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LIMITING OVERSELLING IN INTERNATIONAL EMISSIONS TRADING II:

Analysis of a Commitment Period Reserve at National and Global Levels

By Erik Haites, Margaree Consultants Inc., and Fanny Missfeldt, UNEP Centre

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Foreword

We present in two volumes work undertaken in 2000/2001 on the analysis of rules to reduce the risk of overselling in the context of international emissions trading for greenhouse gases (GHG). GHG trading had been endorsed through its inclusion in the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997. The idea of international trade allowances to emit GHGs was relatively new in 1997, and there was virtually no experience with rules to ensure effective emissions trading at the international level.

The specific problem of emissions trading at the international level is that there is no supranational entity that can credibly enforce compliance. As Chayes and Chayes put it "sanctioning authority is rarely granted by treaty, rarely used when granted, and likely to be ineffective when used" (Chayes and Chayes, 1998). In the context of international GHG trading a country could, for example, maximize its gains by selling off its entire allocated quota, while free riding on the benefits of reduced climate change generated by other countries that reduce their emissions. In the context of the Kyoto Protocol, this quota is called assigned amount. In 2012 the assigned amount held by a country is to be compared with its actual emissions during the 2008-2012 the commitment period. If a country has sold too much of its quota (parts of its assigned amount), it may not be able to cover its actual GHG emissions. Thus a problem of overselling occurs.

While a number of experts and delegates to the climate meetings had identified the problem of overselling as early as summer 1998, the initial work in this area focused on the legal analysis of the problem. One of the first ideas was to introduce buyer or mixed liability to deter purchases from countries that engage in overselling. Since then the problem of overselling has been termed the 'liability problem' or 'liability issue'. By the end of 1999 a multitude of proposals were in circulation. This is when the authors of these reports decided that it might be worthwhile to test the performance of these proposals within the framework of an economic model.

In July 2001 the conference of the parties to the UNFCCC adopted one of these liability rules: the commitment period reserve. In this first volume we present the economic analysis of the numerous proposals under consideration at the time. The analysis identified the 'permanent reserve' as the proposal that best meets the criteria specified. In October 2000 the permanent reserve was modified to provide liquidity for buyer countries and was renamed the 'commitment period reserve'. In our second report we analyze alternative specifications of the commitment period reserve in terms of their effectiveness in constraining overselling, impact on compliance costs and liquidity in the emissions trading market. This analysis is performed at the country level for countries with emissions limitation commitments (Annex B Parties) under the Kyoto Protocol.

We gratefully acknowledge the financial support provided by EPRI. We would also like to thank Richard Baron, Kyle Danish, Denny Ellerman, Donald Goldberg, Ian Marsh, Chris McDermott, Byron Swift and Tom Wilson for the numerous helpful comments provided on earlier versions of this paper. We would also like to thank the UNEP Centre and EPRI for

enabling us to publish our work in full report size. Of course, we alone are responsible for the content and any remaining errors.

In the meantime we have published or submitted for publication part of the work presented here to make it available to a wider community in a more concise and problem-oriented format. Elements of our first reports are contained in the first issue of Climate Policy, published in early 2001 (Haites and Missfeldt, 2001a)), and in a more technical paper submitted to the Journal of Environmental Economics and Management (Haites and Missfeldt, 2001c). Further work derived from our second report has been submitted to Climate Policy (Missfeldt and Haites, 2001), and to the Journal of Financial Markets (Haites and Missfeldt, 2001b). Those interested in the details of our analysis and results produced are invited to read on.

Erik Haites, Toronto, and Fanny Missfeldt, Roskilde
August 2002

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Executive Summary

Emissions trading can significantly reduce the cost of meeting an overall emissions target and so enhances the prospects of achieving that target. On the other hand, emissions trading creates the potential for rewarding non-compliance and for greater non-compliance. The presence of a regulator with the authority to impose penalties on participants who do not hold sufficient allowances to cover their actual emissions has meant that these potential problems have been minimal in the case domestic emissions trading programs.

The entities responsible for compliance under an international emissions trading program are sovereign nations. A regulatory agency with the power to impose penalties for non-compliance on sovereign nations does not exist. Given the lack of effective non-compliance penalties for international emissions trading, various "liability" proposals have been suggested to limit international sales of emissions quota to amounts surplus to the compliance needs of the seller. A liability provision complements, but does not replace, non-compliance penalties.

The Kyoto Protocol, if it comes into force, will allow Parties listed in Annex B to the Protocol to use international emissions trading to reduce the cost of meeting their national emissions limitation commitments. A compliance regime for the Kyoto Protocol, with penalties for non-compliance, is being negotiated. However, a Party that finds proposed penalties for non-compliance too onerous could withdraw from the Protocol and so avoid the penalties. Thus, the effective penalties may be less than the potential gains due to non-compliance.

Haites and Missfeldt found that, even assuming the worst behaviour by the Annex B seller, several of the liability proposals can prevent abuse of international emissions trading at negligible cost in terms of excess emissions or extra compliance costs. They also found that a permanent reserve was the only proposal able to meet all of the criteria. Further consideration of the permanent reserve has led to a modified proposal called the commitment period reserve.

The May 2001 proposals by the President of the 6th Conference of the Parties include a provision requiring each Annex B country to maintain a commitment period reserve. The purpose of the commitment period reserve is to limit potential non-compliance due to the sale of quota that is not surplus to the seller's compliance needs -- overselling. Non-compliance due to overselling can occur only if:

- the reserve requirement is set so that a country can sell quota surplus to the reserve requirement, but not surplus to the country's compliance needs;

- the available quota is purchased by another Annex B country and is used to meet its emissions limitation commitment; and

- the seller country does not comply with its emissions limitation commitment.

All proposed international transfers of quota would be reviewed by electronic or other means to ensure that they would not reduce the quantity remaining in the seller's national registry to less than the reserve requirement. Proposed transfers that would lead to violation of the reserve requirement would be rejected. Transfers of quota between entities within a given country and acquisitions of quota from other countries are not affected by the reserve requirement.

The commitment period reserve proposal requires each Annex B Party to hold in its national registry quota equal to the ***lower*** of:

- X% of five times the Party's most recently reviewed emissions inventory; and

- Y% of the Party's initial assigned amount pursuant to Articles 3.7 and 3.8.

The first provision would typically apply to a country that is a net seller, while the second would apply to a net buyer.

Parties have suggested values of X ranging from 70% to 100% and values of Y ranging from 70% to 98%. The Chairman's proposal sets X = 100% and Y = 90%. The considerations that affect the values for X and Y are:

- The extent of possible non-compliance due to overselling. The lower the values of X and Y, the larger is the possible non-compliance due to overselling.

- The extent to which sales of quota surplus to compliance needs are temporarily restricted. The higher the value of X, the higher is the probability that some surplus quota can not be sold until after compliance has been established. This increases compliance costs during the first commitment period, but reduces costs when the surplus quota becomes available.

- Liquidity in the international market. As the values of X and Y rise, the quantity available for trade in the international market is reduced, thus reducing liquidity.

- International liquidity for domestic markets. Under some circumstances international liquidity is desirable for participants in domestic emissions trading programs. That requires a value of Y < 100%.

The purpose of this paper is to analyse different specifications (values of X and Y) of the commitment period reserve in terms of the above considerations.

The analysis assumes that the Kyoto Protocol is ratified by all Annex B Parties and comes into force prior to 2008. The reserve requirement (the values of X and Y) is assumed to be the same for all Annex B countries. The reserve requirement for each Annex B Party is assumed to be recalculated each year based on the most recent reviewed emissions inventory. The compilation and review process is assumed to take two years, so that the reserve requirement for 2008 is based on emissions in 2006, etc.

Monaco and Liechtenstein are excluded from the analysis because the requisite data are not available. The remaining 36 Annex B countries are covered. For the cost analysis they are aggregated into two groups; 23 Annex II countries, most of which are expected to be net buyers, and the remaining 13 Rest of Annex B countries, most of which are expected to be net sellers. A sensitivity scenario for the Russian Federation, with projected emissions almost 40% below the assigned amount, is included to test whether the temporarily restricted sales of surplus quota rise significantly if emissions decline substantially.

Ideally, the commitment period reserve would limit the potential excess emissions while allowing all surplus quota to be sold. Actual emissions vary, so it is not possible to set the reserve requirement (values of X and Y) in advance to meet these objectives precisely for all countries. To model the effect of fluctuations in actual emissions, projected emissions are adjusted by a random component estimated from the actual emissions for the period 1990 through 1997. Then 500 runs with different random adjustments are analysed.

Certified Emission Reductions (CERs) generated by clean development mechanism projects in non-Annex B countries and assigned amount units (AAUs) issued for net sequestration during 2008-2012 resulting from eligible sink enhancement actions in Annex B countries are largely excluded from the analysis. They do not affect calculation of the reserve and do not change the quantity of surplus quota, if any, whose sales are restricted by the reserve requirement.

The reserve requirement produces two possible impacts:

- Sales of quota surplus to the compliance needs of a country may be restricted by the first provision of the reserve requirement (the value of X). This restriction is temporary. After the country has demonstrated compliance with its commitment, the surplus quota can be sold. However, that may be too late to allow other countries to use the quota for compliance with their commitments. Under those conditions the temporary restriction on sales of surplus quota raises compliance costs for countries that are net buyers.

- Sales of quota surplus to the reserve requirement, but not surplus to the country's compliance needs -- overselling -- may be possible. This can occur under either provision of the reserve requirement, but is a risk specifically associated with the second provision (the value of Y). If quota that is not surplus to the country's compliance needs is sold and not replaced, the result is non-compliance due to overselling.

Analysis of the potential for temporarily restricted sales of surplus quota and non-compliance due to overselling for Annex B countries as a whole indicates that:

- Every Annex B country either faces temporarily restricted sales of surplus quota or the opportunity to sell non-surplus quota and hence contribute to non-compliance due to overselling, except for specifications with Y= 100%. When Y = 100%, countries that are net buyers must keep all of their initial assigned amount as a reserve and so can not contribute to non-compliance due to overselling.

- The probability of temporarily restricted sales falls and the potential for non-compliance due to overselling rises as the values of X and Y are reduced.

- The average and maximum quantity of temporarily restricted sales of surplus quota decline as the probability of such restrictions declines.

- The potential non-compliance due to overselling is maximized when the demand for quota by buyers equals the supply of quota not surplus to the compliance needs of the other countries. The maximum potential non-compliance due to overselling rises as the values of X and Y fall. It is more sensitive to changes in the value of Y than in the value of X.

- Specifications with X and Y less than 85% render the commitment period ineffective as a means of limiting overselling. With such specifications all of the potential non-compliance could take the form of overselling, although such an outcome would be unlikely in practice because it would involve large purchases by some countries and equally large non-compliance overall by the other countries.

- Temporarily restricted sales are small relative to the maximum potential non-compliance due to overselling for almost all specifications analysed. With Y less than 100%, the restricted sales are less than 10% of the maximum potential non-compliance due to overselling when X = 100% and less than 3% of the maximum potential non-compliance due to overselling when X = 95%.

These results indicate that if the commitment period reserve is to be effective in limiting potential non-compliance due to overselling, the values of X and Y must be greater than 85%. Any specification will involve balancing temporarily restricted sales with potential non-compliance due to overselling, but for specifications with Y less than 100% and X less than or equal to 100% the restricted sales are small relative to the maximum potential non-compliance due to overselling.

The sensitivity scenario indicates that lower emissions by net sellers reduce the maximum potential non-compliance due to overselling for a given specification of the commitment period reserve. Lower emissions by net sellers means more quota surplus to the compliance needs of sellers is available, so non-compliance is reduced.

Conversely, higher emissions by net buyers will increase the maximum potential due to overselling for a given specification of the commitment period reserve if Y is less than 100%. Higher emissions by net buyers mean a larger demand for quota, so countries can sell more quota surplus to the reserve requirement but not surplus to their compliance needs.

A given specification of the commitment period reserve (values of X and Y) will apply to all Annex B countries, but affect each one differently. The probability of temporarily restricted sales of surplus quota is sensitive to both the value of X and the value of Y.

- With Y = 98% and X = 100%, 20 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The

probability of being affected is greater than 25% for 11 of those 20 countries and greater than 50% for 3 of the countries.

- With Y = 98% and X = 95%, 13 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% for 3 of those 13 countries.

- With Y = 98% and X = 90%, 9 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% in every case and greater than 10% for only 2 of the countries, Luxembourg and Latvia.

The reason why Latvia and Luxembourg face the highest probability of temporarily restricted sales is due to the sharp decline in their emissions during the early 1990s relative to their projected emissions. In practice only one outcome will occur and it may affect Latvia and Luxembourg less, and other countries more, than suggested by the analysis.

To reduce the probability of temporarily restricted sales to zero for all countries requires that X be 65% and Y be no higher than 90%. Such specifications would render the reserve requirement ineffective in limiting overselling. Thus, the specification adopted must balance potential non-compliance due to overselling with a risk of temporary restrictions on sales of quota surplus to compliance needs for some countries.

The analysis suggest that equitable treatment of countries that are net sellers requires a value of X close to 90%. This reduces the risk of temporarily restricted sales to less than 10% for almost all countries. Lower values of X reduce the magnitude of temporarily restricted sales more slowly than they increase the magnitude of possible excess emissions.

If temporarily restricted sales of surplus quota are not available in time for use by buyer countries to meet their emissions limitation commitment for the current period, they increase compliance costs for those countries. To estimate the impacts of potential non-compliance due to overselling a model with a single Annex B buyer -- Annex II countries -- and a single Annex B seller -- the rest of the Annex B countries -- was used to estimate compliance costs and non-compliance. The model calculates the maximum possible non-compliance and the maximum increase in compliance cost due to temporarily restricted sales.

Aggregating the information for the countries that constitute each region nets out any trade among countries within a region, although such trade is small relative to the interregional trade under all but the highest reserve requirements. The model assumes that surplus quota whose sale is restricted is not available to other countries for the purpose of complying with the emissions limitation commitments of the first commitment period. This leads to the maximum possible cost increase due to restricted sales of surplus quota.

Every specification analysed, on average, allows some excess emissions overall. With the exception of the specifications with X equal to 105% and Y greater than or equal to 85%, the non-compliance due to the excess emissions reduces the compliance cost for the Annex II

region below that for the least-cost, full-compliance case. The lower the values of X and Y the larger the potential non-compliance and the lower the Annex II compliance costs, on average.

The range of possible outcomes for a given specification is very wide for the 500 runs analysed. For most specifications, possible outcomes range from over-compliance at a cost saving, if emissions in many countries are much lower than projected, to excess emissions and increased compliance costs, if emissions in many countries are higher than projected.

Liquidity is the ease with which a good can be bought or sold. A liquid market is one where a buyer (seller) can purchase (sell) the desired quantity of the good quickly at the market price. This means that liquidity is a matter of degree, rather than a condition a market has or does not have. In turn, this means it is not possible to specify what level of liquidity is "necessary" or "satisfactory" for a given market.

Liquidity does not change the total supply of allowances and so does not make compliance easier (or more difficult) for entities participating in an emissions trading program. However, greater liquidity makes it easier for an entity to buy (sell) the desired quantity of quota quickly. This increases confidence in emissions trading as a viable component of a compliance strategy. To the extent that increased confidence enhances the use of emissions trading for compliance, liquidity helps reduce compliance costs.

The only "standard" available to judge the liquidity of the international emissions trading market is the liquidity of existing emissions trading markets. The quantity of allowances traded between economically-independent entities relative to the annual allocation or annual emissions are rough indicators of liquidity. The allowances traded include those for the current year and for all future years for which they have been allocated. The data indicate that the quantity of allowances traded is 15% to 70% of the annual allocation plus banked allowances. When the quantity traded is related to annual emissions, the percentage is higher, ranging from 20% to 180%, since emissions are less than the allowances allocated.

Since international emissions trading is not yet operational, data on the quantity of quota traded annually are not available. However, the country data and model results provide different estimates of the quantity that might be traded. These estimates implicitly assume that a given unit of quota is only traded once, although there is considerable evidence from existing programs that allowances are often traded more than once. Estimates of the liquidity of the international emissions trading market are calculated using projections of the quantity traded, the annual allocation of quota, and annual emissions.

Although the compliance period for Annex B Parties is five years, at least some of the firms participating in the international market will have annual compliance obligations and the emissions trading programs examined have one-year compliance periods. Therefore, we believe that estimates of annual liquidity are most relevant and provide the fairest comparison with the liquidity of existing emissions trading programs.

The five measures calculated indicate that the liquidity of the international emissions trading market is likely to be comparable to, or greater than, that of existing emissions trading programs for every specification of the commitment period reserve analysed.

Some Annex B Parties may choose to implement an emissions trading program domestically to help meet their emissions limitation commitments. The American experience with emissions trading programs indicates that it is clearly possible to design a purely domestic emissions trading system with sufficient liquidity. This may not be true for a smaller country.

The liquidity of a purely domestic emissions trading market could be enhanced by the following provisions:

- Allowing entities not subject to compliance obligations to own allowances;
- Requiring annual compliance by participants;
- Allowing banking of allowances; and
- Distributing at least some allowances for several years into the future.

These are all reasonable provisions for a domestic greenhouse gas emissions trading program designed to meet Kyoto Protocol emissions limitation commitments.

A participant in a domestic emissions trading program may wish to export quota surplus to its needs, but not surplus to the compliance needs of the country. Export of quota could be desirable for a firm in an Annex B country if:

- The domestic emissions trading program includes a large buyer who exercises market power by offering low prices to small sellers. This would usually happen only in a small country.
- The transfer pricing provisions of the tax law of the exporting country allow the quota to be transferred at cost, rather than market price, and the cost of the allowances to the participants is less than the market price. By allowing exports of quota under these circumstances, the country loses corporate income tax revenue.
- The accounting treatment of quota received from a related entity in another country differs from that for transfers of cash in a way that is attractive to the companies involved.

Since there are circumstances under which exports of quota are desirable for a firm, but not necessarily the government, the commitment period reserve rule should be designed to accommodate such exports, but to allow individual Annex B governments to decide under what conditions to allow such exports.

The potential liquidity of domestic emissions trading programs for greenhouse gases is assessed in terms of the quota available for international trade relative to the annual allocation

or to the annual emissions since those are the measures calculated for the existing programs. Those calculations implicitly assume that the only source of liquidity for the domestic program is the international market and the each allowance available for international trade is traded once each year, both conservative assumptions.

The analysis considers the international liquidity for two possible designs for a domestic emissions trading program in each of the 36 Annex B countries analysed under different specifications of the commitment period reserve. The purpose of the provision that sets the reserve at Y% of the initial assigned amount is to provide international liquidity for domestic trading programs in net buyer, mainly Annex II, countries. The domestic emissions trading program options are:

- A downstream program that covers all energy-related CO_2 emissions by industry; and

- An upstream or hybrid program that covers all energy-related CO_2 emissions.

Most domestic emissions trading programs implemented or proposed to-date are downstream designs which cover less than 50% of the country's total emissions.

For a downstream program, specifications with Y equal to 98% and X equal to 90% or 95% provide international liquidity equal to or greater than that of existing emissions trading programs for all countries, except for the Russian Federation using one of the two liquidity measures.

For an upstream design, specifications with Y equal to 98% and X equal to 90% provide international liquidity less than that of existing emissions trading programs for three to eight Annex II countries and greater than that of existing emissions trading programs in two to seven Annex II countries, depending upon the measure used. Specifications with Y equal to 95% and X equal to 90% or 95% provide international liquidity equal to or greater than that of existing emissions trading programs for all countries, except for the Russian Federation using one of the two liquidity measures.

These results suggest that a value of Y between 95% and 98% with X equal to 90% should provide sufficient international liquidity for domestic emissions trading programs in all countries. The value of Y could be linked to the scope of the domestic emissions trading program; 95% for countries where the domestic trading program covers more than 50% of the total greenhouse gas emissions and 98% for other countries.

In summary, negotiators need to balance potential non-compliance and temporarily restricted sales. To limit potential non-compliance due to over selling, the main purpose of the commitment period reserve proposal, the values of X and Y must be greater than 85%. Increasing the value of Y increases the effectiveness more than a comparable increase in the value of X.

Negotiators also need to treat individual countries fairly. Each will be affected differently by a given specification of the commitment period reserve. Equitable treatment of countries that

are net sellers requires a value of X close to 90%. This reduces the risk of temporarily restricted sales to less than 10% for almost all countries.

Setting Y equal to 98% (with X = 90%) provides international liquidity comparable to or greater than the liquidity of existing emissions trading programs for most Annex B countries regardless of the design of the domestic emissions trading program. With an upstream design for the domestic program, Y equal to 95% (with X equal to 90%) provides liquidity comparable to or greater than that of existing emissions trading programs for all Annex B countries except the Russian Federation under one of the two measures.

Sufficient liquidity should be available in the international market regardless of the specification adopted. Temporarily restricted sales will be small with both X and Y less than 100%. As a result compliance costs will be close to those for the least-cost, full compliance case even if there is no overselling. If there is non-compliance, the compliance costs will be lower than for the least-cost, full compliance case.

In short, the analysis suggests that a value of X close to 90% and of Y between 95% and 98% will maximize the effectiveness of the commitment period reserve in limiting possible non-compliance due to overselling while minimizing the number of Annex B countries subject to restricted sales of surplus quota or low international liquidity for domestic emissions trading programs. Such specifications still allow potential non-compliance due to overselling equal to between 40% (X = 90% and Y =98%) and 53% (X = 90% and Y = 95%) of the total possible non-compliance.

1. Introduction

1.1 International Emissions Trading Creates the Potential for Greater Non-compliance

Emissions trading can significantly reduce the cost of meeting an overall emissions target and so enhances the prospects of achieving that target. On the other hand, emissions trading creates the potential for rewarding non-compliance and for greater non-compliance. The presence of a regulator with the authority to impose penalties on participants who do not hold sufficient allowances to cover their actual emissions has meant that these potential problems have been minimal in the case domestic emissions trading programs.

Responsibility for compliance at the international level will reside with the participating countries, which are sovereign nations. A regulatory agency with the power to impose penalties for non-compliance on sovereign nations does not exist. Chayes and Chayes summarizes the situation with respect to non-compliance penalties for the roughly 200 existing international environmental agreements as follows: "sanctioning authority is rarely granted by treaty, rarely used when granted, and likely to be ineffective when used."[1]

Thus, an international emissions trading program creates the ***potential*** for:

- Greater non-compliance. If international emissions trading is not allowed, non-compliance is limited to the reductions needed to meet the national emissions limitation commitment. But with international emissions trading, the entire allocation of allowable emissions (the national emissions limitation commitment) can also be sold to other Parties.

- Rewarding non-compliance. If international emissions trading is not allowed, the economic benefits of non-compliance are limited to the costs avoided by not reducing emissions to meet the national emissions limitation commitment. If international emissions trading is allowed, a country can avoid those costs and receive payment for allowable emissions sold to other countries.

The word **potential** is emphasized because many countries substantially comply with their treaty obligations despite the absence of effective sanctions for non-compliance. Chayes & Chayes note that there are host of non-sanction factors that promote compliance with treaty obligations. But international emissions trading creates incentives for non-compliance not present in other treaties.

The Kyoto Protocol, if it comes into force, will impose national limits on emissions of greenhouse gases during 2008-2012 by Parties listed in Annex B to the Protocol. The Protocol also creates three mechanisms for international cooperation to reduce the cost of meeting the national emissions limitation commitments. International emissions trading under Article 17 of the Protocol is one of those mechanisms.

[1] Chayes and Chayes 1998, p. 32.

A compliance regime for the Kyoto Protocol, with penalties for non-compliance, is being negotiated. However, a Party that finds proposed penalties for non-compliance too onerous could withdraw from the Protocol and so avoid the penalties. Thus, the effective penalties may be less than the potential gains due to non-compliance.[2]

1.2 Liability Proposals Seek to Limit Non-compliance due to Overselling

Non-compliance with commitments under the Kyoto Protocol could take one of two forms:

- A country's emissions exceed its commitment and the emissions quota[3] it purchased despite the domestic emission reduction and sink enhancement actions implemented; or

- A country's emissions (after implementation of domestic emission reduction and sink enhancement actions) exceed its remaining emissions quota after the sale of quota to other countries.

The first form of non-compliance can be called "underbuying". Compliance can be achieved through the purchase of additional quota. In the absence of international emissions trading it would be the only way in which non-compliance could occur. But in the absence of international emissions trading compliance could be achieved only through additional domestic action, not the purchase of additional emissions quota.

The second from of non-compliance can be called "overselling". Country A does not comply because it sold emissions quota it needs to meet its emissions limitation commitment to other countries, say Country B. Country B purchased the quota to help achieve compliance with its commitment. The fact that Country A then fails to meet its commitment means that the overall emissions limitation objective has not been met despite the efforts of Country B. In addition, Country A has been rewarded for its non-compliance by the revenue from the sale of the non-surplus quota.

Overselling can occur as a result of poor planning or mismanagement of the national compliance strategy, which allows government agencies or private entities to export quota ultimately needed for compliance purposes. Overselling can also occur if compliance with obligations under a domestic emissions trading program is poorly enforced and this allows participants to export quota which is not surplus to such obligations. Finally, overselling can occur as a result of cheating by private entities or government agencies with access to national quota.

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[2] Haites and Missfeldt, 2001b.

[3] The term "quota" is used to mean any or all of assigned amount units (AAUs) under Article 17, Certified Emission Reductions (CERs) under the Clean Development Mechanism (CDM) of Article 12, and Emission Reduction Units (ERUs) from Joint Implementation projects under Article 6.

Effective sanctions for non-compliance are sufficient to deter overselling. Given effective penalties for non-compliance, Country A would face sanctions more severe than the cost of the quota needed to comply with its commitment. Then it would restrict its sales to remain in compliance or purchase quota if a shortfall became evident. Domestic emissions trading programs rely on effective penalties to deter overselling.

Concern that the non-compliance regime under the Kyoto Protocol may not be sufficient had led to a number of proposals in the literature and the negotiations to limit the scope of overselling. Most of these so-called "liability" proposals seek to limit international sales of emissions quota to amounts surplus to the compliance needs of the seller. The compliance needs of the seller can not be known precisely until after the end of the commitment period. But if international emissions trading is to be effective in reducing overall compliance costs, sales must occur during the commitment period.

Proposals to limit overselling, then, must balance higher compliance costs due to restrictions on sales of quota surplus to the seller's compliance needs with non-compliance due to the sale of quota that is not surplus to the seller's compliance needs. If the limit on sales is set below the seller's compliance needs, sales may lead to non-compliance by the seller. This is what the liability proposal seeks to prevent. But if the limit is set so that quota surplus to the seller's compliance needs can not be sold until after compliance is established, it can increase compliance costs for buyers.

A liability provision complements, but does not replace, non-compliance penalties at the international level. A liability provision has no effect on a country that does not sell emissions quota or a country's quota purchase decisions, unless it includes a buyer liability component.[4] Thus, a liability provision without a buyer liability component does not affect non-compliance due to underbuying.

A liability provision can limit overselling. But a liability provision is not a precise instrument because future compliance needs can not be accurately known when trades occur. If the liability provisions is designed to prevent gross overselling it will allow limited overselling by at least some countries. Non-compliance sanctions and complement the liability provision by encouraging countries to retain or purchase enough quota to cover their actual emissions even though limited overselling is possible under the liability provision.

