the total amount of the critical use exemption allowed. Smaller amounts of total methyl bromide in CUEs leads to lower savings and a narrower market, while greater amounts of CUEs lead to a broader market and more trading.

Similarly, trading across sectors leads to broader markets and greater impetus to trade. One factor that may lead to underestimating the gains from a trading system include our assumption that the point estimate of costs for a portion of a sector is representative of all methyl bromide users in the sector, whereas there may be greater heterogeneity among users. Another factor is heterogeneity in implicit costs of adopting methyl bromide alternatives (e.g., transaction costs, R&D) that would lead to gains from trading.

Theoretically, the different initial allocation of the permits to use methyl bromide should not affect the efficient outcome of the permit system. No one would be worse off when permit trading is allowed. Permits could correct inefficiency in initial allocation because trading would tend to allocate methyl bromide to users with the highest costs of adoption alternatives. Initial allocation can, however, affect how much each user gains or losses from the CUE allocation process, as well as the transaction costs of the program. Below we briefly introduce and discuss four possible options for allocating initial permits. Each option varies widely in the method and amount of information required to distribute the initial allocation of permits.

***Allocation to CUE Applicants***

In this option, the permits could be allocated to the individuals or organizations submitting CUE applications to the U.S. government, based on the U.S. nomination affirmed by the International Parties to the Montreal Protocol. CUE applicants who incurred significant costs in applying for a CUE would probably favor this option, which implicitly confers to them a property right to the initial distribution of permits. Methyl bromide users not represented among those applicants would have to buy permits to be able to use methyl bromide. Because most of the CUE applicants are not individual users, but consortia representing many users, this option requires a process to distribute the permits to individual users in each consortium. Permits could be distributed to consortia that completed CUE applications, and the consortia might distribute permits to their members. However, there are many ways consortia could use to make distributions to members, with many potential equity issues. The U.S. nomination was based on users with a critical need for methyl bromide, which for many sectors was less than applicants' request. The challenge for consortia under this allocation scheme, therefore, is to distribute permits to members with a critical need for methyl bromide use, recognizing heterogeneity among members in a consortium, with respect to costs of adopting alternatives.

***Allocation by Grandfathering***

Permits could be distributed in proportion to historical use, for the types of uses and regions granted a CUE. This option could be satisfactory to current methyl bromide users, but would reward those who have used the most methyl bromide in the past. Those who have already switched to methyl bromide alternatives could receive fewer permits under this system. This option would provide an incentive to use as much methyl bromide as possible now in order to get the most permits.

***Output-based Allocation***

In this option, permits would be distributed in proportion to the acres grown by each grower of a crop in a region. For post-harvest uses, allocation could be based on the volume of commodity treated or by the area treated (for structural uses). This option treats all users equally according to output, but not necessarily according to patterns of production costs. Users who already switched to alternatives would be rewarded by being able to sell their permits. However, this option might not be viewed as fair by others who attempt to buy permits to supplement their initial allocation.

### *Allocation Auction*

Permits could also be distributed to the highest bidder among those uses covered by the CUE. This option would probably lead to minimal permit trading, if any. Some users may object to bidding for permits after incurring the cost of applying for the CUE. A small portion of auction proceeds could be to applicants to offset part of the costs of applying for the CUE, or a portion of the CUE could be allocated for applicants, again to offset costs.

## CONCLUSION

Marketable permit trading for methyl bromide critical use exemptions could significantly reduce economic losses to current methyl bromide users, when they are faced with adopting less effective pesticide alternatives. The effectiveness of marketable permit trading largely depends on the four factors; 1) heterogeneity in the incremental costs associated with alternatives, 2) the initial allocation of the critical use exemptions, 3) price of methyl bromide, and 4) total amount of the critical use exemption allowed.

This study shows that there are considerable variations of the incremental costs among the methyl bromide uses, and that this could lead to gains from trade in CUEs. The allocation system affects the distribution of gains from trade (but not overall efficiency), and we explored several different options for allocation. The total amounts of the critical use exemptions influence the total size of potential efficiency gains. The potential savings of marketable permit trading to methyl bromide critical use exemptions are likely to be significant, compared to a fixed allocation system. However, the size of the savings cannot be measured accurately until the allocation and the total amounts of the critical use exemptions are determined and price of methyl bromide in 2005 can be reasonably forecasted. This also forms the basis for the continued research in this area.