1.3 A Liability Provision can be Effective in Limiting Overselling

Fourteen different liability proposals were evaluated by Haites and Missfeldt using a highly aggregated model with a single Annex B buyer and a single Annex B seller.[5] They evaluated the proposals in terms of:

[4] Under buyer liability the buyer is not able to use the quota purchased if the seller does not meet its emissions limitation commitment. The commitment period reserve, which is the focus of this report, does not include a buyer liability component.

[5] Haites and Missfeldt, 2001a.

- The ability to limit excess emissions by the Annex B seller.
- The impact on the compliance cost for the Annex B buyer.
- Whether the operational specification of the liability proposal is sensitive to national circumstances.
- Whether the performance of the liability proposal is sensitive to market power by the seller.
- Whether the liability proposal limits the period during which trading may take place.
- Whether the liability proposal changes the distribution of net income across regions.

Haites and Missfeldt found that some proposals were not effective in limiting overselling, while others increased compliance costs substantially by restricting sales of quota surplus to the seller's compliance needs. However, "several of the liability proposals can achieve results essentially equivalent to the least-cost full-compliance equilibrium even assuming the worst behaviour by the Annex B seller. In other words, these proposals can prevent abuse of [international] emissions trading at negligible cost in terms of excess emissions or extra compliance costs."[6] They also found that a permanent reserve was the only proposal studied able to meet all of the criteria.

Further consideration of the permanent reserve has led to a modified formulation that is now called the commitment period reserve.

1.4 The Commitment Period Reserve Proposal

The commitment period reserve proposal requires each Annex B Party to hold in its national registry quota equal to the ***lower*** of:

- X% of five times the Party's most recently reviewed emissions inventory; and
- Y% of the Party's initial assigned amount pursuant to Articles 3.7 and 3.8.[7]

The President of the 6th Conference of the Parties (COP 6) has proposed a commitment period reserve as part of the rules for international emissions trading.[8] His proposal sets X = 100%

[6] Haites and Missfeldt, 2001a, p. 106.

[7] The main differences from the permanent reserve proposal are that X and Y have been introduced and the second option has been introduced to allow entities in buyer countries to export quota.

[8] See UNFCCC, 2001, p. 13.

and Y = 90%. Parties have proposed values of X ranging from 70% to 100% and values of Y ranging from 70% to 98%. Regardless of the values finally adopted, they would be the same for all Annex B countries.

The first calculation would typically be the lower quantity for an Annex B country that is a possible net seller of quota through the Kyoto mechanisms. The country could export quota equal to the difference between its total assigned amount and the reserve requirement. The reserve requirement changes each time a new emissions inventory is reviewed. Review of an emissions inventory may not be completed until two or three years after the end of the year during which the emissions occurred.

If a country's actual emissions are declining, the lag in reviewing the inventory may limit sales of some quota surplus to its compliance needs. If a country's actual emissions are rising, the lag in reviewing the inventory can increase the extent of potential non-compliance by the seller. The value of X balances these considerations. High values of X can reduce the potential non-compliance to zero, but at the cost of restricting sales of surplus quota. Low values of X allow all surplus quota to be sold, but increase the risk of non-compliance. Intermediate values of X will restrict sales of surplus quota by some countries while limiting non-compliance by other countries.

The second calculation would typically be the lower quantity for an Annex B country that is a net buyer of quota through the Kyoto mechanisms. With Y < 100% such a Party could export some quota even though it is a net buyer overall.[9] The ability to export would increase over time as the country acquired quota. The acquired quota does not affect the size of the reserve and hence can be re-exported subject to the rules governing the different mechanisms.

The considerations that affect the values for X and Y are:

- The extent of possible non-compliance. The lower the values of X and Y, the larger is the possible non-compliance.

- The impact on compliance costs. The higher the value of X, the higher is the probability that some surplus allowances can not be sold due to the reserve requirement until compliance with the country's emissions limitation commitment has been established. This increases compliance costs during the commitment period, but reduces them when the surplus quota becomes available.

- Liquidity in the international market. As the values of X and Y rise, the quantity of quota available for international trade (the "float") is reduced, thus reducing liquidity in the international market.

- International liquidity for domestic markets. At least some Annex B Parties are expected to implement domestic emissions trading programs to help meet their emissions limitation

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[9] Note that while the maximum value for Y is 100, the value of X could be greater than 100.

commitments. A reserve requirement does not restrict domestic trading, so domestic emissions trading programs can be designed to provide sufficient liquidity in the domestic market. However, under some circumstances international liquidity is desirable for participants in domestic emissions trading programs. That requires a value of Y < 100%.

In short, some considerations argue for higher values of X and Y while other considerations argue for lower values.

The commitment period reserve would be implemented by electronic or other controls that reject a proposed transfer of quota from a country's national registry if it would cause the holdings in the registry to fall below the reserve requirement. Trading among entities within the country would not be affected. And acquisitions of quota from other countries would not be affected. Only transfers that would cause the reserve requirement to be violated would be prohibited.

1.5 Purpose

The purpose of this paper is to analyse the effect of specifications (values of X and Y) of the commitment period reserve in terms of the above considerations.

This analysis differs from our previous work in several important respects.

- First, we analyse how the commitment period reserve would apply to each Annex B country individually and to Annex B countries as a group. In contrast, the previous analysis grouped Annex B countries into a single buyer and a single seller.

- Second, we examine the operation of the commitment period reserve with random fluctuations in future emissions. The previous analysis assumed that future emissions were known with certainty.

- Third, we consider different values of X and Y, where our previous work assumed both X and Y were equal to 100.

- Fourth, we introduce liquidity at both the international and national levels. Liquidity was not considered in our previous work.

2. Analytical Framework

This section describes the framework developed to analyse the commitment period reserve. The analysis focuses on the impacts of alternative specifications of the reserve requirement. Alternative specifications are assessed in terms of:

- The extent of possible non-compliance;
- Restricted sales of quota surplus to the country's compliance needs leading to higher compliance costs;
- Liquidity in the international market; and
- International liquidity for domestic emissions trading markets.

2.1 Ratification of the Kyoto Protocol by All Annex B Parties is Assumed

Although the issues associated with the commitment period reserve apply to any form of international emissions trading, the analysis focuses on the Kyoto Protocol because much of the information required for the analysis is specific to those negotiations.

Specifically, we assume that the Kyoto Protocol is ratified by all Parties listed in Annex B and that it comes into force prior to 2008. We also assume that the commitments of Annex B Parties cover the gases and sources listed in Annex A and are calculated in accordance with the provisions of Articles 3.6, 3.7 and 3.8. We assume that international emissions trading among Annex B Parties is allowed under Article 17 and that such trade is not constrained by quantitative supplementarity restrictions.

2.2 Annex B Countries Covered by the Analysis

Annex B of the Kyoto Protocol includes 38 countries as well as the European Community. The rules relating to use of the Kyoto mechanisms, including maintenance of the reserve required by the commitment period reserve proposal, are expected to apply to the individual member countries of the European Community, hence the European Community as a Party is excluded from the analysis. The necessary data are not available for two of the countries -- Liechtenstein and Monaco -- so they are also excluded from the analysis. Thus, results reported for Annex B countries as a whole in fact apply only to the remaining 36 countries.

To estimate the impact of alternative specifications of the commitment period reserve on compliance costs, we use the same model as in our previous work. This model features a

single Annex B buyer, the Annex II Parties[10], and a single Annex B seller, the remaining Annex B countries. This requires that the Annex B countries be aggregated into those two groups. The 23 countries that comprise the Annex II Parties and 13 countries in the Rest of Annex B are shown in Table 1.

Table 1
Aggregation of Annex B Countries for the Cost Analysis

Annex II Parties		**Rest of Annex B**
Australia	Japan	Bulgaria
Austria	Luxembourg	Croatia
Belgium	Netherlands	Czech Republic
Canada	New Zealand	Estonia
Denmark	Norway	Hungary
Finland	Portugal	Latvia
France	Spain	Lithuania
Germany	Sweden	Poland
Greece	Switzerland	Romania
Iceland	United Kingdom	Russian Federation
Ireland	United States	Slovakia
Italy		Slovenia
		Ukraine
Note: Includes all Annex B Parties except the European Community, Liechtenstein and Monaco.		

2.3 Data Collected

The data collected for each of the countries listed in Table 1 are:

- Total greenhouse gas emissions for the gases covered by the Kyoto Protocol, expressed in terms of CO_2 equivalent emissions, excluding emissions due to land use, land-use change, and forestry.

- Total CO_2 emissions due to fossil fuel combustion.

- Total CO_2 emissions by industry due to fossil fuel combustion.

The data on total greenhouse gas emissions are used to analyse the performance of different specifications of the commitment period reserve. The data on CO_2 emissions due to fossil

[10] The Parties listed in Annex II to the Framework Convention on Climate Change. Turkey is listed in the Annex, but has not ratified the Convention and so is excluded from this analysis.

fuel combustion and on CO_2 emissions by industry due to fossil fuel combustion are used as estimates of the emissions that might be covered by a domestic emissions trading program in the analysis of the international liquidity available for domestic emissions trading programs.

In each case data on actual emissions were collected for as many years as are available from 1990 on. Data on actual emissions usually extend through 1997. Projected emissions for any years available through 2020 were also collected. Projections typically were available only for selected years, such as 2010 and 2020. Values for intervening years were calculated by linear interpolation. Where projections beyond 2010 were not available, figures for later years were estimated by extrapolating the growth rate for the period prior to 2010.

The data and projections for total greenhouse gas emissions come primarily from national inventories submitted to the secretariat for the United Nations Framework Convention on Climate Change (UNFCCC). The data on CO_2 emissions due to fossil fuel combustion and on CO_2 emissions by industry due to fossil fuel combustion come mainly from the Greenhouse Gas Inventory Database released by the UNFCCC secretariat in September 2000. Gaps were filled with data from *CO_2 Emissions from Fuel Combustion*, IEA and OECD (1997), Paris and *Anthropogenic Emissions of CO_2 (1980-2010) in the ECE Region*, United Nations Economic Commission for Europe (2000).

The initial assigned amount was calculated for each country according to the provisions of Articles 3.6, 3.7 and 3.8 of the Kyoto Protocol and relevant decisions of the Conference of the Parties using the data on total greenhouse gas emissions. For many countries the initial assigned amount is calculated using its 1990 emissions of CO_2 methane (CH_4) and nitrous oxide (N_2O) and its 1995 emissions of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

The initial assigned amount for several countries in central and eastern Europe is based on emissions for a single year or period between 1985 and 1989 rather than 1990. In these cases the relevant emissions data were collected to calculate the initial assigned amount. Countries that are members of the European Union are expected to create a "bubble" under the provisions of Article 4. This involves a redistribution of the emissions limitation commitments and hence the initial assigned amounts. The initial assigned amount for each member of the European Union reflects the burden sharing agreement of June 1998.

The initial assigned amount and total greenhouse gas emissions for selected years by country are shown in Table A-1 in Appendix A.

2.4 The Commitment Period Reserve

A commitment period reserve requirement is assumed to be adopted as part of the rules for international emissions trading. This provision requires each Annex B Party to hold in its national registry quota equal to the ***lower*** of:

- X% of five times the Party's most recently reviewed emissions inventory; and

- Y% of the Party's initial assigned amount pursuant to Articles 3.7 and 3.8.

The size of the reserve is recalculated each year after review of a new emissions inventory. Compilation of the emissions inventory and its review in accordance with the provisions of Article 8 are assumed to take two years. Thus, for the analysis the reserve requirement for 2008 is based on emissions in 2006. This reserve requirement is adjusted in 2009 based on 2007 emissions, and so on.

The specification of the reserve requirement, the values of X and Y, is assumed to be the same for every Annex B Party. The reason for analysing the commitment period reserve at the country level is to assess whether application of a uniform specification adversely affects individual countries.

2.5 Treatment of ERUs, CERs and Sequestration

Transfers of emission reduction units (ERUs) awarded by an Annex B government for a joint implementation project under Article 6 are not analysed separately. Holdings of ERUs in a national registry are assumed to help meet the reserve requirement. Under the provisions of Articles 3.10 and 3.11 transfers of ERUs are equivalent to transfers of assigned amount (AAUs), so there is no need to distinguish between ERUs and AAUs in the analysis.

Calculation of the reserve requirement is not affected by holdings of certified emission reductions (CERs) created by projects under the clean development mechanism. However, CERs would contribute to meeting the reserve requirement. Thus transfers of CERs from an Annex B country registry would be subject to maintenance of the reserve requirement in the same way as any other proposed quota transfer.[11] Use of CERs by an Annex B country for compliance purposes reduces the quantity of other quota purchased. This means that use of CERs reduces the potential non-compliance, so the scale of potential non-compliance is overstated by excluding CERs.

The availability of CERs increases liquidity. The potential impact of CERs on liquidity in the international market is considered, since estimates of the global supply of CERs are available. But the impact of CERs on liquidity for domestic emissions trading markets is ignored because country-specific estimates of CER acquisition are not available. This results in an understatement of the international liquidity of the domestic markets.

Annex B countries will be allowed to issue AAUs equal to the net quantity of carbon sequestered during 2008-2012 by specified sink enhancement activities. The eligible sink enhancement activities are still under negotiation. Estimates of the magnitude of the net sequestration vary widely. In addition, the lags involved in documenting the net sequestration

[11] This assumes that the rules for the clean development mechanism allow CERs to be transferred after they have been acquired by an Annex B entity for the first time.

severely limits the quantity available for trading during 2008-2012.[12] Net sequestration is excluded from the analysis due to these uncertainties.

Net sequestration, in any case, does not affect the determination of the reserve requirement or change the quantity of surplus quota, if any, that can not be sold. Net sequestration by an Annex B country reduces the quantity of quota purchased. Thus by excluding net sequestration, the analysis overstates the scale of potential non-compliance.

Net sequestration increases liquidity. The potential impact of net sequestration on liquidity in the international market is not considered because more conservative estimates are used and the effect on the estimates of liquidity of including net sequestration would be small. The impact of net sequestration on liquidity for domestic emissions trading markets is ignored because country-specific estimates are not available for most countries. This results in an understatement of the international liquidity for the domestic markets.

2.6 Uncertainty of Future Emissions

The commitment period reserve proposal sets a reserve requirement before a country's actual emissions are known. The projections used reflect government estimates of future economic growth, the impacts of existing and anticipated policies, and other factors. In aggregate the projections do not meet the Kyoto commitments. Countries may implement additional emission reduction policies, purchase quota, or fail to meet their commitments.

Implementation of additional emission reduction policies in countries where the reserve requirement is based on actual emissions will lower the reserve requirement, with an assumed two-year lag, and then allow additional quota to be exported. Implementation of additional emission reduction policies in countries where the reserve requirement is based on the initial assigned amount will not change the reserve requirement, but would reduce the extent of the potential non-compliance.

Greenhouse gas emissions can not be forecast with perfect accuracy, so the reserve requirement may allow the sale of more emissions quota than anticipated or may restrict sales of quota surplus to a country's compliance needs and so raise compliance costs. To simulate this aspect of the performance of the commitment period reserve, future emissions are assumed to fluctuate from the projected values.

For total greenhouse gas emissions, the standard error is calculated using the data on actual emissions for the years 1990 through 1997. Then the value for each future year is equal to the projected value plus or minus a random adjustment. The random adjustment is calculated as the product of a normally distributed random number and the standard error.[13]

[12] Net sequestration can not be documented until after it has occurred. Thus sequestration that occurs during 2008 can be documented in the 2009 emissions inventory, which is reviewed in 2011. This means that at most AAUs corresponding to two years of sequestration can be issued before the end of 2012.

[13] The random numbers have a normal distribution with mean = 0 and standard deviation = 1.

Some 500 runs of randomized future greenhouse gas emissions are generated for each of the 36 Annex B countries. The procedure assumes that random variations from one year to the next in a given country are independent of each other. The limited period for which data on actual emissions are available (1990 through 1997) is not sufficient to test whether differences from a country's emissions trend are serially correlated or not. The procedure also assumes that random variations from one country to another in a given year are independent of each other. Again sufficient historical data to test whether actual greenhouse gas emissions of various Annex B countries are correlated are lacking.

2.7 Sensitivity Scenario

The projected emissions typically reflect the estimated impact of existing and known policy initiatives. Many Annex B countries will need to implement additional policies to meet their emissions limitation commitments. In the case of a seller country, policies that reduce actual emissions over time could lead to a reserve that prohibits the sale of emissions quota surplus to its compliance needs. This would raise compliance costs for buyer countries and deprive the seller of revenue from the sale of the surplus quota until compliance had been established and the surplus quota could be sold.

In the case of a buyer country, the reserve requirement is likely to be based on the initial assigned amount. As long as the country remains a net buyer despite the impact of the emissions reduction policies, its reserve requirement would not change. While the demand for emissions quota would be lower, this is independent of the commitment period reserve provision.

As a result of declining actual emissions due to climate change policies, a country could move from being a net buyer to being a net seller. The calculation of the reserve requirement would automatically reflect such a change. There is a possibility that as a net seller the reserve requirement temporarily restricts the sale of some surplus quota.

To test the sensitivity of the commitment period reserve rule to declining emissions by a net seller we consider a sensitivity scenario with a much lower emissions projection for the Russian Federation. The Russian Federation is selected for the sensitivity analysis because it is projected to be the largest net seller and several alternative projections are available. The sensitivity scenario selected is the lowest published projection of Russian emissions during the commitment period we could find, Moe and Tangen's sustained decline scenario.[14] This scenario projects energy-related CO_2 emissions for 2010 at 1.305 $GtCO_2$ equivalent, or total greenhouse gas emissions of 1.877 $GtCO_2$ equivalent based on the historic relationship between energy-related CO_2 emissions and total greenhouse gas emissions.

In the sensitivity scenario, average total emissions for the commitment period are 9.385 $GtCO_2$ equivalent, which is 38% below the initial assigned amount of 15.202 $GtCO_2$

[14] Moe and Tangen, 2000, Table 3.4, p. 41.

equivalent. Even the run with the largest random adjustment results in emissions of only 11.530 $GtCO_2$ equivalent, some 24% below the initial assigned amount. The sensitivity scenario emissions are about 35% lower than the projection of 2.912 $GtCO_2$ equivalent in 2010 in the national communication, which is used as the reference scenario.

We found only one alternative projection for the Ukraine, the other likely substantial net seller. This projection, by Victor et al., placed the surplus quota for the Ukraine at 0.011 to 0.734 $GtCO_2$ equivalent (3 to 200 MtC) during the commitment period compared with their projection of 0.033 to 3.303 $GtCO_2$ equivalent (9 to 900 MtC) for the Russian Federation.

Our sensitivity scenario for the Russian Federation has a larger surplus than for the Russia Federation and the Ukraine combined under the Victor et al. maximum estimates.[15] Hence, our sensitivity scenario should be sufficient to highlight insights into the performance of the commitment period reserve given impact of sharp reductions in emissions of a single country. In terms of the impact on Annex B countries as a group, a large surplus in the Russian Federation is equivalent to combined surpluses of equal size in other countries. Thus, we believe that introducing alternative projections for the Ukraine or other net sellers would not yield any insights not available from the Russian sensitivity scenario.

[15] The surplus quota averages 5.817 $GtCO_2$ equivalent; the initial assigned amount of 15.202 $GtCO_2$ equivalent less the total emissions, which averages 9.385 $GtCO_2$ equivalent. Victor et al.'s maximum surplus is 3.303 $GtCO_2$ equivalent for the Russian Federation and 0.734 $GtCO_2$ equivalent for the Ukraine, for a total of 4.037 $GtCO_2$ equivalent. This is 30% less than for the sensitivity scenario.

3. Possible Non-Compliance Due to Overselling and Temporarily Restricted Sales

Our analysis considers various specifications (combinations of values for X and Y) of the commitment period reserve in terms of:

- The extent of possible non-compliance due to overselling;
- Temporarily restricted sales of surplus quota and the resultant impact on compliance costs;
- Liquidity in the international market; and
- International liquidity for domestic markets.

Our analysis of the first two items -- possible non-compliance due to overselling and temporarily restricted sales -- is presented in this section. Our analysis of the liquidity issues is presented in section 4.

3.1 Introduction

3.1.1 Possible Non-compliance Due to Overselling

As noted in section 1.2, non-compliance by a country with its emissions limitation commitment can take two forms. The effect of a country's domestic emission reduction and sink enhancement actions may not be enough to reduce its emissions to the level of its commitment plus the emissions quota purchased. This is called underbuying. The country does not sell any of its quota, so it is subject to, but unaffected by, the commitment period reserve requirement.

Non-compliance due to overselling occurs when a country's emissions, after implementation of domestic emission reduction and sink enhancement actions, exceed its remaining emissions quota after sales of quota to other countries. The commitment period reserve specifically targets this form of non-compliance by limiting the quantity of quota a country can sell.

Note that non-compliance due to overselling can occur only if there are international transfers of quota. There must be a buyer and seller that subsequently does not meet its emissions limitation commitment. The possible non-compliance due to overselling then is the lower of the quantity of quota that can be transferred internationally (the supply) and the quantity of quota purchased by other countries (the demand).

The demand and supply, and hence possible non-compliance due to overselling, are easy to calculate if Y =100%. With Y = 100% countries that are net buyers can not transfer any of their emissions quota. Then the demand for quota is the sum over all net buyer countries of the difference between their emissions during the commitment period, after implementation of

domestic emission reduction and sink enhancement actions, and their emissions limitation commitment. The supply is the sum over countries that are net sellers of the quota surplus to the reserve requirement but not surplus to its compliance needs. That is the difference between its emissions during the commitment period, after implementation of domestic emission reduction and sink enhancement actions, and the reserve requirement.

With Y = 100% possible non-compliance due to overselling is generally determined by the supply. The difference between the projected emissions and the assigned amount of net buyer countries in the reference scenario is 10.993 $GtCO_2$ equivalent over the commitment period.[16] With X = 95%, the maximum quantity that could be sold by countries that are net sellers is 3.969 $GtCO_2$ equivalent, of which 2.606 $GtCO_2$ equivalent is surplus to the compliance needs of the sellers and 1.363 $GtCO_2$ equivalent is surplus to the reserve requirement, but not the compliance needs, of the sellers.

In this case the possible overall non-compliance is 8.387 $GtCO_2$ equivalent; the 10.993 $GtCO_2$ equivalent of excess emissions of the buyer countries less the 2.606 $GtCO_2$ equivalent surplus quota of the seller countries. Of this total, possible non-compliance due to overselling is limited to 1.363 $GtCO_2$ equivalent. This would occur only if the buyer countries purchased 3.969 $GtCO_2$ equivalent of quota from the seller countries and the latter took no action to offset the 1.363 $GtCO_2$ equivalent of emissions for which they no longer had quota.

When Y is less than 100% calculating the possible non-compliance due to overselling becomes more complex. With Y < 100% countries that should be net buyers to meet their commitments can sell quota. When a country that should be a net buyer decides to sell quota instead, it reduces the demand for quota and it increases the supply of quota surplus to the reserve requirement, but not the compliance needs, of the sellers. The maximum possible non-compliance due to overselling occurs when the demand of the remaining buyer countries equals the supply of quota surplus to the reserve requirement, but not the compliance needs, of the other Annex B countries. The buyer and seller countries that yield the maximum non-compliance due to overselling change with each specification.

The possible overall non-compliance remains at 8.387 $GtCO_2$ equivalent regardless of the reserve requirement. However, the maximum possible non-compliance due to overselling increases for lower values of X and Y. Data on the maximum possible non-compliance due to overselling for different specifications of the commitment period reserve will be presented later.

3.1.2 Temporarily Restricted Sales

The purpose of the commitment period reserve is to limit the extent of possible non-compliance due to overselling. Setting high values for X and Y (over 100% for X and 100% for Y) minimizes the potential for overselling. But the reserve requirements dictated by such

[16] These calculations are based on the emissions projections for the reference scenario. They are equal to the average emissions for the 500 runs after the random adjustments.

a specification (combination of values for X and Y) may restrict sales of quota surplus to the compliance needs by one or more countries until they have established compliance with their emissions limitation commitment after the end of the commitment period.

Such a temporary restriction on sales of quota surplus to the compliance needs of the seller country means that the seller does not have access to the revenue from the sale of that quota until after it has established compliance with its emissions limitation commitment. It also increases compliance costs temporarily for buyer countries because they are forced to rely on higher cost options during the commitment period to achieve compliance. After the restricted quota becomes available, the compliance costs for buyers decline.

The extent of possible non-compliance and the extent to which sales of surplus quota are constrained for a given specification of the commitment period reserve must be calculated initially for each Annex B country. The country totals can then be summed to get the overall Annex B totals.

3.2 Possible Non-compliance and Temporarily Restricted Sales of Surplus Quota at the Country Level

To illustrate the potential non-compliance and temporarily restricted sales for an individual country, we discuss application of the commitment period reserve to Australia and the Russian Federation.

3.2.1 Application of the Commitment Period Reserve to Australia

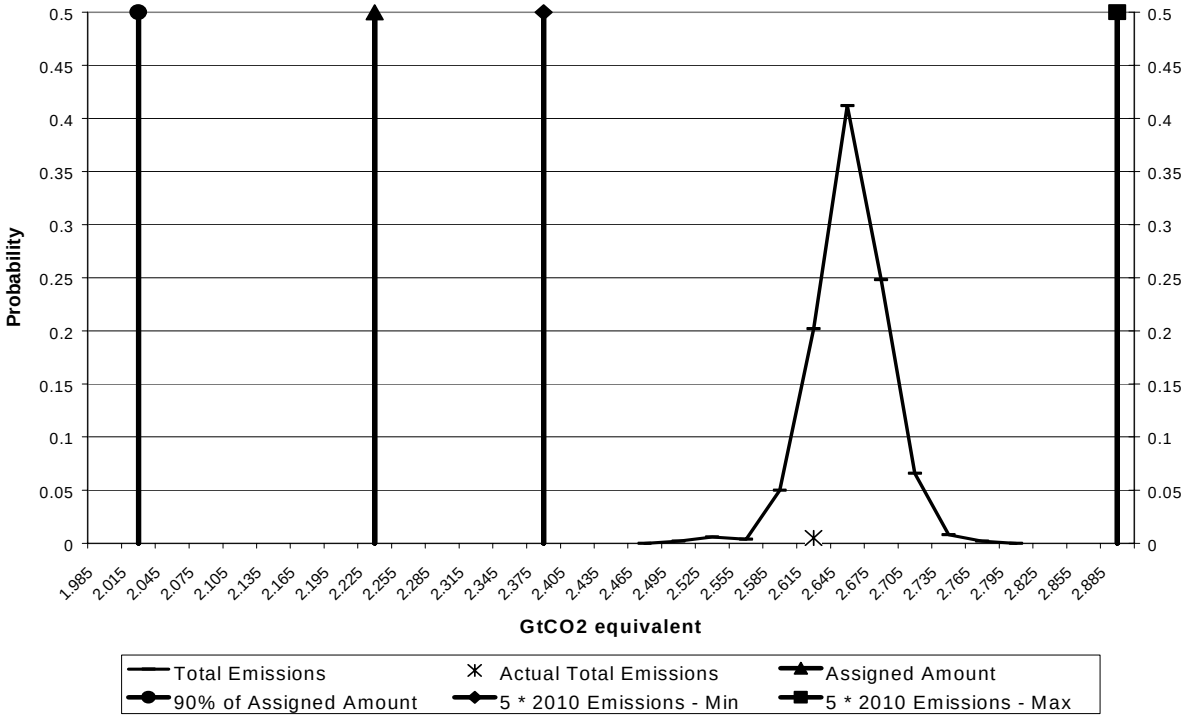
Figure 1 illustrates application of the commitment period reserve proposal to Australia. The distribution shows the distribution of total emissions during the commitment period for the 500 runs. The projected emissions range from 2.453 $GtCO_2$ equivalent to 2.776 $GtCO_2$ equivalent, with a most probable value of 2.648 $GtCO_2$ equivalent. In practice Australia's total emissions during the commitment period will be one value, probably somewhere in the range 2.453 to 2.776 $GtCO_2$ equivalent, arbitrarily shown by the star at 2.630 $GtCO_2$ equivalent on the horizontal axis.