**REFERENCES**


Allen, J. and et al., (1993), "Using Coupon Incentives in Recycling Aluminum: A Market Approach to Energy Conservation Policy," *Journal of Consumer Affairs* 27(2): 300-318.

Atkinson, S.E. and D.H. Lewis (1974), 'A Cost-Effective Analysis of Alternative Air Quality Control Strategies', *Journal of Environmental Economics and Management* **1**, 237-250.

Atkinson, S.E. and T.H. Tietenberg (1982), 'The Empirical Properties of Two Classes of Designs for Transferable Discharge Permit Markets', *Journal of Environmental Economics and Management* **9**, 101-121.

Austin, S. (2001), "Designing a Nonpoint Source Selenium Load Trading Program," *The Harvard Environmental Law Review* 25(2): 339-403.

Berry, D. (2002), "The Market for Tradable Renewable Energy Credits," *Ecological Economics* 42(3): 369-379.

Boots, M. (2003), "Green Certificates and Carbon Trading in the Netherlands," *Energy Policy* 31(1): 43-50.

Dinan, T. M. (1992), “Implementation Issues for Marketable Permits: A Case Study of Newprint,” *Journal of Regulatory Economics* 4(1): 71-87.

Kraemer, A. and K. M. Banholzer (1999), Ch. IV – Tradable Permits in Water Resource Management and Water Pollution Control, Implementing Domestic Tradable Permits for Environmental Protection, OECD, Organization for Economic Co-Operation and Development.

Morgan, C. L. and et al., (2001), “Tradable Permits for Controlling Nitrates in Groundwater at the Farm Level: A Conceptual Model,” Journal of Agricultural and Applied Economics 32(2).

Nielsen, L. and T. Jeppesen (2003), “Tradable Green Certificates in Selected European Countries – Overview and Assessment,” *Energy Policy* 31(1): 3-14.

Oates, W.E.,P.R. Portney and A.M. McGartland (1989), ‘The Net Behavior of Incentive-based Regulation: A Case study of Environmental Standard Setting’, *American Economic Review* **79**, 1233-1242.

Schmalensee, R. and P.L. Joskow , A.D. Ellerman, J.P. Montero, and E.M. Bailey (1998), “An Interim Evaluation of Sulfur Dioxide Emissions Trading,” *Journal of Economic Perspectives* **12(3)**, 53-68

Sprenger, R. –U. (1999), "Designing a scheme for trading non-returnable beverage containers in Germany," UK, Edward Elgar Publishing Limited: 231-254.

Stephenson, K. and Shabman, L. (2001), "The Trouble with Implementing TMDLs," *Regulation* 24(1): 28-32.

Tietenberg, T.H. (1995), 'Tradable Permits for Pollution Control when Emission Location Matters: What have we Learned?', *Environmental and Resource Economics* **5**, 95-113.

United States Environmental Protection Agency (2003a), methyl bromide phase out website, http://www.epa.gov/spdpublic/mbr.

United States Environmental Protection Agency (2003b), methyl bromide dockets and documents, http://cascade.epa.gov/RightSite/dk_public_home.htm.

**Table 1: Total Methyl Bromide Request and U.S. Nomination for each sector in 2005.**

| Sector | Total Request by Sector (kilograms) | U.S. Sector Nomination (kilograms) |
|---|---|---|
| Fresh Market Tomatoes | 5,233,521 | 2,865,262 |
| Strawberries | 2,893,763 | 2,468,873 |
| Cucurbits[1] | 1,187,773 | 1,187,773 |
| Peppers | 2,003,793 | 1,085,265 |
| Orchard Replant[2] | 1,256,223 | 706,176 |
| Food Processing[3] | 612,576 | 536,328 |
| Turfgrass | 791,427 | 352,194 |
| Sweet Potatoes | 224,528 | 224,528 |
| Forest Seedlings[4] | 454,289 | 192,515 |
| Commodity Uses[5] | 135,828 | 87,753 |
| Eggplant | 163,173 | 73,565 |
| Strawberry Nursery | 380,948 | 54,988 |
| Orchard Seedlings[6] | 290,088 | 45,789 |
| Ornamental Nurseries[7] | 267,461 | 29,412 |
| Ginger | 18,336 | 9,221 |
| Tobacco | 4,612 | 1,323 |
| Total | 15,918,339 | 9,920,968 |
| Percentage of 1991 Baseline (25,527,550) | 62% | 39% |

[1]Cucurbits represents a crop group that includes cucumbers, melons, cantaloupes, honeydews, watermelons, and various squash varieties.
[2]Orchard replant represents stone fruit (including cherry, peach, nectarine, plum, and prune), almonds, walnuts, and grapes.
[3]Food Processing represents rice milling, flour milling, pet food manufacturing, and bakeries.
[4]Forest Seedlings represent seedlings of conifers and hardwoods.
[5]Commodity Uses represent dried fruits, nuts, beans, and meat warehouses.
[6]Orchard Seedlings represent fruit tree nurseries that includes citrus, peaches, prunes, nectarines, cherries, plums, apples, avocados, pears, ornamental fruit trees, and raspberry nurseries.
[7]Ornamental Nurseries represent chrysanthemum propagative material and nursery roses.

**Table 2: The Technically Feasible Alternatives and Economic Losses per Kilogram.**

| Sector | Technically Feasible Alternatives | Economic Losses per Kilogram of Methyl Bromide |
|---|---|---|
| Fresh Market Tomatoes | Chloropicrin;<br>1,3 D + Chloropicrin[1];<br>1,3 D + Chloropicrin + Pebulate;<br>Metam sodium | \$6.14 – \$95.96 |
| Strawberries | 1,3 D + Chloropicrin;<br>1,3 D + Metam sodium | \$17.28 – \$46.72 |
| Cucurbits | Metam sodium | \$6.72 - \$37.42 |
| Peppers | 1,3 D + Chloropicrin | \$4.15 – \$20.02 |
| Orchard Replant | 1,3 D;<br>1,3 D + Metam sodium;<br>1,3 D + Chloropicrin | \$10.98 - \$43.91 |
| Food Processing | Heat treatment | \$71 - \$602 |
| Turfgrass | No technically feasible alternatives available | Not available |
| Sweet Potatoes | Fallow/crop rotation | \$9.02 |
| Forest Seedlings | Dazomet w/tarp;<br>Metam sodium;<br>1,3 D + Chloropicrin + Pebulate; | \$7.71 - \$45.32 |
| Commodity Uses | Phosphine | \$80 - \$607 |
| Eggplant | No technically feasible alternatives available | Not available |
| Strawberry Nursery | No technically feasible alternatives available | Not available |
| Orchard Seedlings | 1,3 D + Metam sodium;<br>1,3 D + Chloropicrin; | \$12.92 – \$18.60 |
| Ornamental Nurseries | Steam sterilization;<br>1,3,D +hoeing | \$8.68 - \$21.72 |
| Ginger | Metam sodium;<br>Fallow | \$20.19 |
| Tobacco | No technically feasible alternatives available | Not available |

[1] 1,3-D is also known as 1,3 Dichloropropene and is also sold under the trade name Telone[tm]