The commitment period reserve proposal would require Australia to hold in its national registry quota equal to the ***lower*** of:

- X% of five times the Party's most recently reviewed emissions inventory; and
- Y% of the Party's initial assigned amount pursuant to Articles 3.7 and 3.8.

The following discussion assumes that X = 100% and Y = 90%.

Figure 1
Application of the Commitment Period Reserve to Australia



Under the first provision the reserve requirement is recalculated each year as the latest emissions inventory is reviewed. The process of preparing and reviewing an emissions inventory is assumed to take 2 years. Thus in 2008 the reserve requirement will be based on the emissions inventory for 2006. When the emissions inventory for 2007 has been reviewed in 2009, the reserve requirement is adjusted. This means that the reserve requirement for the last year of the commitment period is based on emissions during 2010.

For simplicity the figure shows only the range within which the reserve requirement for 2012 could fall. Given the 500 values for emissions in 2010, the reserve requirement based on five times 2010 emissions could be as low as 2.386 $GtCO_2$ equivalent or as high as 2.863 $GtCO_2$ equivalent. The low value is shown as the vertical line to the left of the distribution and the high value is shown as the vertical line to the right of the distribution. In practice this provision would yield a single value probably somewhere between the two vertical lines shown.

The second provision would set the reserve requirement at 90% of Australia's initial assigned amount. Australia's initial assigned amount of 2.245 $GtCO_2$ equivalent is shown as the second vertical line from the left. At 90% of the initial assigned amount, the reserve requirement would be 2.020 $GtCO_2$ equivalent, the vertical line at the far left. The calculation under this provision does not change over the commitment period.

The effective reserve requirement for Australia, then, is the lower of 2.020 $GtCO_2$ equivalent, the line on the far left, and a value that lies between 2.386 and 2.863 $GtCO_2$ equivalent, the two lines on the right. The line on the far left is clearly lower, so Australia's reserve requirement would be equal to 90% of its initial assigned amount, 2.020 $GtCO_2$ equivalent. And the size of the reserve requirement is likely to remain constant from 2008 through 2012.

Since the distribution of total emissions lies to the right of the assigned amount (the second line from the left) Australia is likely to be a net buyer. If Australia took no further action to reduce its emissions or enhance its sinks, its level of non-compliance would be 0.385 $GtCO_2$ equivalent, the difference between its actual emissions, the arbitrarily assumed value of the star on the horizontal axis, of 2.630 $GtCO_2$ equivalent and its initial assigned amount of 2.245 $GtCO_2$ equivalent. Non-compliance for some, or all, of this amount represents underbuying and is not addressed by the commitment period reserve.

With this specification, however, Australia could increase the extent of its non-compliance by selling the quota surplus to its reserve requirement. Specifically it could sell 0.225 $GtCO_2$ equivalent, the difference between its initial assigned amount (2.245 $GtCO_2$ equivalent) and the reserve requirement (2.020 $GtCO_2$ equivalent).[17] Non-compliance due to such action is overselling which is the focus of the commitment period reserve.

Changing the value of Y while keeping X = 100% shifts the left-hand vertical line along the horizontal axis. As the value of Y increases the line moves closer to the initial amount (away from the origin) and with Y = 100% it would be identical to the initial assigned amount at 2.245 $GtCO_2$ equivalent. Thus, higher values of Y reduce potential non-compliance, overall and due to overselling, by net buyer countries. Lower values of Y move the reserve requirement closer to the origin and increase the extent of possible non-compliance.

Reducing the value of X while keeping Y = 90% shifts the two vertical lines on the right closer to the origin. Since those lines are well to the right of the reserve requirement of 2.020 $GtCO_2$ equivalent, the value of X must be reduced substantially before either of these lines is shifted to the left of this line and becomes the effective reserve requirement. For values of X between 70% and 85% there is a chance that the reserve requirement would be based on actual emissions rather than the initial assigned amount. Values of X < 70% (with Y = 90%) are sufficient to ensure that the reserve requirement would be based on actual emissions.

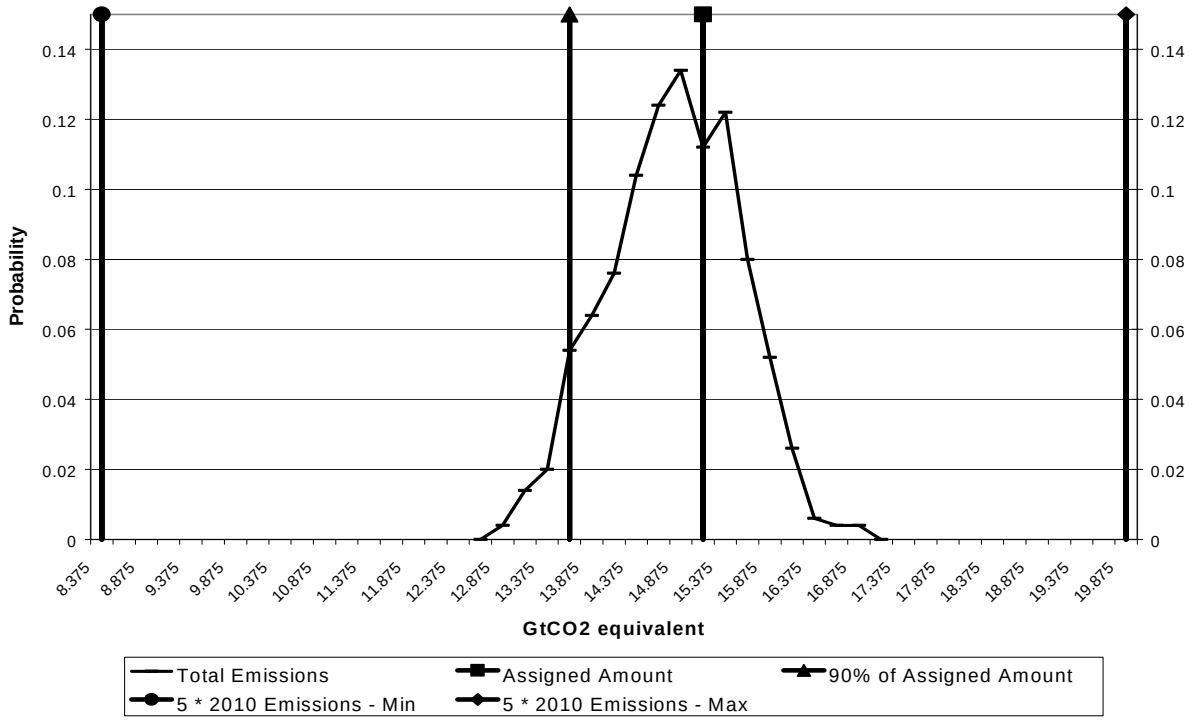
3.2.2 Application of the Commitment period Reserve to the Russian Federation - Reference Scenario

Figure 2 illustrates application of the commitment period reserve proposal to the Russian Federation based on the central case projection as reported to the UNFCCC secretariat by the government. The projected actual emissions over the commitment period range from 12.736 to 16.693 $GtCO_2$ equivalent, with a central value of 14.547 $GtCO_2$ equivalent. The central

[17] Thus total non-compliance could rise to 0.385 + 0.225 = 0.610 $GtCO_2$ equivalent of which 0.225 $GtCO_2$ equivalent is due to overselling.

value less than 5% below Russia's initial assigned amount of 15.202 $GtCO_2$ equivalent. The distribution of total emissions over the commitment period has a much flatter peak than that for Australia, reflecting greater uncertainty about the emissions trend in the Russian Federation.

Figure 2
Application of the Commitment Period Reserve to the Russian Federation



The vertical lines on the left and the right are the reserve requirements corresponding to five times the minimum and maximum 2010 emissions. These lines lie well outside the distribution for total emissions for the five years of the commitment period. The reason is that calculation of those lines implicitly assumes that the low (high) emissions in 2010 are sustained for five years. The distribution presents the total emissions over five years for the 500 runs. The random adjustments mean that for a given run there will be different adjustments for each year, so the lowest (highest) value for a particular year will not be sustained for five years. Thus the distribution spans a narrower range than the potential reserve requirement.

Of course, the reserve requirement for 2012 would be a single value based on actual emissions in 2010 and it would probably lie somewhere in the range between the minimum and maximum values represented by the left- and right-hand lines. The reserve requirement based on the most recent emissions inventory would also change annually as the review of the most recent inventory was completed.

The second vertical line from the left shows the reserve requirement based on 90% of the initial assigned amount, 13.681 $GtCO_2$ equivalent. The third vertical line from the left shows Russia's initial assigned amount of 15.202 $GtCO_2$ equivalent.

The reserve requirement based on 90% of the initial assigned amount lies between the minimum and maximum values of the reserve requirement based on five times actual emissions in 2010. As a result, with this specification (X = 100% and Y = 90%) the reserve requirement for the Russian Federation in 2012 will be determined by actual emissions in 2010 if they are less than 2.736 $GtCO_2$ equivalent, which happens in 31.8% of the runs.[18] In the rest of the runs it is equal to 90% of the initial assigned amount.

Thus, under this emissions scenario, where the projected emissions are close to the initial assigned amount, and this specification of the commitment period reserve, X = 100% and Y = 90%, either of the provisions could determine the reserve requirement for the Russian Federation and the effective provision could change from year to year over the commitment period.

Part of the distribution for total emissions in Figure 2 lies to the left of the vertical line for 90% of the initial assigned amount. If the reserve requirement was equal to 90% of the initial assigned amount in those runs, it would restrict sales of surplus quota until after compliance had been established. However, for the runs to the left of this line in Figure 2, the reserve requirement is determined by actual emissions in 2010 and is less than the total emissions in every case. Thus, with this specification, sales of surplus quota are not restricted.[19]

However, as the value of Y rises, some potential sales of surplus quota are temporarily restricted. For example, with Y = 95%, sales of surplus quota are temporarily restricted in 18% of the 500 runs. The average quantity temporarily restricted in those runs is 0.315 $GtCO_2$ equivalent and the maximum amount temporarily restricted is 1.668 $GtCO_2$ equivalent.[20]

[18] Actual emissions will determine the reserve requirement if five times the actual emissions in 2010 is less than 90% of the initial assigned amount of 13.681 $GtCO_2$ equivalent. In other words the annual emissions in 2010 must be less than 13.681/5 = 2.736 $GtCO_2$ equivalent. Note that the area under the distribution to the left of the line corresponding to 90% of the initial assigned amount is less than 31.8% of the total area. This is because the distribution shows the probability of total emissions over the five years of the commitment period. The 31.8% is the percentage of runs where 2010 emissions are less than 2.736 $GtCO_2$ equivalent.

[19] The projected emissions of the Russian Federation are rising during the commitment period, so the reserve requirement based on five times 2010 emissions is the most restrictive reserve during the period. The sensitivity scenario features declining emissions during the commitment period, which is more likely to create a situation where the reserve requirement restricts sales of quota surplus to compliance needs.

[20] The minimum quantity of surplus quota whose sale is temporarily restricted is zero, which happens in the runs when excess emissions are possible.

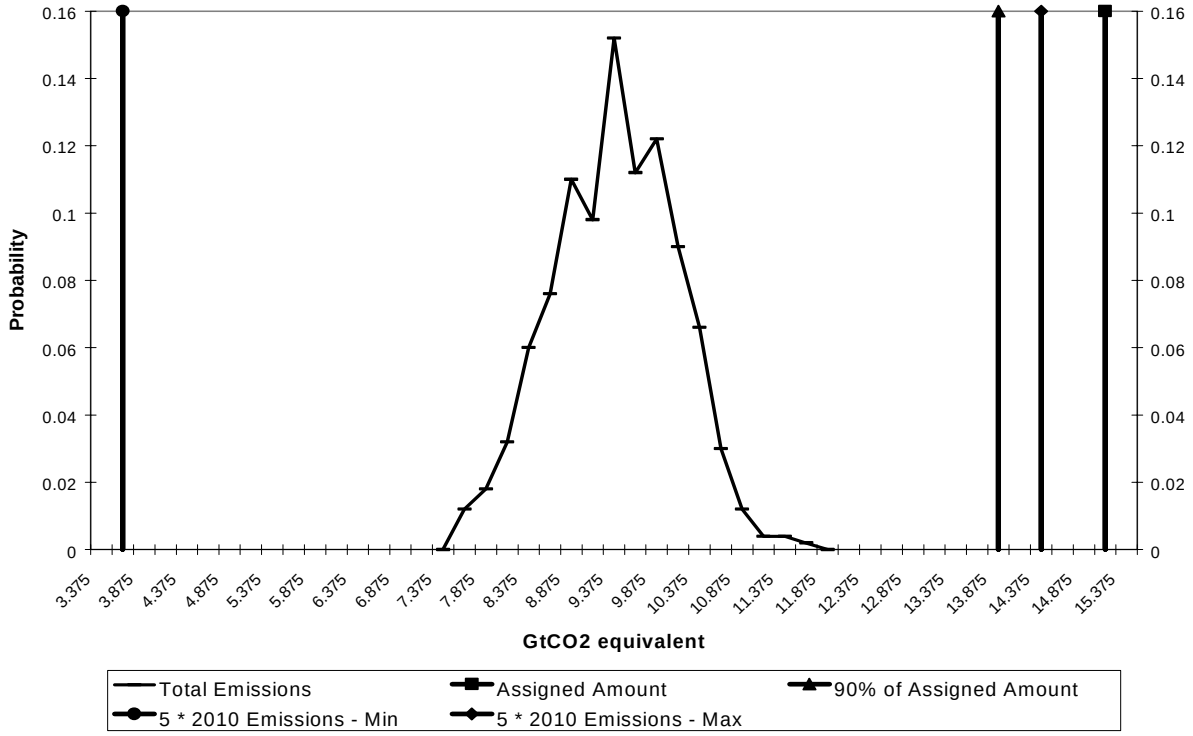
3.2.3 Sensitivity Scenario for the Russian Federation

The projected emissions for the reference scenario discussed in the previous section are based on the central case projection for the Russian Federation as reported to the UNFCCC secretariat. Other sources, including the In-Depth Review of the Russian national communication, suggest substantially lower emissions during the commitment period. Since substantially lower emissions could lead to more temporarily restricted sales of surplus quota for a given specification of the commitment period reserve, a sensitivity scenario with substantially lower emissions is analysed as well.

The emissions for the sensitivity scenario are based on the lowest published projection of Russian emissions during the commitment period we could find. This scenario projects total greenhouse gas emissions for the commitment period at 9.385 $GtCO_2$ equivalent; 35% below the reference case emissions of 14.547 $GtCO_2$ equivalent and 38% below the initial assigned amount of 15.202 $GtCO_2$ equivalent.

Application of the commitment period reserve to the Russian Federation for this sensitivity scenario is shown in Figure 3. The distribution of total emissions over the commitment period is still relatively wide, ranging from 7.572 to 11.530 $GtCO_2$ equivalent.

Figure 3
Application of the Commitment Period Reserve to the Russian Federation Sensitivity Scenario



The reserve requirement for 2012 based on five times actual emissions in 2010 would lie between the minimum value of 3.490 $GtCO_2$ equivalent, shown as the vertical line on the far left, and the maximum value of 14.558 $GtCO_2$ equivalent, shown as the second vertical line from the right. As in the reference scenario, the variation in 2010 emissions multiplied by five is greater than the variation in total emissions over the commitment period. Thus the maximum and minimum reserve requirements represented by these lines lie outside the distribution of total emissions.

The initial assigned amount of 15.202 $GtCO_2$ equivalent is shown as the vertical line on the far right. And a reserve requirement based on 90% of the initial assigned amount, 13.682 $GtCO_2$ equivalent, is shown as the third vertical line from the right.

While the line representing 90% of the initial assigned amount lies to the left of the line for maximum of five times 2010 emissions, the former determines the reserve requirement in only one of the 500 runs. Thus, the reserve requirement is almost always (499 of 500 runs) based on five times the most recent emissions inventory and changes each year as another emissions inventory is reviewed.

In this case the Russian Federation is clearly a net seller; its projected emissions are always substantially less that its initial assigned amount (the vertical line on the far right) leaving substantial surplus quota available for sale.

For simplicity Figure 3 shows only the range for the 2012 reserve requirement based on five times the minimum and maximum values for 2010 emissions. For each run the 2012 reserve requirement lies somewhere between these minimum and maximum values. The total emissions during the commitment period also lie in this range. Although it is not evident in the figure, some runs have total emissions lower than the 2012 reserve requirement, which means that sales of quota surplus to Russia's compliance needs (the difference between the reserve requirement and total emissions) would be restricted until compliance with its commitment had been established. This happens in 47% of the runs.

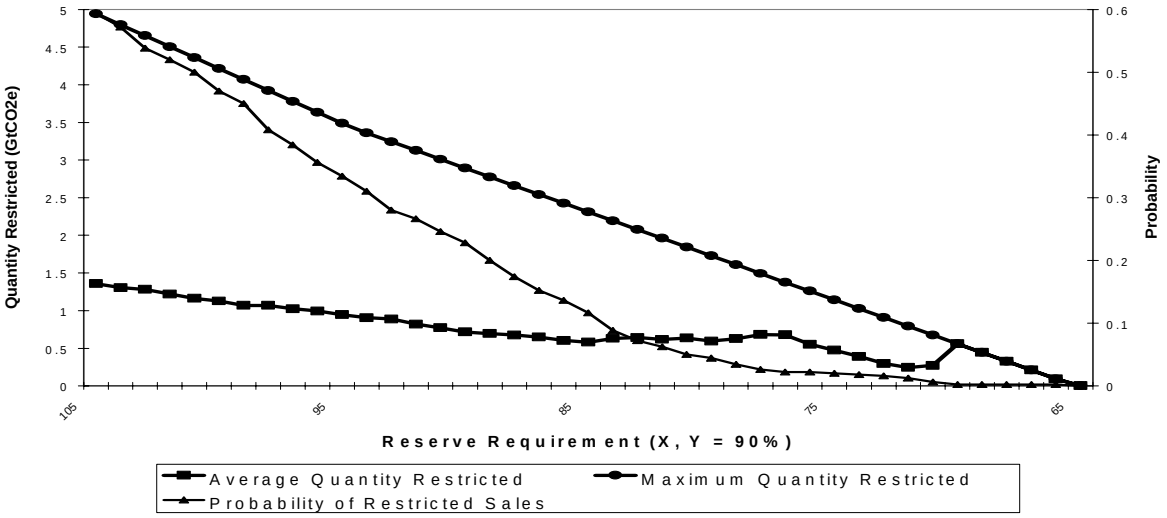
In the remaining 53% of the runs the total emissions exceed the 2012 reserve requirement. This allows quota surplus to the reserve requirement, but not surplus to Russia's compliance needs to be sold. If that quota is purchased and Russia does not meet its emissions limitation commitment it leads to non-compliance due to overselling.

Figure 3 assumes X is 100% (and Y = 90%). Figure 4 shows the probability that sales will be temporarily restricted for different values of X, always assuming Y = 90%. Over this range it is the value of X that determines the reserve requirement.[21] Figure 4 also shows the average quantity of sales temporarily restricted and the maximum quantity of sales temporarily restricted in the runs where sales of surplus quota are restricted.

[21] Recall that with X = 100% the reserve requirement was determined by the initial assigned amount in only one of the 500 runs. With X = 105% this rises to 7 runs. When X falls below 94% the reserve requirement is determined by actual emissions in every case.

Figure 4

Probability of Temporarily Restricted Sales of Surplus Quota, Average Quantity of Sales Temporarily Restricted, and Maximum Quantity of Sales Temporarily Restricted when Sales are Restricted as a Function of the Reserve Requirement Specification, Russian Federation Sensitivity Scenario



The probability of temporarily restricted sales drops from about 0.6 at X = 105%, to 0.5 at X = 101%, to 0.25 at X = 91%, to 0.02 (1 case out of 500) at X = 70% and to 0 at X = 65%. The maximum amount temporarily restricted drops almost linearly from just under 5 $GtCO_2$ equivalent at X = 105% to 0 at X = 65%. The average quantity of sales temporarily restricted, in runs where sales of surplus quota are restricted, drops steadily from 1.35 $GtCO_2$ equivalent at X = 105% to about 0.6 $GtCO_2$ equivalent at X = 85% and then remains fairly stable until X = 75% before falling again to reach 0 at X = 65%.

In short, if this emissions projection for the Russian Federation is accurate, the value of X would need to be set at 65% to ensure that sales of surplus quota would not be temporarily restricted, although a different set of random runs might change this to a higher or lower value. However, as the value of X declines, the potential for non-compliance due to overselling rises because:

- The probability that quota ultimately needed for compliance can be sold rises; and

- The average quantity of quota ultimately needed for compliance that can be sold rises.

Thus, specification of the commitment period reserve involves balancing the risk of temporarily restricting sales of surplus quota with the risk of non-compliance due to overselling.

3.3 Possible Non-compliance Due to Overselling and Temporarily Restricted Sales of Surplus Quota for Annex B as a Whole

For a given specification of the commitment period reserve, each of the 500 runs for a particular country yields a reserve requirement and a projection of its actual emissions during the commitment period. This information is used to calculate the potential non-compliance due to overselling or the temporarily restricted sales of surplus quota for that run for the given country.

Potential non-compliance due to overselling becomes actual non-compliance only if another country buys quota (surplus to the reserve requirement) needed by the seller to achieve compliance and the seller does not purchase replacement quota. As discussed in section 3.1.1, the maximum possible non-compliance is 8.387 $GtCO_2$ equivalent; 10.993 $GtCO_2$ equivalent of excess emissions of the buyer countries less 2.606 $GtCO_2$ equivalent surplus quota of the seller countries. This includes non-compliance due to overselling and underbuying.

The commitment period reserve is intended to address only potential non-compliance due to overselling. The maximum potential non-compliance due to overselling occurs the purchases by Annex B countries that are net buyers equals the sales of quota surplus to the reserve requirement but not the compliance needs of the remaining countries. This maximum potential non-compliance is different for each specification of the reserve requirement; with X = 100% and Y = 90% it is 4.909 $GtCO_2$ equivalent.

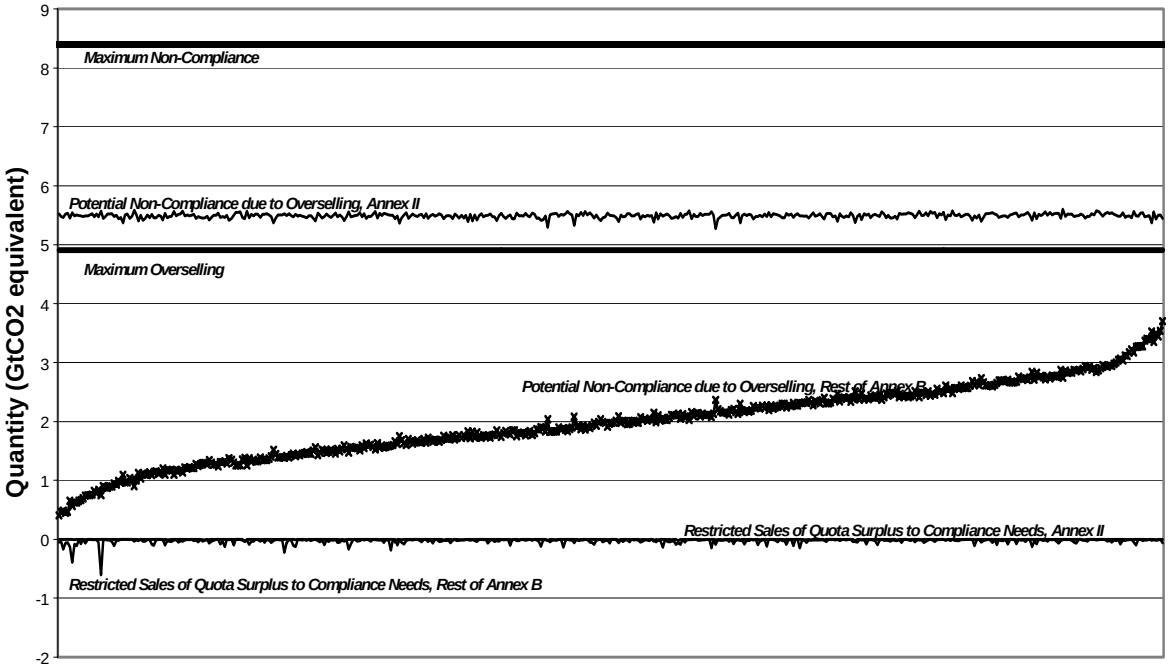
Figure 5 shows the results for the specification X = 100% and Y = 90%. Before being plotted, the 500 runs were ranked in terms of increasing potential non-compliance (regardless of cause) for all Annex B countries as a group. This simply makes it easier to see whether the different series are related. In addition, temporarily restricted sales were converted to negative numbers to move them below the horizontal axis away from the curve for potential non-compliance by the Rest of Annex B countries.

The horizontal line at the top in Figure 5 shows the maximum possible non-compliance of 8.387 $GtCO_2$ equivalent. The top curve shows the potential non-compliance due to overselling by Annex II countries. Almost all of the 23 Annex II countries are net buyers in most runs with this specification, so the potential for overselling is the difference between the initial assigned amount and the reserve requirement. For almost all countries in most runs the reserve requirement is 90% of the initial assigned amount, so the potential for overselling does not fluctuate much and the average (5.490 $GtCO_2$ equivalent) is a little less than 10% of the initial assigned amount of Annex II countries (5.922 $GtCO_2$ equivalent).

The second curve from the top shows the potential non-compliance due to overselling by the Rest of Annex B countries. With this specification many of the 13 Rest of Annex B countries are net sellers in most of the 500 runs. Then the potential for overselling is the difference between total emissions and the reserve requirement when total emissions are higher than the reserve requirement. The potential for overselling averages 1.973 $GtCO_2$ equivalent (range 0.401 to 3.697 $GtCO_2$ equivalent). The rising trend is simply due to the fact that the runs have different total emissions, and hence different levels of potential non-compliance, and for

purposes of the figure the runs have been ordered in terms of increasing non-compliance for Annex B as a whole.

Figure 5
Summary of Potential Non-compliance Due to Overselling and Temporarily Restricted Sales by Annex II and the Rest of Annex B Countries for X = 100% and Y = 90%



The maximum potential non-compliance due to overselling averaged across the 500 runs, 4.909 $GtCO_2$ equivalent, is shown as the lower horizontal line. It lies below the potential non-compliance due to overselling by Annex II countries. The potential non-compliance by Annex II countries shows the amount of quota surplus to the reserve requirement, but not the compliance needs, of the countries in this group. To lead to non-compliance through overselling, another country must purchase the quota. Thus, some Annex II countries must be buyers rather than sellers. This causes the line for maximum potential non-compliance due to overselling to lie below the curve for potential non-compliance by Annex II countries.