## Table 3: Cost Savings of Marketable Permit Systems

| Sector | 2005 Request in 1,000 kg | Command and Control System | | | | Sectoral Marketable Permit System (SMPS)[4] | | Uniform Marketable Permit System (UMPS)[5] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Reduction in Methyl Bromide use in 1,000 kg | Incremental Cost to the Sector in 1,000 $ | | | Reduction in Methyl Bromide use in 1,000 kg | Incremental Cost to the Sector in 1,000 $ | Reduction in Methyl Bromide use in 1,000 kg | Incremental Cost to the Sector in 1,000 $ |
| | | | High Cost Scenario[1] | Average Cost Scenario[2] | Low Cost Scenario[3] | | | | |
| Commodity | 135 | 47 | $14,745 | $7,531 | $3,752 | 47 | $3,752 | 0 | $680 |
| Food Processing | 606 | 75 | $41,937 | $31,551 | $5,353 | 75 | $5,353 | 0 | $1,093 |
| Forest Seedling | 443 | 262 | $4,353 | $3,671 | $2,549 | 262 | $2,549 | 364 | $2,344 |
| Ginger | 18 | 9 | $184 | $184 | $184 | 9 | $184 | 0 | $132 |
| Orchard Replant | 1,091 | 384 | $16,883 | $12,539 | $4,560 | 384 | $4,560 | 374 | $4,258 |
| Orchard Seedling | 290 | 244 | $3,424 | $3,382 | $3,164 | 244 | $3,164 | 244 | $3,161 |
| Ornamental Nurseries | 267 | 238 | $5,142 | $4,804 | $4,758 | 238 | $4,758 | 32 | $3,266 |
| Pepper | 2,004 | 919 | $18,389 | $14,315 | $9,502 | 919 | $9,502 | 632 | $7,918 |
| Strawberry | 2,894 | 425 | $19,851 | $10,592 | $7,342 | 425 | $7,342 | 0 | $6,157 |
| Tomatoes | 5,234 | 2,368 | $52,272 | $31,615 | $14,541 | 2,368 | $14,541 | 3,327 | $6,539 |
| **Total** | **12,981** | **4,972** | **$177,180** | **$120,193** | **$55,706** | **4,972** | **$55,706** | **4,972** | **$35,546** |

[1] High-cost scenario represents the case when all the permits are initially allocated to the applicants with lower costs in each sector.
[2] Average-cost scenario represents the case when all the applicants in each sector are required to have the same percentage reduction in their uses of methyl bromide to meet the U.S. nominations in each sector.
[3] Low-cost scenario represents the case when all the permits are initially allocated to the applicants with higher costs in each sector.
[4] Sectoral Marketable Permit System (SMPS) allows one-to-one permit trading only for the CUE applicants in the same sector.
[5] Uniform Marketable Permit System (UMPS) allows all the CUE applicants freely trade their methyl bromide permits to use by one-to-one basis.

**Appendix A: The Technically Feasible Alternatives and Economic Losses for each CUE Application in 2005.**

| Sector | CUE Application | Technically Feasible Alternatives | 2005 Applicant Requested (in kilograms) | Economic Losses per Kilogram of Methyl Bromide |
|---|---|---|---|---|
| Fresh Market Tomatoes | Tomato #1 | Chloropicrin | 52,348 | $95.96 |
| | Tomato #2 | 1,3 D + Chloropicrin + Metam sodium | 136,078 | $24.77 |
| | Tomato #2 | 1,3 D + Herbicide | 453,592 | $29.59 |
| | Tomato #3 | 1,3 D + Chloropicrin + Pebulate | 902,603 | $23.34 |
| | Tomato #4 | 1,3 D + Chloropicrin | 3,326,644 | $6.14 |
| | Tomato #5 | 1,3 D + Chloropicrin + Pebulate | 362, 257 | $18.10 |
| | Total kilograms requested : 5,233,521 | | | |
| Strawberries | Straw #1 | 1,3 D + Chloropicrin | 2,041,164 | $17.28 |
| | Straw #2 | 1,3 D + Chloropicrin | 272,908 | $35.83 |
| | Straw #3 | 1,3 D + Chloropicrin | 579,691 | $46.72 |
| | Total kilograms requested : 2,893,763 | | | |
| Cucurbits | Cuke #1 | Metam sodium | 28,187 | $37.42 |
| | Cuke #2 | No Technically Feasible Alternative | 753,688 | N/A |
| | Cuke #3 | Metam sodium | 92,874 | $6.71 |
| | Cuke #4 | No Technically Feasible Alternative | 67,224 | N/A |
| | Cuke #5 | Metam sodium | 245,800 | $6.92 |
| | Total kilograms requested : 1,187,773 | | | |
| Peppers | Pepper #1 | 1,3 D + Chloropicrin | 181,437 | $4.15 |
| | Pepper #2 | 1,3 D + Chloropicrin | 112,445 | $6.69 |
| | Pepper #3 | 1,3 D + Chloropicrin | 338,248 | $6.69 |
| | Pepper #4 | 1,3 D + Chloropicrin | 1,371,662 | $20.02 |
| | Total kilograms requested : 2,003,793 | | | |