The temporarily restricted sales of surplus quota for Annex II countries average 0.002[22] (range 0 to 0.051) $GtCO_2$ equivalent. The temporarily restricted sales of surplus quota for the Rest of Annex B countries average 0.027 (range 0 to 0.604) $GtCO_2$ equivalent. Both of these curves are shown as negative values in Figure 5, but given the scale they are virtually

[22] These averages are calculated for all 500 runs, rather than the runs where sales restrictions occur to provide a better comparison with the potential non-compliance where the values are greater than zero for all 500 runs.

indistinguishable from the horizontal axis. For both groups of countries, the temporarily restricted sales of surplus quota decline slightly as the potential non-compliance increases.

3.4 The Effect of Alternative Specifications of the Commitment Period Reserve

3.4.1 Number of Countries Affected

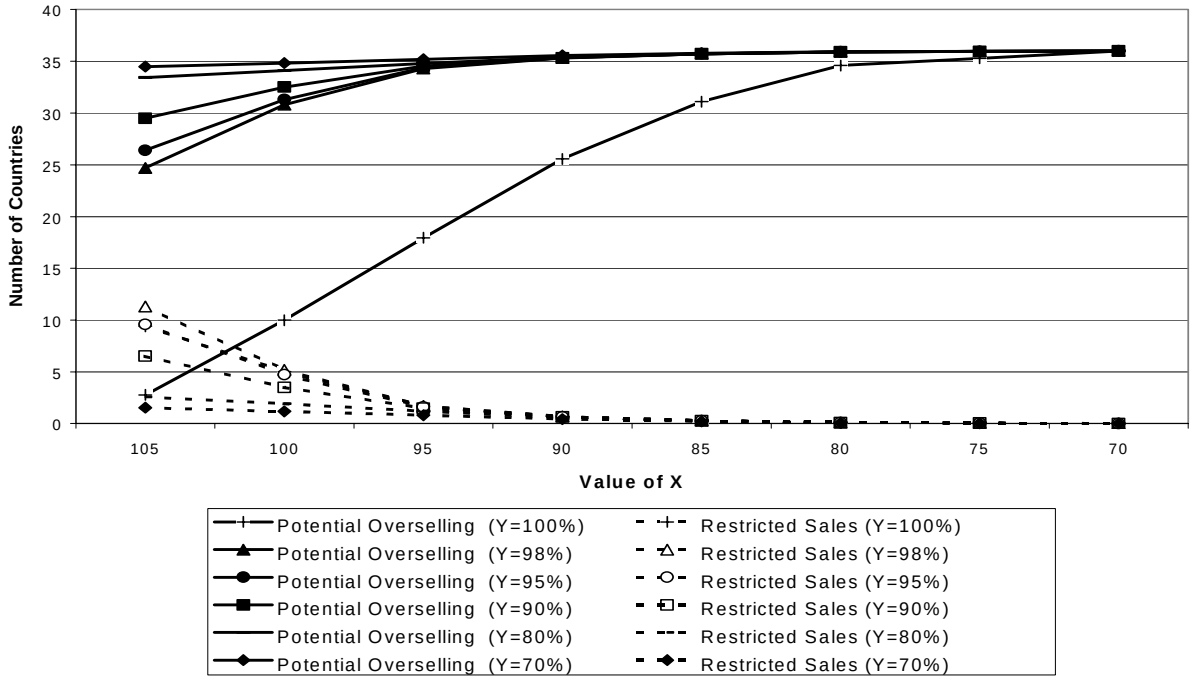
The analysis described in the previous section of the potential for non-compliance due to overselling and the temporarily restricted sales of surplus quota for Annex B countries as a whole is repeated for alternative specifications of the commitment period reserve. Table B-1 in Appendix B shows for each of the specifications:

- The average number of countries where non-compliance due to overselling is possible over the 500 runs; and

- The average number of countries where sales of surplus quota are temporarily restricted over the 500 runs.

The results are summarized in Figure 6. It indicates that all 36 countries have either temporarily restricted sales or the potential to sell quota surplus to their reserve requirement, but not surplus to their compliance needs, except for specifications with Y = 100%. The number of countries with temporarily restricted sales falls and the number of countries with the potential to sell quota surplus to their reserve requirement, but not surplus to their compliance needs, rises as the values of X and Y decline.

Figure 6
Number of Countries with Temporarily Restricted Sales and Potential Non-compliance Due to Overselling for Different Specifications of the Commitment Period Reserve



When Y = 100% the reserve requirement based on X% of five times the most recent emissions inventory will be higher than the initial assigned amount for net some buyers. In that case the country does not have any quota it is able to sell, so the number of countries able to sell quota is less than 36. As the value of X falls, the reserve requirement is less than the initial assigned amount for some net buyers. Then they can sell the difference between the reserve requirement and their initial assigned amount. Hence as the value of X falls, more net buyer countries have the potential to contribute to non-compliance due to overselling.

The purpose of the commitment period reserve is to limit potential non-compliance due to overselling. Since potential non-compliance due to overselling exists at X equal to 105%, the value must be higher than this (with Y equal to 100%), to eliminate the potential non-compliance due to overselling. Eliminating the potential non-compliance due to overselling would restrict sales by all net sellers until they had demonstrated compliance with their emissions limitation commitments. Then the cost savings due to emissions trading would be largely or completely eliminated.

Figure 6 also indicates that X must be less than 70% to eliminate temporarily restricted sales. The full cost-savings due to emissions trading are unlikely to be achieved as long as sales of some surplus quota are restricted until after compliance has been established. However, specifications with X less than 70% allow potential non-compliance due to overselling by all countries and thus defeating the purpose of the commitment period reserve.

In short, the specification of the commitment period reserve must accept some risk of potential non-compliance due to overselling and some risk of temporarily restricted sales.

3.4.2. Maximum Potential Non-compliance Due to Overselling for Different Specifications of the Commitment Period Reserve

The quantities of potential non-compliance due to overselling and of temporarily restricted sales of surplus quota for Annex II and the Rest of Annex B countries are shown in Table B-2 (Appendix B) for different specifications of the commitment period reserve. The results reported are averages for the 500 runs. The random numbers used to generate the 500 runs are the same for each specification, so the differences are due to the specification rather than the random numbers.

The figures shown in Table B-2 for the potential non-compliance due to overselling are the amount of quota surplus to the reserve requirement, but not surplus to the compliance needs, of the country summed over the countries in the Annex II and Rest of Annex B groups. As noted earlier, this is the quantity of available quota not surplus to compliance needs. To lead to non-compliance due to overselling, one or more countries must buy some of this quota which means that those countries will not sell their non-surplus quota.

The maximum potential non-compliance due to overselling is less than the available quota not surplus to compliance needs. The potential non-compliance due to overselling is maximized

when the demand for quota by buyers equals the supply of quota not surplus to the compliance needs of the other countries. The maximum potential non-compliance due to overselling for different specifications of the commitment period reserve is shown in Figure 7.

Figure 7
Maximum Potential Non-compliance Due to Overselling for Different Specifications of the Commitment Period Reserve

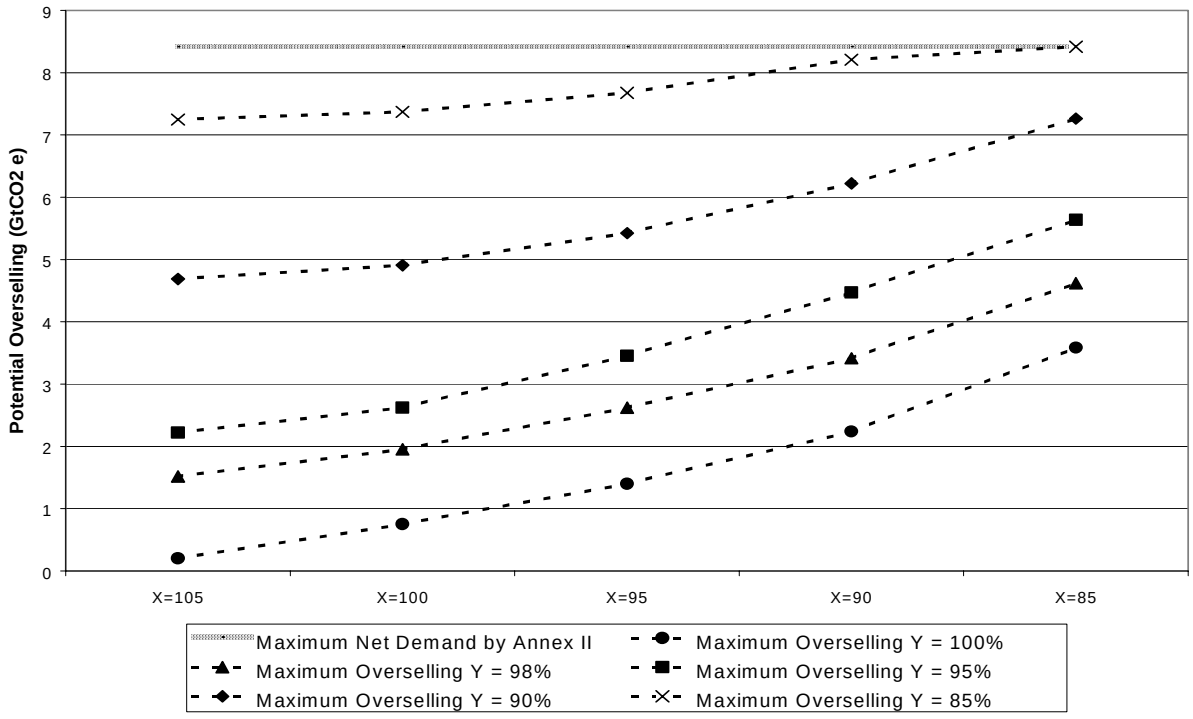


Figure 7 shows that the maximum potential non-compliance due to overselling rises as the value of X declines (these curves slope upward to the right) and as the value of Y declines (curves for lower values of Y are farther above the axis). This simply means that the smaller the reserve requirement, the larger the maximum potential non-compliance due to overselling.

The maximum potential non-compliance due to overselling is more sensitive to the value of Y than the value of X; the vertical distance between adjacent points on a given line, a change of 5% in the value of X, is less than the vertical distance between two lines where the value of Y differs by 5%. The reason is that the reserve requirement for a net buyer, mainly Annex II countries, is usually determined by the value of Y while the reserve requirement for a net seller, mainly Rest of Annex B countries, is usually determined by the value of X and the total assigned amount of the 23 Annex II countries is about 2.2 times the total assigned amount of the 13 Rest of Annex B countries. Hence a given change in Y affects over twice as much of the total assigned amount as the same change in X.

With X = 85% and Y = 85% all of the potential non-compliance could take the form of overselling, although such an outcome is unlikely in practice because it would involve large purchases by some countries and large non-compliance by the rest.

Table B-2 shows that for all specifications with Y equal to 98% and 100%, the potential for overselling is larger for the Rest of Annex B countries than for Annex II countries. For specifications with Y less than 98% the potential for overselling is larger for Annex II countries. This reflects the fact that the potential for overselling is more sensitive to Y than to X the Annex II countries represent a larger share of the total assigned amount (69%) than the Rest of Annex B countries. and projected emissions of Annex B countries.

The quantity of temporarily restricted sales, on the other hand, is larger for the Rest of Annex B countries (the net sellers) than for Annex II countries under all specifications. Temporarily restricted sales of surplus quota decline with lower values of X and lower values of Y (see Table B-2, Appendix B). This simply means that a lower reserve requirement leads to a smaller quantity of quota surplus to compliance needs that can not be sold.

3.4.3 Temporarily Restricted Sales for Different Specifications of the Commitment Period Reserve

Specification of the commitment period reserve involves balancing potential non-compliance due to overselling and temporarily restricted sales of surplus quota. Figure 8 shows the temporarily restricted quota as a percentage of the maximum potential non-compliance due to overselling. To avoid distorting the scale, the value for X = 105% and Y = 100%, 263%, is not shown in the figure. All of the other values are less than 30%.

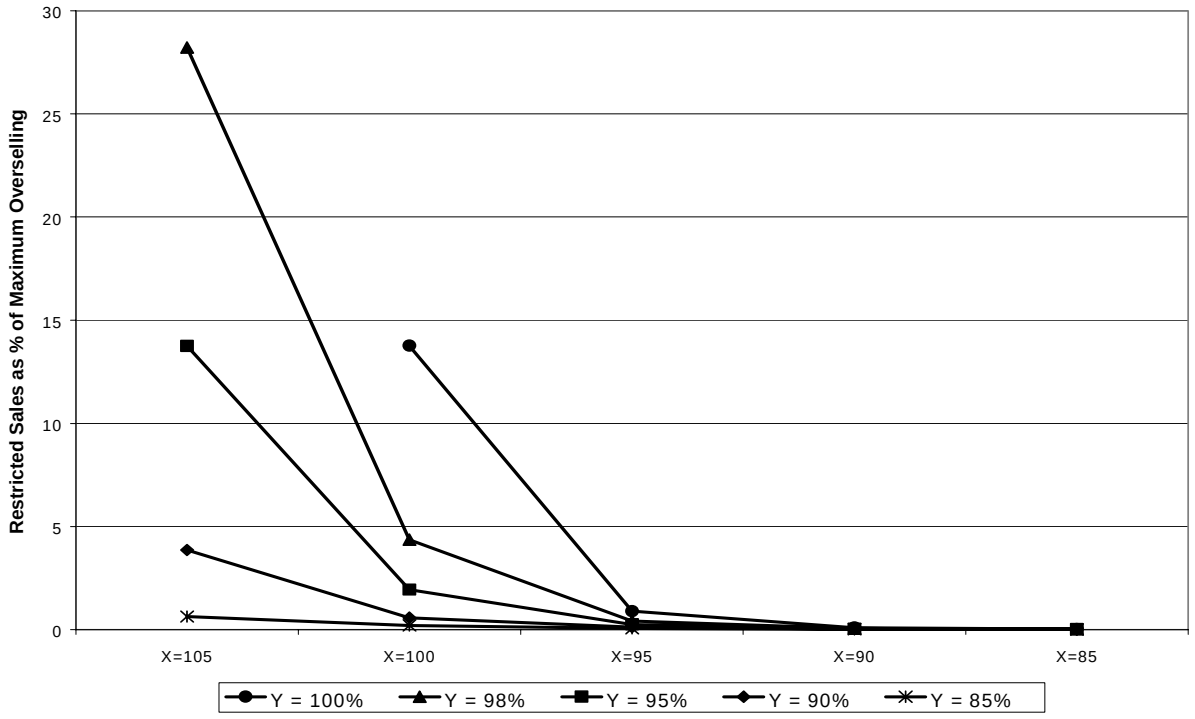
The figure indicates that temporarily restricted sales are small relative to the maximum potential non-compliance due to overselling for most specifications analysed. With X equal to or less than 95%, the restricted sales are less than 1% of the maximum potential non-compliance due to overselling, except for Y = 98% and 100% when they are between 1% and 3%.

3.5 The Effect of Alternative Specifications of the Commitment Period Reserve -- Sensitivity Scenario

The analysis of different specifications of the commitment period reserve rule described in the previous section is repeated with the sensitivity scenario for the Russian Federation. The results are summarized in Tables B-3 and B-4 (Appendix B). The results reported are averages for the 500 runs. The random numbers used to generate the 500 runs are the same as those used for the reference scenario, except for the Russian Federation. The random numbers used for the analysis of each specification for the sensitivity scenario are the same.

Figure 8

Temporarily Restricted Quota as a Percentage of the Maximum Potential Non-Compliance Due to Overselling for Different Specifications of the Commitment Period Reserve



In the reference scenario the projected emissions of the Russian Federation during the commitment period are close to its initial assigned amount, hence its reserve requirement can be determined by either of the provisions and is sensitive to the values of both X and Y. In the sensitivity scenario, its projected emissions are substantially below its initial assigned amount, so its reserve requirement is determined mainly by its actual emissions during previous years and the value of X.

The figures for the potential non-compliance due to overselling in Table B-3, like those in Table B-2 for the reference scenario, are the amount of quota surplus to the reserve requirement, but not surplus to the compliance needs, of the country summed over the countries in the Annex II and Rest of Annex B groups. To result in non-compliance due to overselling, one or more countries must buy some of this quota. A comparison of Tables B-2 and B-4 indicates that the quantities for Annex II countries are identical for all specifications, which is not surprising since only the situation of the Russian Federation has changed.

Since the emissions of the Russian Federation are lower than in the reference scenario, the supply of quota surplus to its compliance needs is higher and the overall potential non-compliance is lower in the sensitivity scenario. For the same reason the maximum potential non-compliance due to overselling is lower in the sensitivity scenario than in the reference scenario for every specification of the commitment period reserve analysed.

In summary, the sensitivity scenario yields qualitatively similar results to those for the reference scenario. The sensitivity scenario has higher temporarily restricted sales and lower potential non-compliance due to overselling under all specifications of the commitment period reserve, although the absolute differences vary with the specification.

3.6 Temporarily Restricted Sales of Surplus Quota at the Country Level for Different Specifications of the Commitment Period Reserve

A given specification of the commitment period reserve (values of X and Y) will apply to all Annex B countries, but affect each one differently as was seen in Section 3.2 above. Figure 6 indicated the average number of countries facing temporarily restricted sales of surplus quota for different specifications of the commitment period reserve. The impact of different specifications of the commitment period reserve on individual Annex B countries is summarized in Table B-4 (Appendix B). For a given country and specification, the table shows:

- The probability that sales of surplus quota will be temporarily restricted;
- The average quantity of sales of surplus quota temporarily restricted in runs where sales of surplus quota are restricted; and
- The maximum quantity of sales of surplus quota temporarily restricted.

As in Figure 4, the probability of sales of surplus quota being temporarily restricted is more sensitive to the specification than the average quantity of sales temporarily restricted in runs where sales are restricted. And the maximum quantity of surplus quota whose sales are temporarily restricted is more sensitive to the specification than the average.

The probability of sales being temporarily restricted under different specifications of the commitment period reserve is summarized in Table 2. The table shows:

Table 2

Percentage of Runs in which Sales of Surplus Quota are Temporarily Restricted by Country for Different Specifications of the Commitment Period Reserve

	X = 105%			**X = 100%**			**X = 95%**			**X = 90%**		
Country	**Y =**			**Y =**			**Y =**			**Y =**		
Annex II Parties	**98**	**95**	**90**	**98**	**95**	**90**	**98**	**95**	**90**	**98**	**95**	**90**
Australia												
Austria												
Belgium												
Canada												
Denmark	✓			✓								
Finland	✓✓	✓✓	✓	✓✓	✓✓	✓	✓					
France	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓						
Germany	✓			✓								
Greece	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓						
Iceland												
Ireland												
Italy	✓✓			✓								
Japan												
Luxembourg	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Netherlands												
New Zealand												
Norway												
Portugal	✓✓	✓✓		✓	✓							
Spain												
Sweden												
Switzerland												
United Kingdom												
United States												
Rest of Annex B												
Bulgaria	✓	✓		✓	✓		✓					
Croatia	✓✓	✓✓	✓✓	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓	✓
Czech Republic	✓			✓			✓					
Estonia	✓✓	✓✓	✓✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hungary	✓✓	✓✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Latvia	✓✓	✓✓	✓✓	✓	✓	✓	✓	✓	✓	✓✓	✓✓	✓✓
Lithuania	✓	✓		✓	✓							
Poland	✓✓	✓	✓	✓	✓✓	✓	✓	✓	✓	✓		
Romania	✓✓	✓✓	✓✓	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓	✓
Russian Federation	✓	✓	✓	✓✓	✓✓	✓	✓	✓	✓	✓	✓	✓
Sensitivity scenario	✓✓	✓✓	✓✓	✓	✓	✓	✓✓	✓✓	✓✓	✓	✓	✓
Slovakia	✓✓	✓	✓	✓✓	✓	✓	✓	✓	✓	✓		
Slovenia												
Ukraine	✓✓	✓✓	✓✓	✓	✓	✓	✓	✓	✓			

Legend:

✓✓ Percentage of runs with restricted sales of surplus quota over 50% (up to and including100%)

✓ Percentage of runs with restricted sales of surplus quota between 25.01% and 50%

✓✓ Percentage of runs with restricted sales of surplus quota between 10.01% and 25%

✓ Percentage of runs with restricted sales of surplus quota less than 10%

- The Rest of Annex B countries are more likely to face restrictions on sales of surplus quota than Annex II Parties. This is not surprising given that the Rest of Annex B countries are generally expected to be net sellers while Annex II Parties are generally expected to be net buyers. However, the European Union burden-sharing agreement means that some of the EU member countries could face temporary restrictions on sales of surplus quota under some specifications of the commitment period reserve.

- The probability of temporarily restricted sales of surplus quota is sensitive to both the value of X the value of Y. For roughly half of the countries vulnerable to restriction of sales of surplus quota, the probability varies with the value of Y for a given value of X. For the balance of the countries, the probability is constant for a given value of X. The former are countries that could be net buyers or net sellers depending upon their future emissions, while the latter are likely to be net sellers in under almost all runs.

- With Y = 98% and X = 100%, 20 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% for 11 of those 20 countries and greater than 50% for 3 of the countries.

- With Y = 98% and X = 95%, 13 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% for 3 of those 13 countries.

- With Y = 98% and X = 90%, 9 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% in every case and greater than 10% for only 2 of the countries, Luxembourg and Latvia.

In Latvia and Luxembourg actual emissions have fallen by about 50% from the 1990 level and future emissions are projected to remain near the current level. The decline in actual emissions during the 1990s results in a relatively large value for the standard error, which is the basis for the random adjustments to the future emissions. The result is large changes in projected emissions from year to year relative to the trend. This increases the probability that the reserve will be set at a level that restricts sales of surplus quota.

In the case of the Russian Federation, the probability that sales of surplus quota will be temporarily restricted is higher for the sensitivity scenario than for the official emissions projection under every specification of the commitment period reserve.

To reduce the probability of temporarily restricted sales to zero for all countries requires that X be 65% and Y be no higher than 90%.

Specification of the commitment period reserve involves balancing potential non-compliance due to overselling and temporarily restricted sales of surplus quota. In striking that balance equitable treatment of all countries is important. Figure 8 indicated that temporarily restricted

sales of surplus quota are relatively small for Y = 98% or less and X = 100% or less. Table 2 suggests that equitable treatment of countries that are net sellers requires a value of X close to 90%.[23] This reduces the risk of temporarily restricted sales to less than 10% for almost all countries.

3.7 The Impact on Compliance Costs

Temporarily restricted sales of surplus quota increase compliance costs for buyer countries and reduce revenues to countries whose sales are restricted during the first commitment period. The surplus quota can be sold after the country demonstrates that it has met its emissions limitation commitment.[24] To estimate the financial impacts of the temporarily restricted sales and non-compliance, we use the model employed in our earlier work.[25] The model has a single Annex B buyer -- Annex II countries -- and a single Annex B seller -- the rest of the Annex B countries. The 36 Annex B countries studied are grouped into these categories as indicated in Table 1.

A given run of the model requires the actual emissions and the reserve requirement for the Annex II buyer and the Rest of Annex B seller. Aggregating this information for the countries that constitute each region nets out any trade among countries within a region, although such trade is small relative to the interregional trade under all but the highest reserve requirements.

The model calculates the compliance costs during the first commitment period for the Annex II buyers, the Rest of Annex B sellers and Non-Annex B countries.[26] The compliance costs for the Rest of Annex B sellers and the Non-Annex B countries are usually negative, the revenue from the sale of surplus quota exceeds the cost of emission reduction measures implemented. The Rest of Annex B countries are assumed to sell as much quota as possible

[23] Note that the percentages in Table 2 are not comparable with those in Figure 8. The figures in Figure 8 are the quantity of temporarily restricted sales of surplus quota as a percentage of the maximum potential non-compliance due to overselling. The figures in Table B-4, which is the basis for Table 2, are the percentage of the 500 runs for a given country in which sales of surplus quota are temporarily restricted. Lower percentages in Figure 8 will correspond to fewer countries with temporarily restricted sales, fewer runs when sales of surplus are temporarily restricted for a given country, and smaller quantities of restricted sales of surplus quota when sales are temporarily restricted.

[24] It is possible that the seller could quickly demonstrate that it had met its emissions limitation commitment, making the surplus quota available before the end of the grace period for achieving compliance. Then the surplus quota could be purchased to help achieve compliance with the emissions limitation commitment for the first commitment period. But this would not occur until several years into the second commitment period. Thus, for ease of exposition it is assumed that the surplus quota becomes available for, and reduces compliance costs for, the second commitment period.

[25] See Haites and Missfeldt, 2000a.

[26] Since the model only covers the first commitment period it does not reflect the impact of the availability of the surplus quota during the second commitment period and the resulting reduction in costs.

subject to the commitment period reserve rule without regard for their commitments. All of the non-compliance calculated by the model is due to overselling.[27]

The results for different specifications of the commitment period reserve are compared to the least-cost, full-compliance scenario. The least-cost, full-compliance scenario differs from that in our earlier work because the business-as-usual emissions now cover all gases rather than just energy-related CO_2 emissions. The assigned amounts are also different for the same reason. The marginal abatement cost curves in the model apply only to energy-related CO_2 emissions. The available evidence suggests that the cost of a given percentage reduction in emissions of all gases is lower than for energy-related CO_2 emissions alone. Thus the cost estimates are biased upward.

The model results for the least-cost, full-compliance case are shown in Table B-5 for the reference scenario projection of Russian emissions. Table B-6 shows the results for the Russian Federation sensitivity scenario. The Annex II compliance cost is substantially lower than for our previous work -- $28.67 billion vs. $141.16 billion -- because its business-as-usual emissions are lower relative to its assigned amount. This means lower domestic reductions and less reliance on all of the mechanisms for compliance. The Rest of Annex B region has higher business-as-usual emissions relative to its assigned amount, which means less surplus quota available for trade. In the sensitivity scenario, the business-as-usual emissions of the Rest of Annex B region are substantially lower. This means more surplus quota traded through IET and less use of the other mechanisms. Annex II compliance costs are lower still as a result.

For a given specification of the commitment period reserve, the model is run for all 500 runs. The average compliance cost and amount of non-compliance due to overselling are calculated and the runs with the highest and lowest compliance costs are recorded for each specification. These results are shown in Figure 9 for the reference scenario projections for the Russian Federation. Full results are provided in Table B-7 (Appendix B).

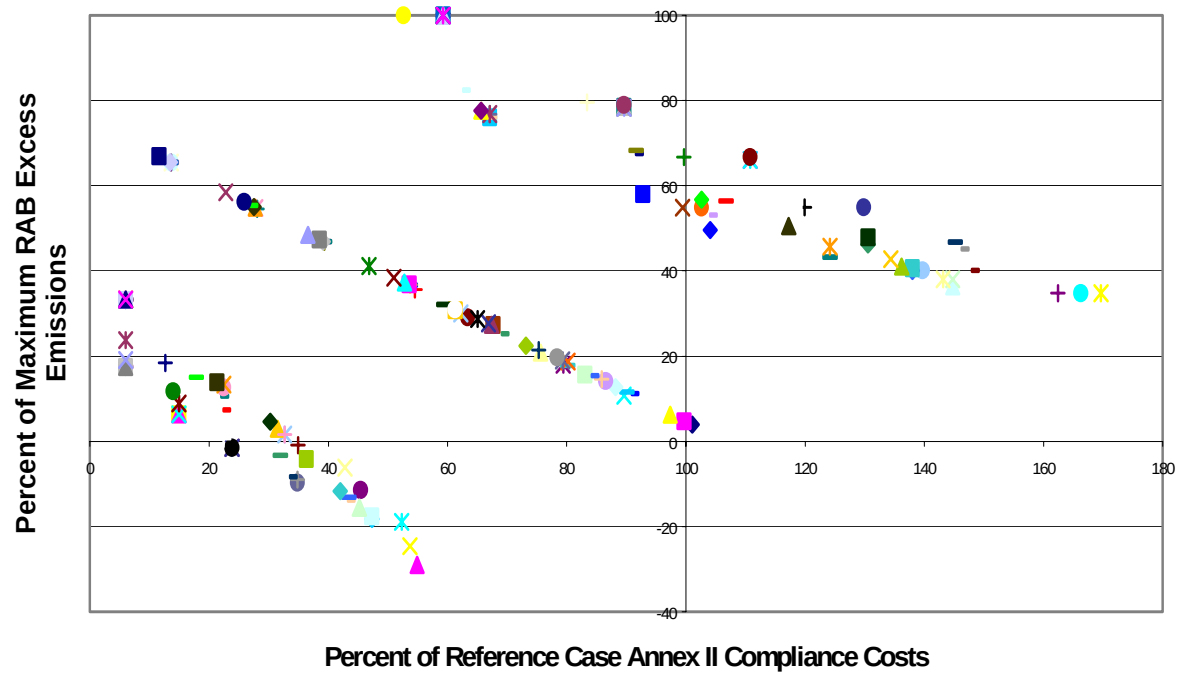
Non-compliance is expressed as a percentage of the maximum level of non-compliance due to overselling calculated by the model, 10.966 $GtCO_2$ equivalent (2.988 GtC see Table C-8). This level of non-compliance occurs for a high emissions case. The maximum level of overall non-compliance of 8.938 $GtCO_2$ equivalent reported above was calculated using the average emissions for the reference scenario assuming that buyers complied with their commitments solely through purchases of quota from other Annex B countries.

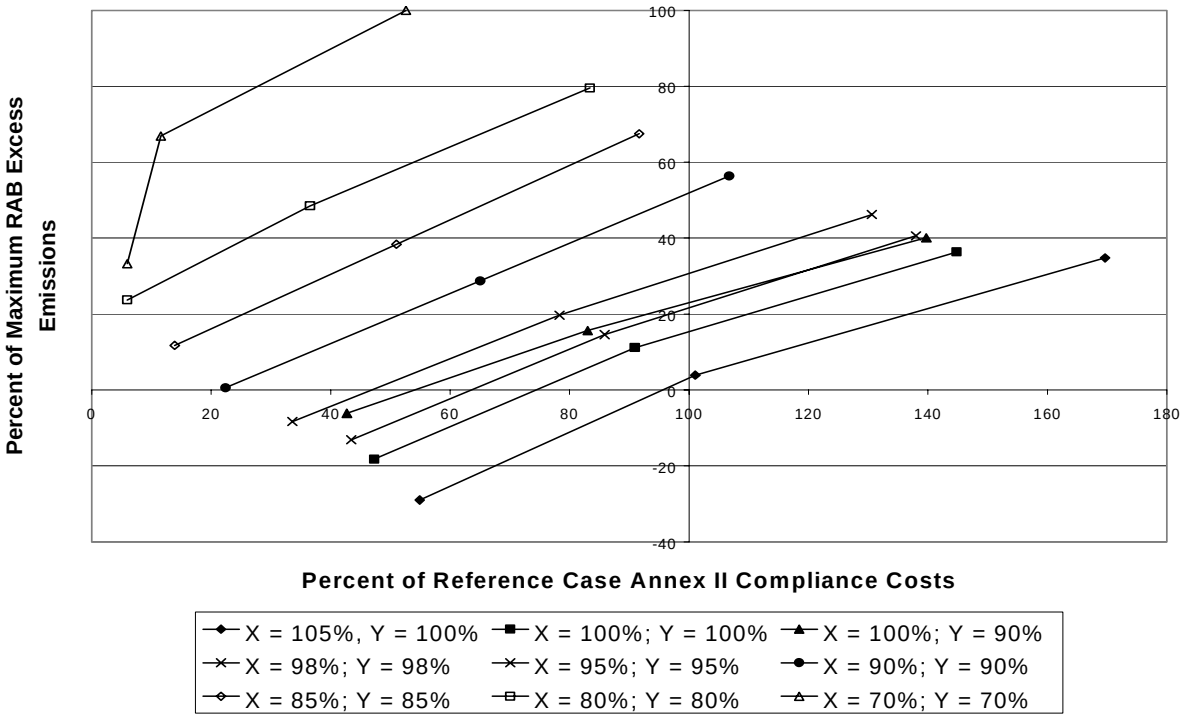
The top panel of the Figure 9 shows three "lines" of points sloping downward from left to right. The middle "line" is the average value for the 500 runs for a given specification (specific values of X and Y). The "line" to the left shows the value for the run with the lowest compliance cost and the "line" to the right the value for the run with the highest compliance

[27] The model assumes that the buyer meets its emissions limitation commitment, but that the seller takes no action to meet its commitment. The seller sells as much of its quota surplus to the reserve requirement as possible, if any of the quota is not surplus to the seller's compliance needs it results in non-compliance by the seller. Thus all of the non-compliance is due to overselling.

Figure 9

Relative Costs and Non-Compliance Due to Overselling for Different Specifications of the Commitment Period Reserve Rule





cost for a given specification. The minimum and maximum "lines" are much more ragged than the average "line" because they each represent a single run, rather than 500 runs.

The bottom panel shows exactly the same data for selected specifications, but with the minimum, average and maximum values linked. The specification with the lowest values of X and Y (X = 70% and Y = 70%) appears at the upper left. As the values of X and Y increase the lines move closer to the origin. The specification with the highest values of X and Y (X = 105% and Y = 100%) appears on the right.

Every specification analysed, on average, allows some excess emissions overall. With the exception of the specification with X = 105% and Y = 100%, the non-compliance due to the excess emissions reduces the compliance cost for the Annex II region below that for the least-cost, full-compliance case. The lower the values of X and Y the larger the potential non-compliance and the lower the Annex II compliance costs, on average.

It is evident from the lower panel of Figure 9 that the range of possible outcomes for a given specification is very wide. In the case of X = 105% and Y = 100%, the average outcome, assuming the no regard for non-compliance consequences, is excess emissions of 4% and increased compliance costs of 1% relative to the least-cost, full-compliance case. However, the outcome could be over-compliance of 29% at a cost saving of 45% if emissions in many countries are much lower than projected. Alternatively, the outcome could be non-compliance of 35% with a 70% increase in costs if the emissions in many countries are much higher than projected.

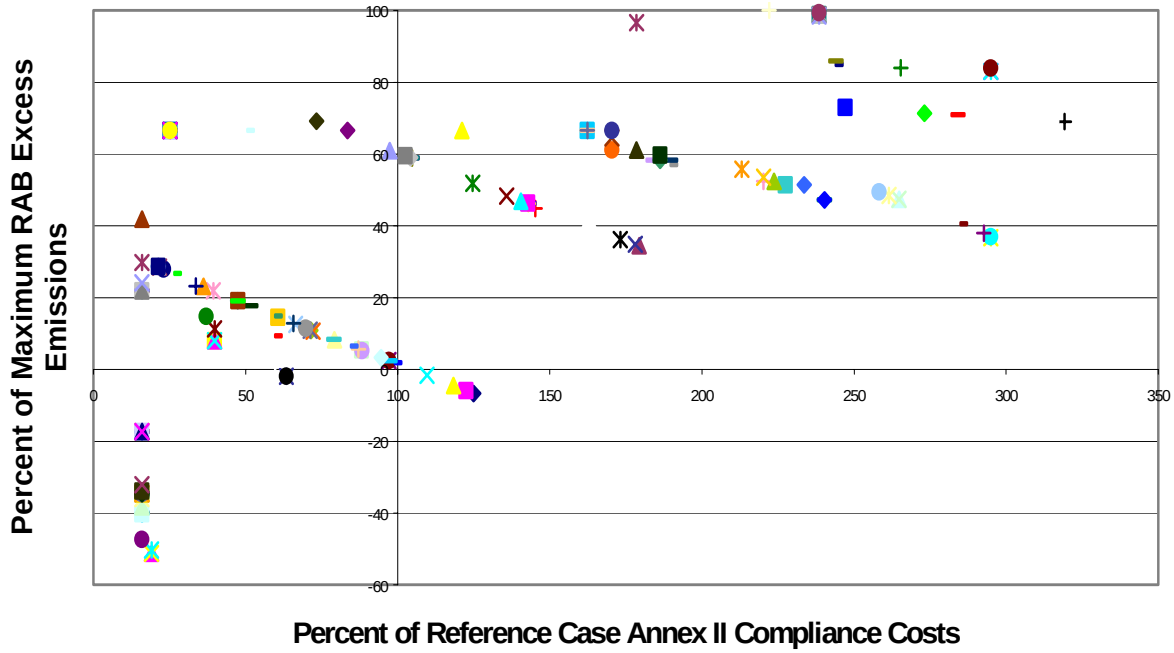
In the case of X = 100% and Y = 90%, the average outcome, assuming the no regard for non-compliance consequences, is excess emissions of 16% and 17% lower compliance costs relative to the least-cost, full-compliance case. However, the outcome could be over-compliance of 6% at a cost saving of 57% if emissions in many countries are much lower than projected. Alternatively, the outcome could be non-compliance of 40% with a 40% increase in costs if the emissions in many countries are much higher than projected.

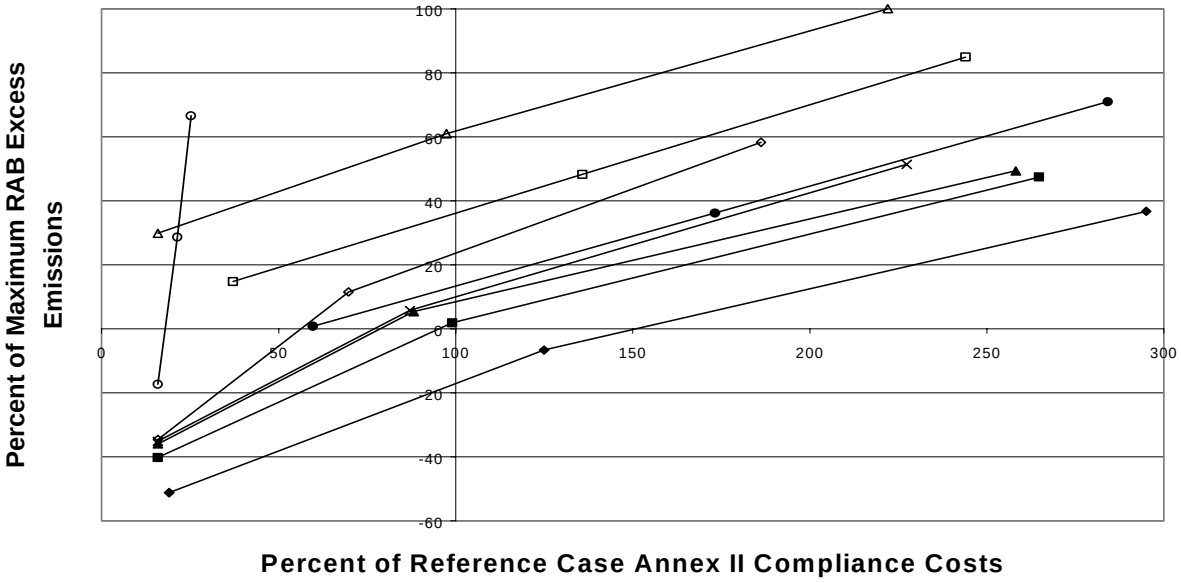
The corresponding results for the sensitivity scenario for Russian Federation emissions are shown in Figure 10. Complete results are presented in Table B-8 (Appendix B). The overall pattern is very similar. The average values for most specifications show some non-compliance which results in lower Annex II compliance costs. The more stringent specifications lie nearest the origin and the specifications with the lowest values of X and Y lie furthest from the origin. As well, the minimum and maximum "lines" are much more ragged than the "line" of average values.

Two differences from the reference scenario emissions are noteworthy. First, more of the specifications, on average, result in over-compliance and higher compliance costs than in the least-cost, full-compliance case. Specifically, all specifications with X = 105% and Y greater than 85% lead to higher compliance costs for Annex II.

Figure 10

Relative Costs and Non-Compliance Due to Overselling for Different Specifications of the Commitment Period Reserve Rule, Russian Federation Sensitivity scenario



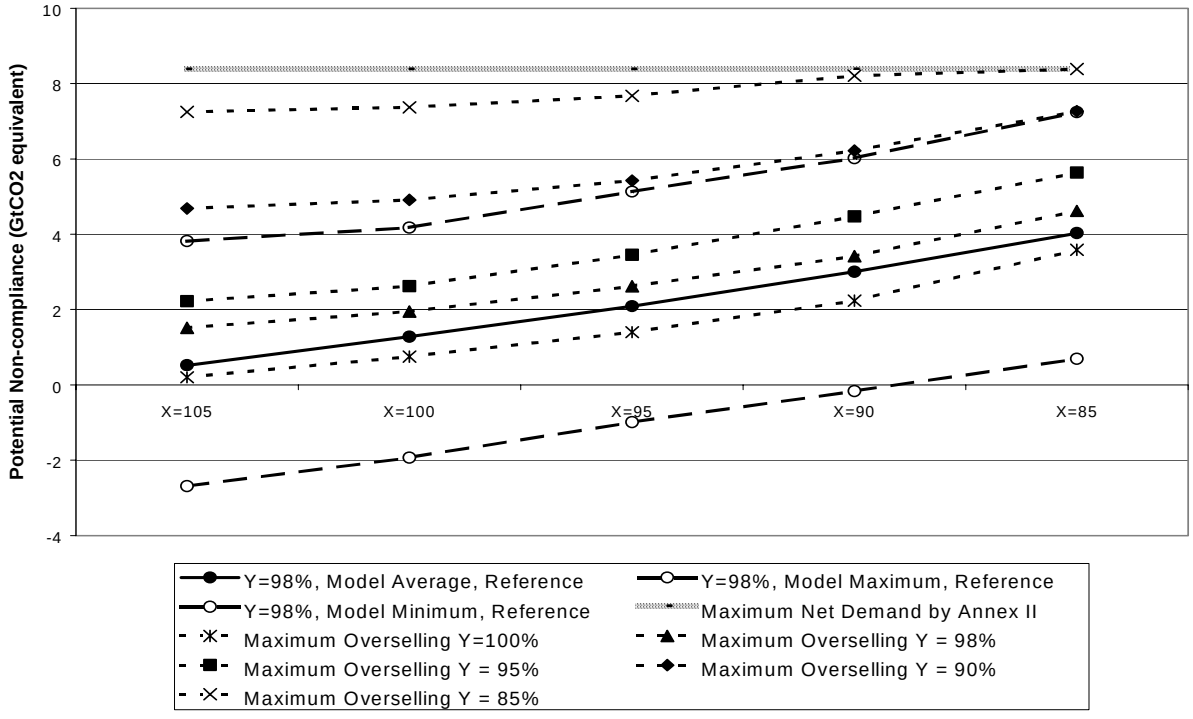


The second difference is that the spread between the minimum and maximum runs for a given specification is even larger. This is because in the sensitivity scenario almost all fluctuations in Russian emissions have a direct impact on the amount of quota available for sale to Annex II and hence have a direct impact on its compliance cost. In the reference scenario the Russian Federation can be a net buyer or seller. Hence, Russian quota is a smaller share of the Annex II compliance strategy and fluctuations in its emissions have a smaller impact on Annex II compliance costs.

The level of non-compliance estimated by the model is compared with the maximum potential non-compliance due to overselling in Figure 11. The model results shown are reference scenario results with Y equal to 98% and X ranging from 85% to 105%. The average, minimum and maximum non-compliance for the 500 runs are shown. The model assumes the worst behaviour on the part of the sellers; the maximum non-compliance consistent with the reserve requirement. The model is structured so that all non-compliance is due to overselling.

The average results from the model should therefore correspond to the maximum potential non-compliance due to overselling. Figure 11 shows that indeed the model averages lie just below the curve of maximum potential non-compliance due to overselling for Y = 98%. The difference between the calculated values and the model results is due to the fact that the maxima are calculated using data for individual countries while the model results are based on aggregation of the 36 countries into the Annex II and Rest of Annex B groups.

Figure 11
Maximum Potential Non-compliance Due to Overselling: Comparison of Estimates with Model Results



The model minimum curve indicates that over-compliance is possible for Y = 98% and X between 90% and 105%.[28] Such outcomes occur when emissions in many of the countries are lower than average. Figure 9 indicates that such results also involve lower compliance costs than the least-cost, full-compliance case. The model maximum results indicate that higher non-compliance (and higher costs) are also possible for as given specification of the reserve requirement.

The range between the minimum and maximum results for a given specification is large relative to the difference in the average for a 5% change in the specification for X or Y. This simply reflects the relatively large uncertainty of future emissions.

3.8 Summary

The purpose of the commitment period reserve is to limit potential non-compliance due to overselling. Non-compliance due to overselling can occur only if:

- the reserve requirement is set so that a country can sell quota surplus to the reserve requirement, but not surplus to the country's compliance needs;
- the available quota is purchased by another Annex B country and is used to meet its emissions limitation commitment; and
- the seller country does not comply with its emissions limitation commitment.

The maximum potential for non-compliance due to overselling increases with lower values for X and Y. The maximum potential non-compliance is more sensitive to the value of Y than the value of X.

The sensitivity scenario indicates that lower emissions by net sellers reduce the maximum potential non-compliance due to overselling for a given specification of the commitment period reserve. Lower emissions by net sellers means more quota surplus to the compliance needs of sellers is available, so non-compliance is reduced.

Conversely, higher emissions by net buyers will increase the maximum potential due to overselling for a given specification of the commitment period reserve if Y is less than 100%. Higher emissions by net buyers mean a larger demand for quota, so countries can sell more quota surplus to the reserve requirement but not surplus to their compliance needs.

[28] The model always generates the maximum amount of non-compliance through overselling given the reserve requirement. The minimum curve shows the lowest values of the maximum non-compliance due to overselling for the 500 runs.

To ensure that every Annex B country has some international liquidity for a domestic emissions trading program, the value of Y must be less than 100%. The liquidity provided by different specifications is analysed in section 4.

The reserve requirement can also restrict sales of quota surplus to a country's compliance needs until after compliance has been established. Lower values of X and Y reduce the probability and magnitude of temporarily restricted sales. For specifications with Y less than 100% and X equal to or less than 100%, the temporarily restricted sales are small (less than 10%) relative to the maximum potential non-compliance due to overselling.

While temporarily restricted sales in total are small for specifications with X equal to 100% (and Y less than 100%), the number of countries affected and the probability of being subject to temporarily restricted sales are relatively high. Equitable treatment of countries that are net sellers requires a value of X close to 90%. This reduces the number of countries affected, lowers the probability of temporarily restricted sales to less than 10% for almost all countries, and lowers the magnitude of temporarily restricted sales when countries are affected.

To reduce the probability of temporarily restricted sales to zero for all countries requires that X be 65% and Y be no higher than 90%. Such specifications would render the reserve requirement ineffective in limiting potential non-compliance due to overselling. Hence, specification of the commitment period reserve involves balancing potential non-compliance due to overselling and temporarily restricted sales of surplus quota.

Model results indicate that specifications with X and Y less than 100% can lead to non-compliance due to overselling. If the full potential non-compliance due to overselling occurs, compliance costs are reduced relative to the least-cost, full-compliance case. However, compliance and costs can vary widely with future emissions.

Specifications with X and Y less than 85% render the commitment period ineffective as a means of limiting overselling. With such specifications all of the potential non-compliance could take the form of overselling, although such an outcome would be unlikely in practice because it would involve large purchases by some countries and equally large non-compliance overall by the other countries.

4. **Liquidity**

This section analyses the consequences of different specifications of the commitment period reserve on:

- Liquidity in the international market; and
- International liquidity for domestic markets.

4.1 Definition

Liquidity is the ease with which a good can be bought or sold. A liquid market is one where a buyer (seller) can purchase (sell) the desired quantity of the good quickly at the market price. This implies the presence of numerous buyers and sellers, none of whose transactions is large relative to the total quantity traded during a given period.

Moving from this concept to operational definitions is difficult. Ease and quickly are relative terms. Each buyer and seller will have his/her own notion of a reasonable period of time to consummate a transaction and hence his/her own assessment of the liquidity of a particular market.[29] This means that liquidity is a matter of degree, rather than a condition a market has or does not have. In turn, this means it is not possible to specify what level of liquidity is "necessary" or "satisfactory" for a given market.

Measures of liquidity can be defined in static or dynamic terms. A static definition looks at market conditions at a selected point in time. A dynamic definition looks at market conditions over time.

At any point in time a demand (supply) curve can be constructed from the available offers to buy (sell) at different prices.[30] A *market* with a small bid-ask spread and large quantities offered (good depth) at the bid and ask quotes can be said to be liquid at that point in time. Completing a transaction is assumed to be easier if the bid-ask spread is "small" and the quantities offered are "large".

[29] Liquidity becomes less meaningful in markets where one or more of the participants is large enough to influence the market price. This market power is usually exercised by withholding supply (demand) until the price rises (falls). A participant that is such a large buyer (seller) can not at the same time expect to be able to buy (sell) any quantity it wishes quickly at the market price. If it buys (sells) large quantities it will affect the market price simply because it is large enough to affect the market.

[30] Computers do precisely this for many commodities that are traded electronically. But the same conceptual framework also applies to unique goods that are traded infrequently, such as a house.

For an *individual trader* liquidity can be measured as the cost of buying (selling) the desired quantity of the good given the static supply (demand) curve.[31] If the trader's desired transaction can be consummated from the quantity available at the ask (bid) quote, the market is liquid from that trader's perspective. As the liquidity falls, the trader has to pay higher (accept lower) prices for a larger share of the quantity he/she wishes to buy (sell). Each trader will have a different desired quantity and hence a different perception of the liquidity of the market.

Static liquidity changes each time a transaction is consummated, a bid or offer is made, or a bid or offer is withdrawn.

A *market* with consistently small bid-ask spreads and consistently large quantities offered for purchase (sale) at the bid (ask) quote has dynamic liquidity. To sustain a condition where large quantities are offered for purchase and sale, the flow of offers must be large relative to the quantity traded. This in turn requires participation in the market of traders who do not need to buy or sell the good, but who are prepared to buy or sell it with the hope of earning a profit as a result of price changes.[32]

In the case of an *individual trader*, a market has dynamic liquidity if the quantities offered at the current bid (ask) price are sufficient to consummate most transactions. As the liquidity falls, the trader has the option of paying higher (accepting lower) prices for a larger share of the quantity he/she wishes to acquire (sell) or of spreading the purchase (sale) over a longer period of time. Hence, the time taken to buy (sell) the desired quantity at the market price is another measure of liquidity for a market participant. What constitutes a reasonable time to complete a transaction varies with the trader.

4.2 Data on Liquidity for Emissions Trading Markets

Clearly, liquidity must be judged in terms of the needs of the buyers and sellers in the particular market. The requirements are very different for goods such as foreign currencies, exchange-listed shares, and commodities than for goods such as a home, or a business.[33] We believe that existing emissions trading markets provide the most relevant data on liquidity for future international and domestic emissions trading markets. Annual data on trading are available for three emissions trading markets -- production allowances for ozone-depleting

[31] This is sometimes called endogenous liquidity while the liquidity of the overall market is called exogenous liquidity, see Hillman, Marsh and Salmon, 2001.

[32] Such traders are sometimes called speculators. Whether they increase or reduce price volatility is a matter of debate. Weiner, 1999, discusses the effects of speculators on energy markets.

[33] Hillman, Marsh and Salmon, 2001 examine the liquidity of the Reuters D2000-2 electronic brokering service for spot value US dollar-Deutschmark transactions where entries are time-stamped to 1/100th of a second. During the week beginning Monday October 5, 1998 over 160,000 entries were made to the system, of which almost 18,000 (11.2%) were transactions. Most transactions were for US$1 million with the largest transactions being for US$14 million (average US$1.8 million) and the total value of transactions being US$32 billion.

substances by American firms, SO_2 allowances, and RECLAIM tradable credits for SOx and NOx. These markets are discussed in turn.

4.2.1 Production Allowances for CFCs

Trade in production allowances for ozone-depleting substances is interesting because it is the only international emissions trading program implemented to-date.

Under the 1987 Montreal Protocol and subsequent amendments, industrialized countries agreed to phase-out production and consumption of ozone-depleting substances, except for essential uses. The first substances to be phased out were the Class I substances, which had the following production phase out schedules for industrialized countries:

- Halons phased out between 1989 and 1993
- The five most common CFCs phased out between 1989 and 1995[34]
- Other fully-halogenated CFCs phased out between 1992 and 1995
- Carbon tetrachloride phased out between 1992 and 1999
- Methyl chloroform phased out between 1992 and 2001.

To facilitate the phase-out, production allowances for these substances could be transferred among countries with the agreement of the governments involved. Such transfers were required to be reported to the Ozone Secretariat at the United Nations Environment Programme in Nairobi, but the data are not publicly available so the liquidity of the international market can not be analysed.

However, data are available for the United States, where production and consumption allowances could be traded domestically as well.[35] Data on production, domestic trades and international trades of Class I ozone-depleting substances by American firms for the period 1989 through 1995 are presented in Table 3.

The data show the sharp decline in production over the period. Domestic trading activity was nominal during the first two years, but represented a large and growing share of total production during the balance of the period. International trades were substantial only during the last three years, accounting for 15% to 20% of total trades during those years.

Production allowances could not be banked.[36] The production allowances traded prior to 1995 include allowances for the current year and for future years. The trades during 1995 were for use during that year.[37] The quantity traded during 1995 amounted to over 100% of

[34] This group consisted of CFC-11, CFC-12, CFC-113, CFC-114, and CFC 115.

[35] Ozone-depleting substances, including CFCs, were also subject to a tax based on their ozone-depleting potential.

[36] However, the substances could be produced and stored for sale in future years.

[37] American production during 1996 was 1,135 tons (Table C-1, Appendix C).

the total production, indicating that at least some of the allowances were traded more than once during the year.

Table 3
Production and Trades of Production Allowances for Class I Ozone-Depleting Substances by American Firms, 1989 to 1995

Year	Regulated Production	International Trades		Domestic Trades		Total Trades	Total Trades as % of Production	Internat'l as % of Total Trades
	Tons[a]	No.	Tons[a]	No.	Tons[a]	Tons[a]		
1989	381,665			4	1,152	1,152	0.3%	
1990	251,098			15	1,107	1,107	0.4%	
1991	213,729			48	80,707	80,707	37.8%	
1992	216,497	1	541	171	73,355	73,896	34.1%	0.7%
1993	183,595	4	11,695	123	67,264	78,959	43.0%	14.8%
1994	99,329	9	13,452	138	56,657	70,109	70.6%	19.2%
1995	48,297	6	10,329	62	40,933	51,262	106.1%	20.1%
Total	547,718[b]	20[b]	36,016[b]	494[b]	238,209[b]	274,226[b]	50.1%[b]	13.1%[b]

Notes: [a] Quantities of individual CFCs weighted by their ozone-depletion potential.
[b] Total for 1992 through 1995.

Sources: Production data from Oberthür, 1999 (see Table C-1, Appendix C of this report). Trade data from the U.S. Environmental Protection Agency as reported by Mullins, 1997, p. 22.