| Sector | CUE Application | Technically Feasible Alternatives | 2005 Applicant Requested (in kilograms) | Economic Losses per Kilogram of Methyl Bromide |
|---|---|---|---|---|
| Orchard Seedlings | OrchSeed #1 | 1,3 D + Chloropicrin | 46,510 | $18.60 |
| | OrchSeed #2 | 1,3 D + Chloropicrin | 224,528 | $12.92 |
| | OrchSeed #3 | 1,3 D + Chloropicrin | 19,051 | $13.12 |
| | | Total kilograms requested : | 290,088 | |
| Food Processing | Food #1 | Heat Treatment | 202,756 | $71 |
| | Food #2 | Heat Treatment | 14,742 | $433 |
| | Food #3 | Heat Treatment | 48,081 | $582 |
| | Food #4 | Heat Treatment | 340,194 | $602 |
| | | Total kilograms requested : | 612,576 | |
| Turfgrass | Turf #1 | No Technically Feasible Alternatives | 680,388 | N/A |
| | Turf #2 | No Technically Feasible Alternatives | 111,039 | N/A |
| | | Total kilograms requested : | 791,427 | |
| Sweet Potato | SweetPot #1 | Crop rotation | 224, 528 | $9.02 |
| Forest Seedling | Forest #1 | Dazomet with tarping | 246,032 | $10.15 |
| | Forest #2 | Dazomet with tarping | 41,730 | $8.76 |
| | Forest #3 | Dazomet with tarping | 20,412 | $7.71 |
| | Forest #4 | Dazomet with tarping | 52,390 | $14.49 |
| | Forest #5 | Dazomet with tarping | 4,264 | $28.89 |
| | Forest #6 | Dazomet with tarping | 22,453 | $24.62 |
| | Forest #7 | Dazomet with tarping | 24,752 | $14.34 |
| | Forest #8 | Dazomet with tarping | 33,112 | $34.61 |
| | Forest #9 | Dazomet with tarping | 9,144 | $45.32 |
| | | Total kilograms requested : | 454,289 | |

| Sector | CUE Application | Technically Feasible Alternatives | 2005 Applicant Requested (in kilograms) | Economic Losses per Kilogram of Methyl Bromide |
|---|---|---|---|---|
| Commodity Uses | Commodity #1 | No Technically Feasible Alternative | 181 | N/A |
| | Commodity #2 | Phosphine | 12,088 | $218 |
| | Commodity #3 | Phosphine | 20,412 | $414 |
| | Commodity #4 | Phosphine | 4,536 | $607 |
| | Commodity #5 | Phosphine | 97,704 | $80 |
| | Commodity #6 | No Technically Feasible Alternative | 907 | N/A |
| | | Total kilograms requested : | 135,828 | |
| Eggplant | Eggplant #1 | No Technically Feasible Alternative | 48,868 | N/A |
| | Eggplant #2 | No Technically Feasible Alternative | 114,305 | N/A |
| | | Total kilograms requested : | 163,173 | |
| Strawberry Nursery | StrawNurs #1 | No Technically Feasible Alternative | 358,338 | N/A |
| | StrawNurs #2 | No Technically Feasible Alternative | 22,611 | N/A |
| | | Total kilograms requested : | 380,948 | |
| Orchard Replant | OrchRep #1 | 1,3 D + Chloropicrin | 716,449 | $43.91 |
| | OrchRep #2 | No Technically Feasible Alternative | 165,561 | N/A |
| | OrchRep #3 | 1,3 D + Chloropicrin | 226,796 | $10.98 |
| | OrchRep #4 | 1,3 D + Chloropicrin | 147,417 | $10.98 |
| | | Total kilograms requested : | 1,256,223 | |
| Ornamental Nurseries | Ornament #1 | Steam sterilization | 31,593 | $8.68 |
| | Ornament #2 | 1,3 D + hoeing | 235,868 | $21.72 |
| | | Total kilograms requested : | 267,461 | |
| Ginger | Ginger | Fallow | 18,336 | $20.19 |
| Tobacco | Tobacco | No Technically Feasible Alternative | 4,612 | N/A |