4.2.2 SO_2 Allowance Trading Under the Acid Rain Program

Title IV of 1990 Clean Air Act Amendments created an allowance trading system for SO_2 emissions by electric utilities. The system was introduced in two phases, each designed to achieve a 5 million ton reduction. Phase I, from 1995 through 1999, was mandatory for 263 units listed in Table A of the Act.[38] Phase II, from 2000 on, applies to all electric utility generating units with an output capacity of 25 MW or greater that use fossil fuels with a sulfur content greater than 0.05%. Approximately 2,400 units are regulated under Phase II.[39]

In Phase I the Table A units are allocated SO_2 allowances on the basis of a standard emission rate (2.5 lbs. Of SO_2 per million BTU) multiplied by the average energy input for the years 1985 through 1987. In Phase II the emission rate drops to 1.2 pounds per million BTU, but it

[38] These units include, with few exceptions, all units of 100 MW capacity or greater with an average emission rate above 2.5 pounds of SO_2 per million BTU of energy input. Other units can elect to opt-in, but need not remain in, during Phase I. Some 125 to 185 additional units have participated in Phase I each year.

[39] Other sources of SO_2 emissions can opt into the trading program and approximately 10 have done so to-date.

is still multiplied by the average energy input for the years 1985 through 1987. Other units receive allowances under a number of different formulae.[40]

Sources built after 1995 receive no allowances and must purchase allowances to cover their total emissions from existing sources.[41] Existing sources continue to receive allowances even if they cease to operate. All units are required to install continuous emissions monitors and to report their actual emissions quarterly to the EPA. The penalty for non-compliance is $2,000 (1990 dollars) plus a loss of one allowance from the next year's allocation per excess ton. All participants have achieved full compliance for the years 1995 through 1999.

State and regional regulations that limit SO_2 emissions by electric utilities to protect human health and the environment take precedence. In another words, if state regulations limit actual emissions (annually or for particular periods) the unit can **not** use allowances to exceed that limit.

Table 4 shows the SO_2 emissions, allowances and allowance trades between economically-distinct organizations for the years 1994 through 2000. Participants are issued, and may trade, their allowances for the next 10 years. The first column shows the allowances issued to participants for the current year and the second column shows the allowances issued for the current year plus banked allowances. This is a very conservative estimate of the allowances available for trade, since it does not include the allowances for the next 10 years.

Each generating unit is a separate participant. When an electric utility owns multiple generating units, allowance transfers between units owned by the utility are not trades between independent entities. The Clean Air Markets Division of the Environmental Protection Agency classifies trades as being between economically-independent organizations or not. Most "trades" involve generating units with common ownership. Table 4 shows only the quantity of allowances traded by economically-independent organizations. The quantity of allowances traded has increased steadily, except for 1999.

The purpose of an emissions trading program is to reduce compliance costs for participants. This suggests that liquidity be measured as the quantity traded between economically distinct entities relative to actual emissions. As shown in Table 4, the quantity of allowances traded between economically-distinct entities has been substantially larger than the annual emissions except for the first two years of the program. This reflects both multiple trades of a given allowance and trades of allowances for future years.

The volume of trading clearly is much higher than needed for compliance reasons alone. Swift examined the allowance allocation and actual emissions for each company for the years 1995 through 1999 and found that only 15 firms had emissions in excess of their allowance

[40] There are 29 different ways of allocating allowances in Phase II, although five of the formulae cover most of the units.

[41] Sources that began to operate after October 1990 and before December 1995 receive allowances at a rate of 0.3 lbs. per million BTU.

allocations for one or more years. The total amount by which their actual emissions exceeded their allowance allocations was 708,373 tons, which represents less than 2.5% of inter-firm trades.[42]

Table 4
SO_2 Emissions, Allowances and Allowance Trades between Distinct Organisations, 1994 through 2000

Year	Allowances Issued	Allowances Available[a]	Actual Emissions (tons)	Allowances Traded[b]	Trades as % of Allowances Available	Trades as % of Actual Emissions
1994				881,852[c]		
1995	8,744,081	8,744,081	5,300,000	1,922,047	22.0%	36.3%
1996	8,296,548	11,732,337	5,440,000	4,407,302	37.6%	81.0%
1997	7,147,464	13,435,799	5,470,000	7,942,366	59.1%	145.2%
1998	6,969,165	14,928,841	5,290,000	9,551,472	64.0%	180.6%
1999	6,990,132	16,618,112	4,940,000	5,432,409	32.7%	110.0%
2000[d]	9,994,947	21,602,902	11,201,747	14,371,159	66.5%	128.3%

Notes: [a] The figures are the sum of the allowances for the current year plus allowances 'banked' (not used) from previous years. Each source receives its allowance allocation for 10 years into the future, so the quantity of allowances available for trade is much larger than the figures shown.

[b] These are the allowances traded between economically distinct organizations are reported by the U.S. Environmental Protection Agency.

[c] Trading started prior to the first compliance year, which was 1995.

[d] Phase II of the acid rain program, involving many more sources, began in 2000, thus the higher allocation and emissions.

Sources: U.S. Environmental Protection Agency, *Acid Rain Program Compliance Reports* for the years 1995 through 1999, Environmental Protection Agency, Washington, D.C. and personal communication with Kathryn Petrillo, Clean Air Markets Division, U.S. Environmental Protection Agency, March 2001.

Another motivation for trading is to earn a return on the SO_2 allowances. The SO_2 allowances are an asset and, as with other assets, the firm should seek to earn a return on them. It is possible to earn a return (or losses) on the allowances through arbitrage trading -- selling allowance with the expectation of being able to buy them later at a lower price, or buying allowances for resale in anticipation of a price increase.[43] Arbitrage trading increases the volume of offers to buy and sell allowances and so increases liquidity.[44]

[42] Swift, 2001, 9.c.iii. This figure is sum of the difference between the allowance allocation for a company and its actual emissions during the same year across all firms and years.

[43] Hillman, Marsh and Salmon distinguish three types of traders in the foreign exchange market -- liquidation traders who must liquidate or accumulate a position within a given timeframe, informed traders who receive

Utilities can engage in arbitrage trading themselves or lend allowances to traders so they can engage in such trading.[45] Due to the tax treatment of allowance sales, the typical arrangement is that a trader will borrow allowances for six months repaying the utility with additional allowances as interest.[46] Reflecting the growing importance of arbitrage trading, responsibility for trading has shifted in many firms from staff responsible for environmental compliance to departments responsible for fuel purchasing or groups responsible for trading energy commodities.[47] The data in Table 4 indicate that trading between economically-independent organizations has ranged between 20% and 70% of a low estimate of the allowances available for trade.

4.2.3 **RECLAIM** *NOx and SOx Programs*

The Regional Clean Air Incentives Market (RECLAIM) was established by the South Coast Air Quality Management District (SCAQMD) for NOx and SOx emissions by point sources beginning January 1, 1994. All stationary sources that held permits for equipment or processes that generally emit more than four tons per year of NOx or SOx or which emit more than four tons of NOx or SOx per year during any year after 1990 must participate.[48]

The NOx program has roughly 340 participants which account for approximately 65% of the NOx emissions from permitted stationary sources in the SCAQMD and the SOx program has approximately 40 participants which account for roughly 85% of the SOx emissions from

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private information that is expected to affect the market price in the short term, and limit order traders who supply liquidity if properly compensated, but have no need to trade. Other studies classify participants as informed traders and "noise" traders.

[44] Conceptually options to buy (sell) allowances at an agreed price on a specified future date offer the same opportunity to earn a return from price changes. In practice options are less flexible than arbitrage trading for this purpose. The date and quantity are fixed for an option. And to keep the cost of an option attractive, the price change must be relatively large over a period of months. This means that options are best suited to providing protection against substantial price changes. In contrast arbitrage trades can be executed at any time in any quantity in response to any price change that is attractive to the trader. Arbitrage trading increases liquidity, while options do not. Indeed options require a liquid spot market, so arbitrage trading and options complement rather than compete with each other.

[45] Many utility holding companies also own unregulated trading entities that trade in energy commodities, so the trader may be a related firm.

[46] Ellerman, 2000, p. 178 and Swift, 2001, 9.d.

[47] Swift, 2001, 9.d. Swift also notes that at least one small trader which was particularly active in the SO_2 allowance market grossed more from this market than from trading in the much larger electricity market.

[48] Sources such as equipment rental facilities, essential public services (police, fire, landfills, wastewater treatment, hospitals, prisons and schools), restaurants, and dry cleaners are exempted.

permitted stationary sources.[49] But these sources are responsible for only 17% of total NOx and 31% of total SOx emissions in the SCAQMD.

Each facility receives an allocation of RECLAIM Trading Credits (RTCs) annually. The allocation is calculated from a starting allocation for 1994, a mid-point allocation for 2000, and an ending allocation for 2003.[50] Each allocation was calculated by multiplying the *historic use* or throughput for each piece of NOx and SOx equipment at the facility by appropriate emission factors based on the adopted and proposed rules. The *historic use* was based on the peak year for each facility between 1989 and 1992. Allocations for intermediate years are straight line interpolations between the 1994, 2000 and 2003 allocations.[51] New sources must purchase RTCs from existing sources to cover their emissions. Existing participants continue to receive allowances if they cease to operate.

An RTC allows the owner to emit one ton of NOx or SOx during the specified year. RTCs may only be used for emissions that occur during the specified year; they can not be banked. All participants are randomly assigned to one of two compliance cycles: January 1- December 31 or July 1 - June 30.[52] Trades can involve participants in either compliance cycle, but the RTCs can only be used for emissions during the year for which they are valid. Trades that involve a new or relocated facility, or a facility exceeding its starting allocation are subject to a geographic restriction.[53]

Each participant must hold sufficient RTCs at the end of the year to cover its actual emissions. At the end of the first year, 46 facilities exceeded their allocations and 20 facilities had not submitted complete compliance reports.[54] During the second year, 28 facilities (8%) exceeded their allocations. The total amount of exceedances was about 400 tons of NOx and

[49] At the end of 1998 there were 331 participants in the NOx program and 37 in the SOx program.

[50] The starting allocation was based on rules adopted as of December 31, 1993. The 2000 allocation reflects 100% implementation of 1991 Air Quality Management Plan proposed Tier I control measures. And the 2003 allocation reflects 100% implementation of proposed Tier I and Tier II control measures.

[51] Each facility has its own emission reduction rate determined by its allocations for 1994, 2000 and 2003 with linear interpolation for the intervening years. The weighted average emission reduction rates are 8.3% per year for NOx and 6.8% per year for SOx from 1994 through 2003.

[52] SCAQMD, 1993, p. EX-15 states that "[s]taggered compliance schedules will help ensure that RTCs will be available, thereby providing a more liquid market with better price stability." Cycle 1 facilities began compliance on January 1, 1994 and Cycle 2 facilities began compliance on July 1, 1994.

[53] A facility in the Coastal zone may only obtain and use RTCs that originated in the Coastal zone. A facility in the Inland zone may obtain and use RTCs from either zone.

[54] SCAQMD, 1996, Chapter 5, pp. 34-39.

about 7 tons for SOx.[55] Initial results for 1998 indicate 27 facilities in non-compliance for NOx.[56]

RTCs used for compliance or remaining unsold in the facility's account are subject to an emission allocation fee of roughly $374 per ton.[57] The fee is intended to stimulate transactions. An exemption for RTC holders that are not "permitted facilities" allows unused RTCs to be transferred to brokers or others to avoid the fee. Thus, the SCAQMD distinguishes between such transfers that are made without a price, and trades between participants, which are made with a price.

Table 5 presents the RTCs available, actual emissions and the quantity of RTCs traded for both the NOx and SOx programs for the years 1994 through 1999.

The quantity traded includes RTCs for the current year and at least 10 years into the future. Apart from 1994 and 1998, trading activity has been 20% and 50% of the annual NOx emissions and of the RTCs issued. Trading during 1994 was low because this was the first year of the program, with some participants being capped for only six months and with most participants having an allocation sufficient to cover their actual emissions. The NOx trades for 1998 are inflated due to a change in ownership of several electricity generating units which was treated as a trade for accounting purposes. For the SOx program, trading activity has been between 20% and 80% of the actual emissions and RTCs issued except in 1994.

4.2.4 Summary

Liquidity does not change the total supply of allowances and so does not make compliance easier (or more difficult) for entities participating in an emissions trading program. Liquidity does make it easier for an entity to buy (sell) the desired quantity of allowances quickly. This increases confidence in emissions trading as a viable component of a compliance strategy. To the extent that increased confidence enhances the use of emissions trading for compliance, liquidity helps reduce compliance costs.

Liquidity requires the participation of arbitrage traders in addition to the entities participating in the emissions trading program. Liquidity also allows the risks of allowance price changes, and hence compliance cost changes, to be shared between the entities participating in the emissions trading program and arbitrage traders willing to accept those risks.

[55] SCAQMD, 1997, Chapter 5, pp. 5-2 to 5-4.

[56] SCAQMD, 1998, Chapter 5, pp. I-27 to I-28.

[57] Dudek and Wiener, 1996, pp. 33-34.

Table 5

Emissions, RTCs Available and RTC Trades between Distinct Organisations For the NOx and SOx Programs of RECLAIM, 1994 through 1999

Year	RTCs[a] Issued	Actual Emissions	Trades with a Price[b]	Trades as % of RTCs Issued	Trades as % of Actual Emissions
	NOx Program				
1994	41,428	25,314	2,210	5.3%	8.7%
1995	37,296	27,645	11,681	31.3%	45.3%
1996	33,215	24,796	5,595	16.8%	22.6%
1997	29,052	21,789	9,716	31.6%	42.1%
1998	24,989	20,982	26,003[c]	104.1%	123.9%
1999	21,015	20,545	8,917	42.4%	43.4%
	SOx Program				
1994	10,491	7,232	4	0.0%	0.1%
1995	9,738	8,064	3,052	31.3%	37.8%
1996	9,020	6,484	5,172	57.3%	79.8%
1997	8,295	6,464	5,077	61.2%	78.5%
1998	7,577	6,793	1,780	23.5%	26.2%
1999	6,911	6,525	1,548	22.4%	23.7%

Notes: [a] An RTC is a RECLAIM trading credit, which allows a participant to emit one ton of the specified pollutant (NOx or SOx) during the specified year.

[b] Trades with a price are trades between economically distinct participants. Participants must report the price at which a trade occurs, but are allowed to transfer RTCs to and from "non permitted" facilities, such as brokers, at zero price.

[c] The NOx trades for 1998 are inflated due to a change in ownership of several electricity generating units which was treated as a trade for accounting purposes.

Source: South Coast Air Quality Management District, *RECLAIM Audit Reports* for the 1994 through 1999 compliance years and *RECLAIM Program Three-Year Audit and Progress Report*, May 1998, Diamond Bar, California.

Liquidity is a relative concept; it is not possible to specify a "minimum" or "necessary" level of liquidity for a market. Indeed, each participant may have a different assessment of the liquidity of a given market.

Good data on the liquidity of existing emissions trading markets are not available. The quantity of allowances traded between economically-independent entities relative to the annual allocation or annual emissions is a rough indicator of liquidity available for three emissions trading programs. The allowances traded include allowances for the current year and for all future years for which allowances have been allocated.

Liquidity data for selected emissions trading programs are summarized in Table 7.[58] They indicate that the quantity of allowances traded is 15% to 70% of the annual allocation plus banked allowances. When the quantity traded is related to annual emissions, the percentage is higher, ranging from 20% to 180%, since emissions are less than the allowances allocated. The percentage is greater than 100% in four of six years for the SO_2 program, one of six years for the ozone depleting substances production program, and under 100% for all five years of the RECLAIM NOx and SOx programs. This is consistent with the perception that the SO_2 allowance program is the most liquid of the emissions trading programs.

Table 6
Summary of Liquidity Data for Emissions Trading Programs

Program	Allowances Traded as % of Annual Allocation	Allowances Traded as % of Annual Emissions
Production Allowances for Class I Ozone Depleting Substances in the U.S. 1989 through 1995		30% to 110%[a]
SO_2 Allowance Trading under the Acid Rain Program in the U.S., 1995 through 2000	20% to 70%[b]	40% to 180%
RECLAIM NOx Program, 1994 through 1999	15% to 45%[c]	20% to 50%[c]
RECLAIM SOx Program, 1994 through 1999	20% to 60%[d]	20% to 80%[d]
Notes: [a] Excludes 1989 and 1990. [b] Annual allocation for the current year plus banked allowances from previous years. [c] Excludes 1994 and 1998. [d] Excludes 1994.		
Source: Tables 3, 4, and 5.		

4.3 Liquidity in the International Emissions Trading Market

A rule, such as the commitment period reserve, to prevent over selling limits the quantity of allowances that can be traded and so affects liquidity. A commitment period reserve would

[58] Other emissions trading markets in the United States are less liquid. The first trading programs established were for offsets in areas whose air quality did not meet national ambient air quality standards (non-attainment areas). A large (definition varies by area) new or expanding source in a non-attainment area was required to install the best available control technology and to purchase offsets, representing emission reductions by existing sources, for any remaining emissions. The demand depends on the number of large new and expanding sources. Data for the South Coast Air Quality Management District, the largest market for offsets at the time, indicate that the total number of trades for the five pollutants (Volatile Organic Compounds, NOx, Particulate Matter, SOx, and carbon monoxide) ranged between 2 and 25 per year over the period 1985 through 1992 (NAPA, Table 2-4, pp. 50-52).

require each Annex B Party to maintain a reserve of AAUs in its national registry, thus restricting transfers to quantities surplus to the reserve. Each specification of the commitment period reserve places a different limit on the quantity that can be transferred and hence on the liquidity of the international market. This section examines liquidity in the international market for different specifications of the commitment period reserve.

The liquidity measures reported in Table 6 for existing emissions trading programs relate the quantity of allowances traded annually to the annual allocation or the annual emissions. Thus, three variables are needed to calculate these measures for the international emissions trading market, given a specification of the commitment period reserve:

- the quantity of quota traded annually
- the annual allocation of quota; and
- annual emissions.

Since international emissions trading is not yet operational, data on the quantity of quota traded annually are not available. However, the country data and model results provide three estimates of the quantity that could be traded annually. These estimates are:

- The sum of the quota surplus to the reserve requirement for each Annex B country and hence available for trade. For all specifications with Y < 100%, all countries have quota surplus to their reserve requirements. Quota surplus to the reserve requirements of net buyers may not be traded.

- The sum of the quota surplus to the reserve requirements of net seller countries. The difference between the projected emissions and the assigned amount of net buyers generally exceeds the quota surplus to the reserve requirements of net sellers, so all of the quota surplus to the reserve requirements of net sellers is likely to be traded in most runs.

- The sum of the quota surplus to the reserve requirements of net seller countries plus CDM credits purchased by net buyers.[59] This is the amount purchased by net buyers to meet their commitments.

All of these estimates implicitly assume that a given unit of quota is only traded once during a given year. This is a conservative assumption. There is considerable evidence from existing emissions trading that allowances are often traded more than once per year. The fact that some of the liquidity ratios in Tables 6 are greater than 100% confirms this. Furthermore, a liquid market requires participation by arbitrage traders, so the quantity traded is likely to be greater than the quantity of trade needed to meet compliance needs.

[59] Certified emission reductions (CERs) created by Clean Development Mechanism (CDM) projects are equivalent to AAUs for compliance purposes and are not subject to the reserve requirement, so they increase liquidity. Estimates of the quantity of CERs range from 65 to 725 MtC/yr or from 20% to 60% of the difference between "business-as-usual" emissions and the emissions limitation commitments of Annex B Parties (Zhang, 1999, Table 8, p. 31). The model used for the cost calculations reported in section 3.7 determines the quantity of CERs purchased in each of the 500 runs.

The allocation can be interpreted as the sum of the emissions limitation commitments of Annex B Parties; their assigned amount. The assigned amount covers a five year period, so the annual allocation is taken to be one-fifth of the assigned amount.

Actual emissions are also not known, because the commitment period has not yet begun. Projections of "business-as-usual" emissions are available. To meet their emissions limitation commitments, countries will implement measures to reduce these emissions. Using the "business-as-usual" emissions in the denominator of the calculation biases the estimate of liquidity downward.

Annex B Parties can use sink enhancement measures to offset some of their emissions. The April 2001 proposals by Chairman Pronk would allow sink enhancement actions of 78 to 184 MtC/yr.[60] Other estimates of the range currently under negotiation go from 168 to 272 MtC/yr.[61] These estimates are 1.5% to 8.0% of "business-as-usual" emissions. The use of sink enhancement actions to help meet emissions limitation commitments will reduce the quantity that needs to be purchased. However, the amount of quota available for trade is not reduced, so sink enhancement actions increase liquidity. Sink enhancement is not included in the model used to estimate the compliance costs reported in section 3.7.

The emissions trading programs examined have one-year compliance periods, while the compliance period for Annex B Parties is five years. It is likely that firms will participate in the international emissions trading market and that at least some of those firms will have annual compliance obligations established by their national government. Given that at least some of the firms participating in the international market will have annual compliance obligations, we believe that estimates of annual liquidity are most relevant. In addition, we believe that estimates of annual liquidity provide the fairest comparison with the liquidity of existing emissions trading programs.

The foregoing considerations produce several possible measures of potential liquidity for the international emissions trading market. These measures are shown in Table 7. Rather than try to select a preferred measure, we calculate several measures of the potential liquidity of the international emissions trading market for comparison with the observed liquidity of existing emissions trading markets. Some of the measures will yield higher or lower estimates of liquidity than others because of the way they are defined. But this range of measures will provide an indication of the conditions under which the potential liquidity is similar to that observed for existing emissions trading markets.

The estimated liquidity of the international market for different specifications of the commitment period reserve is shown in Table B-9 (Appendix B). The table shows the estimated liquidity calculated using measures 1 through 10 in Table 7. Measures 11 through 14 are not reported because the model does not include sink enhancement activities. The

[60] UNFCCC, 2001, Tables 1 and 2, pp. 20-23.

[61] Missfeldt and Haites, 2001.

estimates calculated using these measures, in any case, will be higher than those calculated using measures 7 through 10 respectively. Thus, if liquidity is found to be satisfactory using measures 7 through 10, it will also be satisfactory using measures 11 through 14. The figures presented in Table B-9 are calculated using the average value for the 500 runs run for each specification.

Table 7
Proposed Measures of the Potential Liquidity of the International Emissions Trading Market

Annual Measures		**Commitment Period Measures**	
Liquidity Measured in Relation to the Quantity Allocated			
1	$\frac{\Sigma \text{ AAUs surplus to reserves}}{(\Sigma \text{ AAUs issued})/5}$	2	$\frac{\Sigma \text{ AAUs surplus to reserves}}{\Sigma \text{ AAUs issued}}$
3	$\frac{\Sigma \text{ AAUs surplus to reserves of net sellers}}{(\Sigma \text{ AAUs issued})/5}$	4	$\frac{\Sigma \text{ AAUs surplus to reserves of net sellers}}{\Sigma \text{ AAUs issued}}$
5	$\frac{\Sigma \text{ AAUs surplus to net sellers + CDM}}{(\Sigma \text{ AAUs issued})/5}$	6	$\frac{\Sigma \text{ AAUs surplus to net sellers + CDM}}{\Sigma \text{ AAUs issued}}$
Liquidity Measured in Relation to Emissions			
7	$\frac{\Sigma \text{ AAUs surplus to reserves of net sellers}}{\text{BAU emissions in 2010}}$	8	$\frac{\Sigma \text{ AAUs surplus to reserves of net sellers}}{\text{BAU emissions 2008-2012}}$
9	$\frac{\Sigma \text{ AAUs surplus to net sellers + CDM}}{\text{BAU emissions in 2010}}$	10	$\frac{\Sigma \text{ AAUs surplus to net sellers + CDM}}{\text{BAU emissions 2008-2012}}$
11	$\frac{\Sigma \text{ AAUs surplus to reserves of net sellers}}{\text{BAU emissions - sinks in 2010}}$	12	$\frac{\Sigma \text{ AAUs surplus to reserves of net sellers}}{\text{BAU emissions - sinks, 2008-2012}}$
13	$\frac{\Sigma \text{ AAUs surplus to net sellers + CDM}}{\text{BAU emissions - sinks in 2010}}$	14	$\frac{\Sigma \text{ AAUs surplus to net sellers + CDM}}{\text{BAU emissions - sinks, 2008-2012}}$

The estimates for measures 1, 3 and 5 in Table B-9 should be compared with the figures in the middle column of Table 6, which range from 15% to 70%. The results of that comparison are shown in Table 8. Estimates for measure 1 fall within or exceed this range for every one of the specifications analysed. The estimates for measures 3, and 5 are all in the range of 300% to 400% and so are well above the 70% maximum for the existing programs.

The estimates for measures 7 and 9 in Table B-9 should be compared with the figures in the right hand column of Table 6, which range from 20% to 180%. The results of that comparison are shown in Table 8. The values for measure 7 range from 315% to 370% and so are well above the 180% maximum for existing programs. The estimates for measure 9 range from to 40% to 75% for the specifications analysed, with the exception of one outlier where the estimate is 20%. Despite this outlier, all of the values fall within the range of 20% to 180%.

Table 8

Estimated Liquidity of the International Emissions Trading Market Under Different Specifications of the Commitment Period Reserve

X	Y	Annual Measures				
		1	**3**	**5**	**7**	**9**
105	100		+	+	+	
105	98		+	+	+	
105	95		+	+	+	
105	90		+	+	+	
105	85	+	+	+	+	
100	100		+	+	+	
100	98		+	+	+	
100	95		+	+	+	
100	90		+	+	+	
100	85	+	+	+	+	
98	100		+	+	+	
98	98		+	+	+	
98	95		+	+	+	
98	90		+	+	+	
98	85		+	+	+	
95	100		+	+	+	
95	98		+	+	+	
95	95		+	+	+	
95	90		+	+	+	
95	85	+	+	+	+	
90	100		+	+	+	
90	98		+	+	+	
90	95		+	+	+	
90	90		+	+	+	
90	85	+	+	+	+	
85	100		+	+	+	
85	98		+	+	+	
85	95		+	+	+	
85	90	+	+	+	+	
85	85	+	+	+	+	

Legend: X indicates less than 15% for measures 1, 3 and 5 and less than 20% for measures 7 and 9.

\+ indicates more than 70% for measures 1, 3 and 5 and more than 180% for measures 7 and 9.

In summary, all of the measures indicate that liquidity in the international market will be comparable to or better than that in existing emissions trading markets. Lower values of Y and of X increase liquidity.

We believe the annual measures are more appropriate then the commitment period measures. Nevertheless, results for the commitment period measures defined in Table 7 are presented in Table B-9. The values are approximately one-fifth of the corresponding annual measure. Measures 4, 6 and 8 indicate that the liquidity of the international market would be comparable to that of existing emissions trading markets. Measure 2 suggests comparable liquidity for specifications with lower values of X and Y. And the results for measure 10 are always less than the 20% minimum for existing emissions trading markets.

In summary, the estimates indicate that the liquidity of the international emissions trading market is likely to be comparable to, or greater than, that of existing emissions trading programs for every specification of the commitment period reserve analysed.

4.4 International Liquidity for Domestic Emissions Trading Programs

Some Annex B Parties may choose to implement an emissions trading program domestically to help meet their emissions limitation commitments. Studies of domestic emissions trading programs identify the following principal designs:

- Upstream. A trading program for the carbon content of fossil fuels consumed in the country involving producers and importers of fossil fuels.

- Downstream. A trading program covering greenhouse gas, or only CO_2, emissions by large, stationary sources, such as fossil-fired generating stations and large industries.

- Hybrid. A downstream trading program with fuel oil, natural gas and gasoline distributors responsible for the carbon content of their products.

Most domestic emissions trading programs implemented or proposed to-date are downstream designs which cover less than 50% of the country's total emissions. An upstream design typically covers a much larger share of national emissions than a downstream design. A hybrid design generally closes much of the gap between the upstream and downstream designs. Any of the designs can be extended to encompass additional sources, such as producers and importers of manufactured gases (HFCs, PFCs and SF_6).

4.4.1 Liquidity in a Purely Domestic Emissions Trading Program

The American experience with emissions trading programs summarized in section 4.2 indicates that it is clearly possible to design a purely domestic emissions trading system with sufficient liquidity. All of the programs discussed in section 4.2, except for the international

component of the Class I ODS production allowance trading program, are strictly domestic markets.

In smaller countries, a few participants might be large enough to exercise market power.[62] The trading system design can sometimes reduce market power; auctioned rather than gratis distribution of allowances, for example. However, as noted earlier, reduced liquidity is a concomitant of market power. In short, where it is possible to design a domestic emissions trading program with a competitive market, it should be possible to provide sufficient liquidity.

The liquidity of a purely domestic emissions trading market could be enhanced by the following provisions:

- Allowing entities not subject to compliance obligations to own allowances;
- Requiring annual compliance by participants;
- Allowing banking of allowances; and
- Distributing at least some allowances for several years into the future.

These are all reasonable provisions for a domestic greenhouse gas emissions trading program designed to meet Kyoto Protocol emissions limitation commitments.

4.4.2 International Liquidity for Domestic Emissions Trading

A commitment period reserve rule does not limit the ability of participants in the domestic emissions trading program to purchase quota on the international market for compliance with domestic obligations.[63] The decision to allow the use of international quota for compliance with domestic obligations is strictly a policy decision of the Annex B government. Allowing the use of international quota for domestic compliance could lower compliance costs and reduce adverse impacts on competitiveness. Hence it is likely that most Annex B

[62] The U.S. Department of Justice (US DOJ, 1997, section 1.5) assesses mergers of firms in the same market on the basis of their impact on concentration using the Herfindahl-Hirschman Index (HHI). The HHI is calculated as the sum of the squares of the market shares of the four largest firms. For example, if the four largest firms in a market had shares of 30%, 20%, 15% and 10% (a total of 75%), the HHI is $(30)^2 + (20)^2 + (15)^2 + (10)^2 = 900 + 400 + 225 + 100 = 1,625$. The Department considers markets with an HHI between 1,000 and 1,800, such as the example, to be moderately concentrated. It considers markets with an HHI of less than 1,000 to be unconcentrated. In an unconcentrated market, the market share of the largest firm must be between 15% and 30% and the combined market share of the four largest firms must be between 35% and 65% and probably at least ten participants.

[63] If a participant in a domestic emissions trading program purchases quota on the international market for compliance with domestic obligations, it transfers title to the quota to the national government in exchange for domestic allowances or a credit toward its domestic obligations. The national government can then use the quota to help meet its emissions limitation commitment under the Kyoto Protocol.

governments would allow the use of international quota for compliance with domestic obligations, at least to some extent.

However, some specifications of the commitment period reserve could restrict exports of AAUs by a participant in the domestic emissions trading program, even if this is allowed by the national government.[64]

- For a country whose reserve requirement is established as a percentage of its initial assigned amount (a net buyer), exports of AAUs could be temporarily restricted if the percentage (Y) was set at or close to 100%. But once any entity in the country had purchased quota from another country, this quota would be available for re-export without violating the reserve requirement.

- For a country that is a net seller whose reserve requirement is established as a multiple of its most recent actual emissions, exports could be temporarily restricted if all of the AAUs surplus to the reserve had already been exported. This is the case when sales of surplus quota are temporarily restricted, which was analysed in section 3.

The first situation is the focus of this section. In this case, the quota is surplus to the requirements of the entity, but not surplus to the compliance needs of the country. Whether exports of quota should be allowed from a country in such circumstances is a valid question. We do not address that question. We assume that quota exports are allowed under these circumstances and analyse the impact of different specifications of the commitment period reserve, specifically values of Y, on the potential volume of such trades.

There are three reasons why an entity might wish to export quota:

- The price is higher on the international market than on the domestic market

- To transfer them to a related entity in another Annex B country

- To engage in arbitrage trading on the international market

These reasons are examined in turn.

The price on the international market could be higher than the domestic price under either of two conditions:

- The total quantity of allowances allocated to the participants in the domestic emissions trading program is sufficiently large that the marginal cost of domestic reductions is less than the international market price; and

[64] If the allowances used in the domestic emissions trading program are the national AAUs, they could be exported directly if the sale does not violate the reserve requirement. If the domestic emissions trading program uses separate domestic allowances, the government would need to establish rules under which the domestic allowances could be exchanged for national AAUs for export.

- The domestic emissions trading program in a small country includes one (or a few) large buyer who exercises market power by offering low prices to small sellers.[65]

If the total quantity of allowances allocated to the participants in the domestic emissions trading program is sufficiently large that the marginal cost of domestic reductions is less than the international market price, it might be argued that the allocation constitutes a subsidy to the participants, especially if the country is a net buyer of quota. A successful compliant by an other country under the WTO rules might lead to a requirement to reduce the allocation of allowances and/or countervailing duties on the exports of the subsidized products and quota. Since the main purpose of quota exports in this case is to convert the allowance subsidy into cash, it is difficult to argue that access to the international market is essential. Rather, limiting sales to the domestic market and its lower prices in these circumstances may make such subsidies less attractive.

In the case of a small country where the domestic emissions trading market is dominated by a large buyer, access to the international market offers small sellers an opportunity to get a fair price for their surplus allowances. This may make domestic emissions trading a viable policy option for small countries that otherwise would not have a competitive domestic market.

Either of the above circumstances could occur in a country that is a net seller, where the reserve requirement is based on actual sales, or a country that is a net buyer, where the reserve requirement is based on the initial assigned amount. If the country is a net seller, some quota exports are allowed. As noted in section 3, some sales of surplus quota may be temporarily restricted by the reserve requirement. If the country is a net buyer, quota exports are possible only if the value of Y is less than 100%.

A multinational entity with surplus allowances in one country might wish to transfer them to a related entity in another Annex B country. The tax laws of most Annex B countries require the seller to report revenue for goods or services provided to related entities. If the tax law requires the seller to value the allowances at the market price, there is no financial advantage to transferring them to a related entity in another country. Apart from the transactions costs, the transfer is equivalent to selling the allowances on the international market and having the recipient purchase an equal quantity of quota.

International transfers of quota between related entities may be beneficial under the following circumstances:

- The transfer pricing provisions of the tax law of the exporting country allow the quota to be transferred at cost, rather than market price, and the cost is zero -- the allowances are

[65] Note that the reverse situation of a large seller exercising market power by charging high prices to small buyers is not a concern. The proposed commitment period reserve provision does not restrict *imports* of quota, so the small buyers can purchase quota on the international market. With unrestricted imports, the domestic price in each importing country should be roughly equal to the international price. If imports are restricted by a supplementarity rule, the domestic price in each importing country could be higher than the international price, but this is a consequence of the supplementarity provision rather than the reserve requirement.

allocated free to participants. Then international transfers of quota between related entities could be used to shift profits to jurisdictions with lower corporate tax rates.[66]

- The accounting treatment of quota received differs from that for transfers of cash. If the recipient entity does not have sufficient cash to pay for the quota received, it could "pay" for them by creating an account payable for the amount due to its affiliated entity. If the affiliated entity could not transfer quota but had to sell the allowances and transfer the funds, these funds would need to be treated as a loan or equity investment. An account payable may be preferable to a loan or equity investment in terms of its legal status or ease of repayment.

In short, there may be circumstances under which a transfer of quota is preferable to an equivalent transfer of cash between related entities in different countries.

Liquidity is improved by the participation of arbitrage traders. Arbitrage traders may, but need not, use the allowances they have been allocated for such trading. Thus, even with restrictions on exports of quota participants in a domestic emissions trading program could engage in arbitrage trading domestically. A limit on exports of quota due to a commitment period reserve rule would mean that that a participant in a domestic trading program could not use its domestic allocation for arbitrage trading in the international market. However, it could still engage in arbitrage trading on the international market by first purchasing quota on that market.

In summary, export of quota could be desirable for a company in an Annex B country if:

- The domestic emissions trading program includes one (or a few) large buyer who exercises market power by offering low prices to small sellers, which would usually happen only in a small country.

- The transfer pricing provisions of the tax law of the exporting country allow the quota to be transferred at cost, rather than market price, and the cost of the allowances to the participants is less than the market price. By allowing exports of quota under these circumstances, the country loses corporate income tax revenue.

- The accounting treatment of quota received differs from that for transfers of cash between related entities in different countries.

Since there are circumstances under which exports of quota are desirable for a firm, the commitment period reserve rule should be designed to accommodate such exports. Then individual Annex B governments can decide under what conditions to allow such exports.

[66] The allowances (quota) are transferred at cost (zero) from firm A to a related firm B in a country with a low corporate tax rate. Firm B sells the quota at the market price to a related firm C that needs them for compliance. This moves the profits from the sale of the quota from firm A into firm B where they are taxed at a lower rate. If the transfer must be made at the market price, firm C would pay firm A the market price for the quota and there is no advantage in involving firm B, since it would have to buy the quota from firm A at the market price and then sell them to firm C at the market price.

The question for this paper is the appropriate level of international liquidity for participants in a domestic emissions trading program.

4.4.3 International Liquidity for a Domestic Emissions Trading Program

As is the case for international emissions trading, the actual liquidity of the domestic emissions trading programs can not be assessed, only the potential liquidity. Potential liquidity is assessed in terms of the quota available for international trade relative to the annual allocation or to the annual emissions since those are the measures calculated for the existing programs. Those calculations implicitly assume that each allowance available for international trade is traded once each year, although the average is greater than one in existing programs.

An upstream program is assumed to cover all energy-related CO_2 emissions. A downstream program is assumed to cover all energy-related CO_2 emissions by industry. This overstates the likely coverage of a downstream program, since small sources would probably be excluded. In turn, that means the potential liquidity is understated. Participants in any domestic trading program are assumed to be required to demonstrate compliance annually, hence only annual liquidity measures are calculated. The proposed measures of potential liquidity are shown in Table 9.

Table 9
Proposed Measures of the International Liquidity of Domestic Emissions Trading Programs

	Downstream Program
1	$\frac{\text{AAUs surplus to reserve}}{\text{(Downstream emissions in 2010/National GHG emissions in 2010)*(AAUs issued)/5}}$
2	$\frac{\text{AAUs surplus to reserve}}{\text{Downstream emissions in 2012}}$
	Upstream Program
3	$\frac{\text{AAUs surplus to reserve}}{\text{(Upstream emissions in 2010/National GHG emissions in 2010)*(AAUs issued)/5}}$
4	$\frac{\text{AAUs surplus to reserve}}{\text{Upstream emissions in 2012}}$

The first measure for each type of program relates the quota available for international export to the trading program's pro rata share of the national assigned amount as an estimate of the allowance allocation to participants in the trading program. Those values might be compared to the 15% to 70% values calculated for the existing programs. But the proposed calculation assumes that the *only* liquidity comes from quota available for export, which is clearly not the case. The 10% to 20% that international trade represented of total Class I ODS trading might be a fairer standard for assessing potential liquidity using this measure.

The second measure for each type of program relates the quota available for international export to the trading program's projected "business-as-usual" emissions. Those values might be compared to the 20% to 180% values calculated for the existing programs. The proposed calculation yields a very conservative estimate of the liquidity because it assumes that the *only* liquidity comes from the quota available for export and because the actual emissions are likely to be lower than the "business-as-usual" emissions for participants in an emissions trading program.

4.5 International Liquidity for Domestic Emissions Trading Markets by Country for Different Specifications of the Commitment Period Reserve

To calculate the international liquidity for domestic emissions trading markets, requires projections of energy-related CO_2 emissions and the energy-related CO_2 emissions by industry for each Annex B country for each of the 500 runs. The energy-related CO_2 emissions and the energy-related CO_2 emissions by industry are projected by relating them to the projected total greenhouse gas emissions of the country for the same year in that case. The procedure ensures that industrial CO_2 emissions are less than energy-related CO_2 emissions which, in turn, are less than total greenhouse gas emissions.

- Using the historic data for a given country, linear regression equations are estimated expressing energy-related CO_2 emissions (ERCO2) and energy-related CO_2 emissions by industry (ICO2) as a function of total greenhouse gas emissions (TGHG).

  ERCO2 = a + b*TGHG
  ICO2 = c + d*TGHG

  To ensure that the required relationships are maintained, the constant coefficients are set to zero (a = 0 and c = 0) and the coefficients for TGHG are required to be less than 1 (b < 1 and d < 1) and d is required to be less than b (d < b).

- The value of ERCO2 (ICO2) for a specific year in a given case is forecast as follows:

  (a) Apply the equation to the forecast value of TGHT; the initial values are
  Initial ERCO2 = b*(forecast value of TGHG)
  Initial ICO2 = d*(forecast value of TGHG)

  (b) Apply a random adjustment to the initial value of ERCO2 (ICO2) based on the standard error of the regression equation and a random number with mean zero and standard deviation of 1, so
  ERCO2' = Initial ERCO2 + random adjustment
  ICO2' = Initial ICO2 + random adjustment

  (c) Check to ensure that the adjusted values do not exceed the total greenhouse gas emissions and energy-related CO_2 emissions respectively.

ERCO2' > TGHG
ICO2' > ERCO2'

If an adjusted value does not meet this condition, a new random adjustment is applied (step (b)) and this value is checked against the required constraint (step (c)).

Table B-10 (Appendix B) shows the estimated international liquidity for domestic emissions trading markets by country for different specifications of the commitment period reserve. The international liquidity for downstream domestic emissions trading programs is estimated using measures 1 and 2 in Table 9. The international liquidity for upstream domestic emissions trading programs is estimated using measures 3 and 4 in Table 9. The emissions and quota allocation for a downstream trading program will be lower than those for an upstream program in the same country. Since the quota allocation and emissions are the denominator of the liquidity calculation, the international liquidity will be higher for the downstream program than for the upstream program.

Liquidity measured relative to the quota allocation, measures 1 and 3 in Table B-10, should be compared with the range of 15% to 70% for existing emissions trading programs as shown in the middle column of Table 6. Liquidity measured relative to emissions, measures 2 and 4 in Table B-10, should be compared with the range of 20% to 180% for existing emissions trading programs as shown in The right-hand column of Table 6. The results of these comparisons for selected specifications are shown in Table 10.

The purpose of the provision that sets the reserve at Y% of the initial assigned amount is to provide international liquidity for domestic trading programs in net buyer, mainly Annex II, countries. For a downstream program, specifications with Y equal to 98% and X equal to 90% or 95% provide international liquidity equal to or greater than that of existing emissions trading programs for all countries, except for the Russian Federation using measure 1.

The difference between measures 1 and 2 in terms of the number of countries with international liquidity beyond that of existing emissions trading programs is due mainly to the lower maximum value (70%) for measure 1 than (180%) for measure 2. Using a value of 70% for both measures results in virtually identical results.

For an upstream design, specifications with Y equal to 98% and X equal to 90% provide international liquidity less than that of existing emissions trading programs for three to eight Annex II countries and greater than that of existing emissions trading programs in two to seven Annex II countries, depending upon the measure used. Measure 4 indicates more countries with international liquidity lower than that of existing programs than measure 3.

Specifications with Y equal to 95% and X equal to 90% or 95% provide international liquidity equal to or greater than that of existing emissions trading programs for all countries, except for the Russian Federation using measure 3. Again, the difference between measures 3 and 4 in terms of the number of countries with international liquidity beyond that of existing emissions trading programs is due mainly to the lower maximum value (70%) for measure 3 than (180%) for measure 4.

Table 10

International Liquidity for Domestic Emissions Trading Programs by Country for Different Specifications of the Commitment Period Reserve

Country	Downstream Measure 1						Downstream Measure 2					
	Y = 98%		Y = 95%		Y = 90%		Y = 98%		Y = 95%		Y = 90%	
	X =		X =		X =		X =		X =		X =	
Annex II Parties	**95**	**90**	**95**	**90**	**95**	**90**	**95**	**90**	**95**	**90**	**95**	**90**
Australia			+	+	+	+						
Austria	+	+	+	+	+	+					+	+
Belgium			+	+	+	+					+	+
Canada			+	+	+	+						
Denmark			+	+	+	+						
Finland	+	+	+	+	+	+	+	+	+	+	+	+
France	+	+	+	+	+	+	+	+	+	+	+	+
Germany		+	+	+	+	+						
Greece	+	+	+	+	+	+	+	+	+	+	+	+
Iceland	+	+	+	+	+	+	+	+	+	+	+	+
Ireland	+	+	+	+	+	+		+		+	+	+
Italy	+	+	+	+	+	+		+		+	+	+
Japan			+	+	+	+						
Luxembourg	+	+	+	+	+	+	+	+	+	+	+	+
Netherlands			+	+	+	+						
New Zealand	+	+	+	+	+	+			+	+	+	+
Norway		+	+	+	+	+					+	+
Portugal	+	+	+	+	+	+	+	+	+	+	+	+
Spain		+	+	+	+	+					+	+
Sweden		+	+	+	+	+					+	+
Switzerland	+	+	+	+	+	+	+	+	+	+	+	+
United Kingdom		+	+	+	+	+						
United States					+	+						
Rest of Annex B												
Bulgaria	+	+	+	+	+	+						
Croatia	+	+	+	+	+	+	+	+	+	+	+	+
Czech Republic				+	+	+						
Estonia	+	+	+	+	+	+	+	+	+	+	+	+
Hungary	+	+	+	+	+	+	+	+	+	+	+	+
Latvia	+	+	+	+	+	+	+	+	+	+	+	+
Lithuania	+	+	+	+	+	+						+
Poland	+	+	+	+	+	+						+
Romania	+	+	+	+	+	+	+	+	+	+	+	+
Russian Federation	+	+	+	+	+	+	+	+	+	+	+	+
Sensitivity Case												
Slovakia		+	+	+	+	+						
Slovenia			+	+	+	+				+	+	+
Ukraine	+	+	+	+	+	+	+	+	+	+	+	+

Legend: X indicates less than 15% for measure 3 and less than 20% for measure 4.
+ indicates more than 70% for measure 3 and more than 180% for measure 4.

Country	Upstream Measure 3						Upstream Measure 4					
	Y = 98%		Y = 95%		Y = 90%		Y = 98%		Y = 95%		Y = 90%	
	X =		X =		X =		X =		X =		X =	
Annex II Parties	**95**	**90**	**95**	**90**	**95**	**90**	**95**	**90**	**95**	**90**	**95**	**90**
Australia					+	+	**X**	**X**				
Austria					+	+	**X**	**X**				
Belgium	**X**	**X**					**X**	**X**				
Canada					+	+	**X**	**X**				
Denmark					+	+	**X**					
Finland	+	+	+	+	+	+						
France	+	+	+	+	+	+		+		+		+
Germany												
Greece	+	+	+	+	+	+						
Iceland						+	**X**					
Ireland		+		+	+	+		**X**				
Italy		+		+		+						
Japan	**X**	**X**					**X**	**X**				
Luxembourg	+	+	+	+	+	+	+	+	+	+	+	+
Netherlands	**X**						**X**	**X**				
New Zealand			+	+	+	+						
Norway					+	+	**X**					
Portugal	+	+	+	+	+	+						
Spain					+	+						
Sweden	**X**						**X**					
Switzerland	**X**						**X**					
United Kingdom												
United States	**X**	**X**					**X**	**X**				
Rest of Annex B												
Bulgaria		+		+	+	+						
Croatia	+	+	+	+	+	+	+	+	+	+	+	+
Czech Republic												
Estonia	+	+	+	+	+	+	+	+	+	+	+	+
Hungary	+	+	+	+	+	+						
Latvia	+	+	+	+	+	+	+	+	+	+	+	+
Lithuania	+	+	+	+	+	+						
Poland	+	+	+	+	+	+						
Romania	+	+	+	+	+	+	+	+	+	+	+	+
Russian Federation	+	+	+	+	+	+						
Sensitivity Case												
Slovakia		+		+	+	+						
Slovenia					+	+	**X**	**X**				
Ukraine	+	+	+	+	+	+	+	+	+	+	+	+

Legend: X indicates less than 15% for measure 1 and less than 20% for measure 2.
+ indicates more than 70% for measure 1 and more than 180% for measure 2.

These results suggest that a value of Y between 95% and 98% with X equal to 90% should provide sufficient international liquidity for domestic emissions trading programs in all countries. The value of Y could be linked to the scope of the domestic emissions trading program; 95% for countries where the domestic trading program covers more than 50% of the total greenhouse gas emissions and 98% for other countries.

5. Conclusions

International emissions trading creates the opportunity for a country to sell quota and then fail to comply with its emissions limitation commitment. This possibility is called overselling. The commitment period reserve has been proposed to limit the scope of potential non-compliance due to overselling. The commitment period reserve would complement, but not replace, non-compliance penalties.

The purpose of the commitment period reserve is to limit potential non-compliance due to overselling. It limits overselling by requiring each country to hold a specified amount of quota in its national registry. Only quota surplus to the reserve requirement can be transferred to another country. Transfers of quota among entities within a country and acquisitions of quota from other countries are not affected by the reserve requirement.

The commitment period reserve proposal requires each Annex B Party to hold in its national registry quota equal to the ***lower*** of:

- X% of five times the Party's most recently reviewed emissions inventory; and
- Y% of the Party's initial assigned amount pursuant to Articles 3.7 and 3.8.

The President of the 6th Conference of the Parties (COP 6) has proposed a commitment period reserve with X = 100% and Y = 90%. Parties have proposed values of X ranging from 70% to 100% and values of Y ranging from 70% to 98%.

Alternative specifications of the commitment period reserve (values of X and Y) are assessed in terms of:

- Restricted sales of quota surplus to the country's compliance needs leading to temporarily higher compliance costs;
- The extent of possible non-compliance due to overselling;
- Liquidity in the international market; and
- International liquidity for domestic emissions trading markets.

Once the commitment period reserve has been agreed, the values of X and Y adopted will apply to all Annex B countries. A given specification (values of X and Y) will affect individual countries differently, so the probability of temporarily restricted sales and the international liquidity for domestic emissions trading markets are analysed by country.

The reserve requirement produces two possible impacts:

- Sales of quota surplus to the compliance needs of a country may be restricted by the first provision of the reserve requirement (the value of X). This restriction is temporary. After the country has demonstrated compliance with its commitment, the surplus quota can be sold. However, that may be too late to allow other countries to use the quota for compliance with their commitments. Under those conditions the temporary restriction on sales of surplus quota raises compliance costs for countries that are net buyers.

  The countries most likely to be affected by a restriction on sales are the Rest of Annex B countries, many of which are expected to be net sellers. However, the European Union burden-sharing agreement means that some of the EU member countries could face temporary restrictions on sales of surplus quota under some specifications of the commitment period reserve.

- Sales of quota surplus to the reserve requirement, but not surplus to the country's compliance needs -- potential overselling. This can occur under either provision of the reserve requirement, but is a risk specifically associated with the second option (the value of Y). If quota that is not surplus to the country's compliance needs is sold and not replaced, the result is non-compliance due to overselling. The scale of the potential non-compliance due to overselling is largest for Annex II Parties because they account for almost 70% of the assigned amount and are generally expected to be net buyers.

Non-compliance due to overselling can occur only if:

- the reserve requirement is set so that a country can sell quota surplus to the reserve requirement, but not surplus to the country's compliance needs;

- the available quota is purchased by another Annex B country and is used to meet its emissions limitation commitment; and

- the seller country does not comply with its emissions limitation commitment.

5.1 The Potential for Temporarily Restricted Sales of Surplus Quota and Non-Compliance Due to Overselling for Annex B Countries as a Whole

Analysis of the potential for temporarily restricted sales of surplus quota and non-compliance due to overselling for Annex B countries as a whole indicates that:

- Every Annex B country either faces temporarily restricted sales of surplus quota or the opportunity to sell non-surplus quota and hence contribute to non-compliance due to overselling, except for specifications with Y= 100%. When Y = 100%, countries that are net buyers must keep all of their initial assigned amount as a reserve and so can not contribute to potential non-compliance due to overselling. However, when Y = 100% the international liquidity for domestic trading programs in net buyer is limited to quota purchased from other countries.

- The probability of temporarily restricted sales falls and the potential for non-compliance due to overselling rises as the values of X and Y are reduced.

- The average and maximum quantity of sales of surplus quota temporarily restricted decline as the probability of such restrictions declines.

- The potential non-compliance due to overselling is maximized when the demand for quota by buyers equals the supply of quota not surplus to the compliance needs of the other countries. The maximum potential non-compliance due to overselling rises as the values of X and Y fall. It is more sensitive to changes in the value of Y than in the value of X.

- Specifications with X and Y less than 85% render the commitment period ineffective as a means of limiting overselling. With such specifications all of the potential non-compliance could take the form of overselling. Such an outcome would be unlikely in practice because it would involve large purchases by some countries and equally large non-compliance overall by the other countries.

- Temporarily restricted sales are small relative to the maximum potential non-compliance due to overselling for most specifications analysed. With Y less than 100%, the restricted sales are less than 10% of the maximum potential non-compliance due to overselling when X = 100% and less than 3% of the maximum potential non-compliance due to overselling when X = 95%.

These results indicate that if the commitment period reserve is to be effective in limiting potential non-compliance due to overselling, the values of X and Y must be greater than 85%. Any specification will involve balancing temporarily restricted sales with potential non-compliance due to overselling, but for specifications with Y < 100% and X ▶ 100% the restricted sales are small relative to the maximum potential non-compliance due to overselling.

The sensitivity scenario indicates that lower emissions by net sellers reduce the maximum potential non-compliance due to overselling for a given specification of the commitment period reserve. Lower emissions by net sellers means more quota surplus to the compliance needs of sellers is available, so non-compliance is reduced.

Conversely, higher emissions by net buyers will increase the maximum potential due to overselling for a given specification of the commitment period reserve if Y is less than 100%. Higher emissions by net buyers mean a larger demand for quota, so countries can sell more quota surplus to the reserve requirement but not surplus to their compliance needs.

5.2 Temporarily Restricted Sales of Quota Surplus to the Country's Compliance Needs

A given specification of the commitment period reserve (values of X and Y) will apply to all Annex B countries, but affect each one differently. The probability of temporarily restricted sales of surplus quota is sensitive to both the value of X and the value of Y. For roughly half

of the countries vulnerable to temporary restriction of sales of surplus quota, the probability varies with the value of Y for a given value of X. For the balance of the countries, the probability is constant for a given value of X. The former are countries that could be net buyers or net sellers depending upon their future emissions, while the latter are likely to be net sellers in under almost all runs.

Specifications with lower values of X and Y lead to fewer countries with temporarily restricted sales, fewer runs where sales are restricted for countries that are affected, and smaller average and maximum quantities of temporarily restricted sales.

- With Y = 98% and X = 100%, 20 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% for 11 of those 20 countries and greater than 50% for 3 of the countries.

- With Y = 98% and X = 95%, 13 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% for 3 of those 13 countries.

- With Y = 98% and X = 90%, 9 of the 36 Annex B countries analysed are subject to temporary restrictions on sales of surplus quota in at least some of the 500 runs. The probability of being affected is greater than 25% in every case and greater than 10% for only 2 of the countries, Luxembourg and Latvia.

The reason why Latvia and Luxembourg face the highest probability of temporarily restricted sales is due to the sharp decline in their emissions during the early 1990s relative to their projected emissions. In practice only one outcome will occur and it may affect Latvia and Luxembourg less, and other countries more, than suggested by the analysis.

To reduce the probability of temporarily restricted sales to zero for all countries requires that X be 65% and Y be no higher than 90%. Such specifications would render the commitment period reserve ineffective in limiting overselling, so the possibility of temporarily restricted sales for some countries is a condition of an effective reserve requirement.

5.3 Impact on Annex II Compliance Costs

If temporarily restricted sales of surplus quota are not available in time for use by buyer countries to meet their emissions limitation commitment for the current period, they increase compliance costs for those countries. A model with a single Annex B buyer -- Annex II countries -- and a single Annex B seller -- the rest of the Annex B countries was used to estimate the financial impacts of the temporarily restricted sales and non-compliance.

Aggregating the information for the countries that constitute each region nets out any trade among countries within a region, although such trade is small relative to the interregional trade under all but the highest reserve requirements. The model assumes that surplus quota

whose sale is restricted is not available to other countries for the purpose of complying with the emissions limitation commitments of the first commitment period.

The results for different specifications of the commitment period reserve are compared to the least-cost, full-compliance case. The marginal abatement cost curves in the model apply only to energy-related CO_2 emissions. The available evidence suggests that the cost of a given percentage reduction in emissions of all gases is lower than for energy-related CO_2 emissions alone. Thus the cost estimates are biased upward.

Every specification analysed, on average, allows some excess emissions overall. With the exception of the specifications with X = 105% and Y ≤ 85%, the non-compliance due to the excess emissions reduces the compliance cost for the Annex II region below that for the least-cost, full-compliance case. The lower the values of X and Y the larger the potential non-compliance and the lower the Annex II compliance costs, on average.

The range of possible outcomes for a given specification is very wide for the 500 runs analysed. For most specifications, possible outcomes range from over-compliance at a cost saving if emissions in many countries are much lower than projected to excess emissions and increased compliance costs if emissions in many countries are higher than projected even though the average result is some non-compliance and lower costs relative to the least-cost, full-compliance case.

5.4 Liquidity

Liquidity does not change the total supply of allowances and so does not make compliance easier (or more difficult) for entities participating in an emissions trading program. Liquidity does make it easier for an entity to buy (sell) the desired quantity of allowances quickly. This increases confidence in emissions trading as a viable component of a compliance strategy. To the extent that increased confidence enhances the use of emissions trading for compliance, liquidity helps reduce compliance costs.

Liquidity is a relative concept; it is not possible to specify a "minimum" or "necessary" level of liquidity for a market. The only "standard" that can be used to judge the liquidity of the international emissions trading market is the liquidity of existing emissions trading markets. The quantity of allowances traded between economically-independent entities relative to the annual allocation or annual emissions are rough indicators of liquidity.

These data are available for several years for each of three emissions trading programs. The allowances traded include allowances for the current year and for all future years for which they have been allocated. The data indicate that the quantity of allowances traded is 15% to 70% of the annual allocation plus banked allowances. When the quantity traded is related to annual emissions, the percentage is higher, ranging from 20% to 180%, since emissions are less than the allowances allocated.

5.5 Liquidity in the International Emissions Trading Market

The liquidity measures for existing emissions trading programs relate the quantity of allowances traded annually to the annual allocation or the annual emissions. Thus, the quantity of quota traded annually, the annual allocation of quota; and the annual emissions need to be projected to calculate these measures for the international emissions trading market for a given specification of the commitment period reserve.

Since international emissions trading is not yet operational, data on the quantity of quota traded annually are not available. However, the country data and model results provide estimates of the sum of the quota surplus to the reserve requirement for each Annex B country and hence available for trade, the sum of the quota surplus to the reserve requirements of net seller countries, and the sum of the quota surplus to the reserve requirements of net seller countries plus CDM credits purchased by net buyers. All three of these estimates implicitly assume that a given unit of quota is only traded once during a given year. There is considerable evidence from existing emissions trading that allowances are often traded more than once per year.

The available data are used to calculate several measures of the potential liquidity of the international emissions trading market for comparison with the observed liquidity of existing emissions trading markets. Although the compliance period for Annex B Parties is five years, at least some of the firms participating in the international market will have annual compliance obligations and the emissions trading programs examined have one-year compliance periods. Therefore, we believe that estimates of annual liquidity are most relevant and provide the fairest comparison with the liquidity of existing emissions trading programs.

The estimates for the five measures of liquidity calculated indicate that the liquidity of the international emissions trading market is likely to be comparable to or greater than that of existing emissions trading programs for every specification of the commitment period reserve analysed. As expected lower the values of Y and of X increase liquidity because more of the total quota is available for trade.

5.6 International Liquidity for Domestic Emissions Trading Programs

Some Annex B Parties may choose to implement an emissions trading program domestically to help meet their emissions limitation commitments. The American experience with emissions trading programs indicates that it is clearly possible to design a purely domestic emissions trading system with sufficient liquidity. This may not be true for a smaller country where one buyer might be large enough to depress the prices paid to small sellers.

The liquidity of a purely domestic emissions trading market could be enhanced by the following provisions:

- Allowing entities not subject to compliance obligations to own allowances;

- Requiring annual compliance by participants;

- Allowing banking of allowances; and

- Distributing at least some allowances for several years into the future.

These are all reasonable provisions for a domestic greenhouse gas emissions trading program designed to meet Kyoto Protocol emissions limitation commitments.

A participant in a domestic emissions trading program may wish to export quota surplus to its needs, but not surplus to the compliance needs of the country. Export of quota could be desirable for a company in an Annex B country if:

- The domestic emissions trading program includes a large buyer who exercises market power by offering low prices to small sellers. This would usually happen only in a small country.

- The transfer pricing provisions of the tax law of the exporting country allow the quota to be transferred at cost, rather than market price, and the cost of the allowances to the participants is less than the market price. By allowing exports of quota under these circumstances, the country loses corporate income tax revenue.

- The accounting treatment of quota received from a related entity in another country differs from that for transfers of cash in a way that is attractive to the companies involved.

Since there are circumstances under which exports of quota are desirable for a firm, the commitment period reserve rule should be designed to accommodate such exports. Then individual Annex B governments can decide under what conditions to allow such exports.

5.7 International Liquidity for Domestic Emissions Trading Markets by Country for Different Specifications of the Commitment Period Reserve

The actual liquidity of the domestic emissions trading programs for greenhouse gases can not be assessed. Their potential liquidity is assessed in terms of the quota available for international trade relative to the annual allocation or to the annual emissions since those are the measures calculated for the existing programs. Those calculations implicitly assume that each allowance available for international trade is traded once each year, although the average is greater than one in existing programs.

The analysis considers the international liquidity of a domestic emissions trading program in each of the 36 Annex B countries analysed for different specifications of the commitment period reserve. The analysis considers two possible designs for the domestic emissions trading program:

- An upstream program that covers all energy-related CO_2 emissions; and

- A downstream program is assumed to cover all energy-related CO_2 emissions by industry.

Two measures of liquidity are calculated for each design. The first measure for each type of program relates the quota available for international export to the trading program's pro rata share of the national assigned amount as an estimate of the allowance allocation to participants in the trading program. The second measure for each type of program relates the quota available for international export to the trading program's projected "business-as-usual" emissions. Both calculations assume that the *only* liquidity comes from quota available for export, which is clearly a very conservative estimate.

The results ……

5.8 Summary

The purpose of the commitment period reserve is to limit potential non-compliance due to overselling. To be effective the values of X and Y must be greater than 85%. Increasing the value of Y increases the effectiveness more than a comparable increase in the value of X.

Negotiators need to treat individual countries fairly. Each will be affected differently by a given specification of the commitment period reserve. A value of X of about 90% reduces the number of countries potentially affected, the probability that those countries will be affected, and the magnitude of the restricted sales when they are affected, to reasonably low levels.

The value of Y must be less than 100% to ensure that every Annex B country can provide international liquidity for its domestic emissions trading program if it chooses. With Y = 98% (and X = 90%) the international liquidity for a downstream emissions trading program is comparable to or greater than the liquidity of existing emissions trading programs for all Annex B countries. In the case of an upstream design, the Y must be ??% (with X = 90%) to provide international liquidity at least equal to that of existing emissions trading programs for all Annex B countries. In short, based on liquidity considerations for national emissions trading programs, the value of Y could be set between ??% and 98%.

Sufficient liquidity should be available in the international market regardless of the specification adopted. Temporarily restricted sales will be small with both X and Y less than 100%. As a result compliance costs will be close to those for the least-cost, full compliance case even if there is no overselling. If there is non-compliance, the compliance costs will be lower than for the least-cost, full compliance case.

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Appendix A

Initial Assigned Amount and Emissions for Selected Years by Country

Table A-1

Initial Assigned Amount and Emissions for Selected Years by Country (1,000 tCO_2 equivalent)

Annex II Parties	Initial Assigned Amount	Emissions				
		1990	1995	2000	2005	2010
Australia	2,244,542	415,656	435,471	463,800	495,905	528,810
Austria	336,129	77,271	80,718	79,640	77,031	74,433
Belgium	644,152	139,276	145,126	145,754	153,602	160,514
Canada	2,811,065	598,099	635,570	609,118	635,513	669,252
Denmark	272,945	69,100	76,500	69,000	72,800	75,400
Finland	363,930	72,786	72,489	69,660	68,752	67,845
France	2,787,260	557,452	547,981	441,831	459,318	476,805
Germany	4,775,973	1,209,107	1,073,748	1,038,058	994,991	979,403
Greece	657,719	105,235	112,189	107,288	112,116	116,944
Iceland	15,890	2,889	2,773	3,250	3,365	3,494
Ireland	321,265	56,861	59,324	60,625	64,486	66,454
Italy	2,491,401	532,920	541,900	526,801	496,176	475,593
Japan	5,815,996	1,237,446	1,369,311	1,244,815	1,334,810	1,424,806
Luxembourg	48,557	13,488	10,223	6,359	6,431	6,653
Netherlands	1,020,403	217,107	234,432	219,160	226,670	235,642
New Zealand	362,495	72,499	72,777	78,151	80,789	84,044
Norway	278,073	55,064	55,984	60,279	63,057	63,611
Portugal	434,607	68,442	69,025	69,608	76,125	82,091
Spain	1,733,228	301,431	325,530	336,863	349,411	361,959
Sweden	345,576	66,457	69,004	71,447	73,919	74,996
Switzerland	247,245	53,749	53,749	52,336	52,727	53,235
United Kingdom	3,315,598	757,851	692,301	641,154	683,696	679,148
United States	27,891,641	5,998,204	6,344,659	6,444,828	6,789,432	7,134,036
Rest of Annex B						
Bulgaria	650,187	136,093	87,100	110,083	130,035	138,619
Croatia	151,734	31,944	22,259	23,007	23,755	24,503
Czech Republic	884,074	192,190	150,975	161,402	178,594	194,031
Estonia	187,307	40,719	30,484	20,250	21,566	22,882
Hungary	489,185	101,634	77,857	77,536	82,576	87,616
Latvia	164,077	35,669	20,998	18,919	17,817	20,139
Lithuania	237,121	51,548	43,264	34,980	42,829	50,678
Poland	2,689,608	564,286	437,756	459,886	489,779	519,671
Romania	1,312,858	264,879	167,770	186,491	191,658	204,134
Russian Federation	15,201,660	3,040,332	2,171,201	2,281,100	2,571,200	2,911,800
Sensitivity scenario				1,657,870	1,767,280	1,876,690
Slovakia	335,777	72,995	54,546	55,840	61,875	66,975
Slovenia	88,375	19,212	19,267	19,323	19,378	19,433
Ukraine	4,529,390	905,878	811,394	716,910	748,369	767,540

Appendix B

Detailed Numerical Results

Table B-1

Results for Alternative Specifications of the Commitment Period Reserve: Average Number of the 36 countries in (a) potential non-compliance due to overselling and (b) subject to restrictions on sales of surplus quota

Average of 500 random runs for each country

Y = Percentage of Initial Assigned Amount		**X = Percentage of Five Times Actual Emissions**							
		105%	**100%**	**98%**	**95%**	**90%**	**85%**	**80%**	**70%**
100%	Non-compliance	2.78	9.99	13.47	17.96	25.56	31.11	34.59	35.91
	Restricted	*9.40*	*5.03*	*3.05*	*1.68*	*0.67*	*0.28*	*0.09*	*0.09*
98%	Non-compliance	24.70	30.81	32.89	34.30	35.33	35.72	35.91	35.91
	Restricted	*11.30*	*5.19*	*3.11*	*1.70*	*0.67*	*0.28*	*0.09*	*0.09*
95%	Non-compliance	26.41	31.29	33.13	34.39	35.34	35.72	35.91	35.91
	Restricted	*9.58*	*4.71*	*2.87*	*1.61*	*0.66*	*0.28*	*0.09*	*0.09*
90%	Non-compliance	29.49	32.50	33.66	34.53	35.35	35.72	35.91	35.91
	Restricted	*6.51*	*3.50*	*2.34*	*1.47*	*0.65*	*0.28*	*0.09*	*0.09*
80%	Non-compliance	33.43	34.09	34.37	34.80	35.40	35.73	35.91	35.91
	Restricted	*2.57*	*1.91*	*1.63*	*1.20*	*0.60*	*0.27*	*0.09*	*0.09*
70%	Non-compliance	34.47	34.82	34.97	35.20	35.56	35.79	35.96	35.91
	Restricted	*1.53*	*1.18*	*1.03*	*0.80*	*0.44*	*0.21*	*0.04*	*0.09*

Table B-2

Results for Alternative Specifications of the Commitment Period Reserve: Average quantity of potential non-compliance due to overselling (a) by Annex II countries, (b) by the Rest of Annex B countries, and (c) all Annex B countries

(1,000 tCO_2 equivalent)

Average of 500 random runs for each country

Y = Percentage of Initial Assigned Amount		**X = Percentage of Five Times Actual Emissions**					
		105%	**100%**	**98%**	**95%**	**90%**	**85%**
100%	Overselling-AII	5,158	124,212	281,636	644,122	1,462,469	2,566,754
	Overselling-RAB	529,222	1,128,193	1,479,691	2,083,504	3,200,105	4,381,410
	Total overselling	*534,380*	*1,252,405*	*1,761,326*	*2,727,625*	*4,662,574*	*6,948,164*
98%	Overselling-AII	1,044,679	1,138,807	1,265,012	1,560,203	2,284,641	3,263,632
	Overselling-RAB	667,858	1,233,650	1,562,984	2,136,482	3,220,200	4,386,885
	Total overselling	*1,712,536*	*2,372,456*	*2,827,996*	*3,696,686*	*5,504,841*	*7,650,517*
95%	Overselling-AII	2,648,892	2,729,107	2,813,516	3,018,854	3,576,186	4,413,024
	Overselling-RAB	944,079	1,446,941	1,741,536	2,257,662	3,270,708	4,401,970
	Total overselling	*3,592,171*	*4,176,049*	*4,555,052*	*5,276,516*	*6,846,894*	*8,814,994*
90%	Overselling-AII	5,424,936	5,490,250	5,550,971	5,655,302	5,943,170	6,509,216
	Overselling-RAB	1,600,753	1,973,002	2,198,949	2,606,848	3,444,900	4,466,895
	Total overselling	*7,025,689*	*7,463,252*	*7,749,920*	*8,262,150*	*9,388,070*	*10,976,111*
85%	Overselling-AII	8,272,823	8,309,523	8,346,562	8,422,607	8,585,321	8,867,700
	Overselling-RAB	2,498,052	2,735,670	2,884,929	3,167,271	3,801,149	4,637,342
	Total overselling	*10,770,875*	*11,045,193*	*11,231,491*	*11,589,879*	*12,386,470*	*13,505,041*

Table B-2 (continued)

Results for Alternative Specifications of the Commitment Period Reserve: Average quantity of restricted sales of quota surplus to compliance needs (a) by Annex II countries, (b) by the Rest of Annex B countries, and (c) by all Annex B countries

(1,000 tCO_2 equivalent)

Average of 500 random runs for each country

Y = Percentage of Initial Assigned Amount		**X = Percentage of Five Times Actual Emissions**					
		105%	**100%**	**98%**	**95%**	**90%**	**85%**
100%	Restricted Sales-AII	211,002	30,848	2,325	792	372	149
	Restricted Sales-RAB	325,788	72,494	35,452	11,859	1,882	519
	Total Restricted Sales	*536,790*	*103,341*	*37,777*	*12,651*	*2,255*	*667*
98%	Restricted Sales-AII	151,785	23,954	1,752	775	366	146
	Restricted Sales-RAB	276,885	61,333	29,798	10,380	1,874	519
	Total Restricted Sales	*428,671*	*85,286*	*31,550*	*11,155*	*2,241*	*665*
95%	Restricted Sales-AII	94,226	4,785	1,483	750	356	142
	Restricted Sales-RAB	211,449	45,312	21,917	8,247	1,845	518
	Total Restricted Sales	*305,675*	*50,097*	*23,401*	*8,997*	*2,201*	*660*
90%	Restricted Sales-AII	59,478	2,157	986	694	327	132
	Restricted Sales-RAB	121,711	26,724	13,879	6,531	1,771	511
	Total Restricted Sales	*181,189*	*28,881*	*14,866*	*7,224*	*2,098*	*643*
85%	Restricted Sales-AII	4,512	1,136	857	611	293	118
	Restricted Sales-RAB	42,129	14,627	9,270	4,979	1,638	497
	Total Restricted Sales	*46,641*	*15,763*	*10,097*	*5,590*	*1,931*	*615*

Table B-3

Results for Alternative Specifications of the Commitment Period Reserve: Average quantity of potential non-compliance due to overselling (a) by Annex II countries, (b) by the Rest of Annex B countries, (c) by all Annex B countries

(1,000 tCO_2 equivalent)

Average of 500 random runs for each country

Russian Federation Sensitivity scenario

Y = Percentage of Initial Assigned Amount		**X = Percentage of Five Times Actual Emissions**					
		105%	**100%**	**98%**	**95%**	**90%**	**85%**
100%	Overselling-AII	5,158	124,212	281,636	644,122	1,462	2,566,754
	Overselling-RAB	292,537	717,149	982,217	1,445,993	2,317,828	3,261,211
	Total overselling	*297,695*	*841,362*	*1,263,852*	*2,090,115*	*3,780,298*	*5,827,965*
98%	Overselling-AII	1,044,679	1,138,807	1,265,012	1,560,203	2,284,641	3,263,632
	Overselling-RAB	344,534	760,398	1,018,858	1,472,795	2,329,705	3,264,605
	Total overselling	*1,389,213*	*1,899,205*	*2,283,870*	*3,032,999*	*4,614,347*	*6,528,237*
95%	Overselling-AII	2,648,892	2,729,107	2,813,516	3,018,854	3,576,186	4,413,024
	Overselling-RAB	440,653	841,647	1,089,731	1,525,977	2,358,353	3,273,520
	Total overselling	*3,089,545*	*3,570,755*	*3,903,247*	*4,544,830*	*5,934,539*	*7,686,544*
90%	Overselling-AII	5,424,936	5,490,250	5,550,971	5,655,302	5,943,170	6,509,216
	Overselling-RAB	655,849	1,027,137	1,255,211	1,658,484	2,437,853	3,311,064
	Total overselling	*6,080,784*	*6,517,387*	*6,806,182*	*7,313,786*	*8,380,993*	*9,820,280*
85%	Overselling-AII	8,272,823	8,309,523	8,346,562	8,422,607	8,585,321	8,867,700
	Overselling-RAB	972,511	1,2984	1,496,595	1,856,635	2,572,604	3,389,332
	Total overselling	*9,245,334*	*9,607,507*	*9,843,156*	*10,279,243*	*11,157,925*	*12,257,031*

Table B-3 (continued)

Results for Alternative Specifications of the Commitment Period Reserve: Average quantity of restricted sales of quota surplus to compliance needs (a) by Annex II countries, (b) by the Rest of Annex B countries, and (c) by all Annex B countries

(1,000 tCO_2 equivalent)

Average of 500 random runs for each country

Russian Federation Sensitivity scenario

Y = Percentage of Initial Assigned Amount		**X = Percentage of Five Times Actual Emissions**					
		105%	**100%**	**98%**	**95%**	**90%**	**85%**
100%	Restricted Sales-AII	211,002	30,848	2,325	792	372	149
	Restricted Sales-RAB	645,425	232,789	148,524	74,714	18,361	2,173
	Total Restricted Sales	*856,427*	*263,637*	*150,849*	*75,506*	*18,733*	*2,321*
98%	Restricted Sales-AII	151,785	23,954	1,752	775	366	146
	Restricted Sales-RAB	629,607	229,962	147,455	74,465	18,352	2,173
	Total Restricted Sales	*781,393*	*253,915*	*149,207*	*75,240*	*18,719*	*2,319*
95%	Restricted Sales-AII	94,226	4,785	1,483	750	356	142
	Restricted Sales-RAB	604,901	225,588	145,750	74,009	18,324	2,172
	Total Restricted Sales	*699,126*	*230,373*	*147,234*	*74,760*	*18,680*	*2,313*
90%	Restricted Sales-AII	59,478	2,157	986	694	327	132
	Restricted Sales-RAB	549,677	217,417	142,516	73,301	18,249	2,165
	Total Restricted Sales	*609,155*	*219,573*	*143,502*	*73,995*	*18,576*	*2,297*
85%	Restricted Sales-AII	4,512	1,136	857	611	293	118
	Restricted Sales-RAB	471,974	204,301	137,655	71,991	18,116	2,151
	Total Restricted Sales	*476,486*	*205,437*	*138,512*	*72,602*	*18,409*	*2,269*

Table B-4

Temporarily restricted Sales of Surplus Quota by Country for Different Specifications of the Commitment Period Reserve
***Percent* of 500 random runs in which sales of surplus quota are restricted**
***Average* and *Maximum* quantity of temporarily restricted sales of surplus quota**
(1,000 tCO_2 equivalent)

Country	**X = 105%**			**X = 100%**		
Annex II Parties	**Y = 98%**	**Y = 95%**	**Y = 90%**	**Y = 98%**	**Y = 95%**	**Y = 90%**
Australia						
Austria						
Belgium						
Canada						
Denmark	0.2 3,791 3,791			0.2 3,791 3,791		
Finland	100 16,041 29,876	96 7,973 21,247	2 1,007 3,051	66 5,229 19,355	64 4,118 14,436	1 1,256 3,051
France	98 93,816 216,526	98 93,778 216,526	98 78,933 177,505	24 23,286 91,025	24 23,286 91,025	24 22,804 89,527
Germany	2 42,698 132,794			2 32,549 93,923		
Greece	100 26,516 59,500	100 25,619 50,691	82 9,681 31,838	35 6,588 28,960	35 6,588 28,960	28 4,814 17,805
Iceland						
Ireland						
Italy	100 41,640 60,182			10 3,281 14,133		
Japan						
Luxembourg	64 4,409 14,293	64 4,347 12,836	64 4,128 12,206	52 3,482 13,127	52 3,467 12,836	52 3,337 11,408
Netherlands						
New Zealand						
Norway						
Portugal	100 17,291 18,748	100 4,265 6,008		1 223 404	1 223 404	
Spain						
Sweden						
Switzerland						
United Kingdom						
United States						

Rest of Annex B						
Bulgaria	5 10,694 30,468	2 7,960 17,973		2 7,281 19,209	0.4 7,255 10,963	
Croatia	75 9,143 26,434	74 8,950 26,434	73 7,781 26,338	47 6,396 19,920	47 6,320 19,920	47 5,867 19,920
Czech Republic	0.4 10,805 13,128			0.4 13,128 13,128		
Estonia	64 11,209 39,282	64 11,209 39,282	64 11,209 39,282	44 8,732 32,025	44 8,732 32,025	44 8,732 32,025
Hungary	82 21,972 68,857	76 18,568 62,571	47 12,137 47,903	45 13,896 48,118	42 12,152 47,893	26 8,697 40,908
Latvia	60 14,949 48,369	60 14,901 48,369	60 14,710 48,369	50 11,822 41,869	50 11,788 41,869	50 11,692 41,869
Lithuania	1 4,036 7,676	1 1,372 2,603		0.4 4,191 7,676	0.2 562 562	
Poland	53 84,416 272,170	31 62,355 233,621	6 38,760 103,118	28 68,402 196,289	17 57,713 149,235	3 30,526 99,140
Romania	64 80,882 282,911	64 78,784 275,226	61 73,167 229,590	39 62,239 250,221	39 61,321 243,525	38 58,798 209,780
Russian Federation	49 490,677 2,124,349	31 414,585 1,668,299	9 276,428 908,216	27 377,974 2,122,415	18 314,725 1,668,299	5 229,509 908,216
Sensitivity scenario	69 820,555 2,877,760	69 820,555 2,877,760	69 820,555 2,877,760	44 641,479 2,280,133	44 641,479 2,280,133	44 641,479 2,280,133
Slovakia	24 7,763 30,427	10 6,429 20,354	1 1,706 3,565	13 5,980 24,087	5 6,272 18,510	1 2,269 3,565
Slovenia						
Ukraine	85 162,762 480,533	85 160,492 453,185	83 123,322 388,671	30 71,644 275,974	30 71,638 275,974	29 63,615 250,281

Notes:
1. The top figure in each cell is the percentage of the 500 random runs in which sales of surplus quota are temporarily restricted.
2. The middle figure in each cell is the average quantity of surplus quota in runs where sales are temporarily restricted (1,000 tCO_2 equivalent). To get the average quantity of surplus quota sales temporarily restricted for all 500 runs multiply the average by the percentage (expressed as a decimal). For example, for the Ukraine under the X = 105% and Y = 98% specification, the average for the 85% of the runs where sales are temporarily restricted are 162,749. The average for all 500 runs is 162,749 * 0.85 = 138,337 (1,000 tCO_2 equivalent).
3. The bottom figure in each cell is the maximum quantity of surplus sales temporarily restricted in 1,000 tCO_2 equivalent.

Country	**X = 95%**			**X = 90%**		
Annex II Parties	**Y = 98%**	**Y = 95%**	**Y = 90%**	**Y = 98%**	**Y = 95%**	**Y = 90%**
Australia						
Austria						
Belgium						
Canada						
Denmark						
Finland	0.2 1,629 1,629	0.2 1,629 1,629				
France						
Germany						
Greece						
Iceland						
Ireland						
Italy						
Japan						
Luxembourg	36 2,790 10,806	36 2,804 10,806	36 2,756 10,806	21 2,205 8,485	21 2,223 8,485	21 2,223 8,485
Netherlands						
New Zealand						
Norway						
Portugal						
Spain						
Sweden						
Switzerland						
United Kingdom						
United States						
Rest of Annex B						
Bulgaria	1 8,419 18,234					
Croatia	19 4,453 13,503	19 4,409 13,503	19 4,157 13,503	4 2,619 7,085	4 2,619 7,085	4 2,718 7,085
Czech Republic	0.2 2,024 2,024					
Estonia	27 6,207 24,767	27 6,207 24,767	27 6,207 24,767	10 5,751 17,510	10 5,751 17,510	10 5,751 17,510
Hungary	10 9,122 24,971	10 8,195 24,971	6 7,072 24,971	0.4 1,413 2,049	0.4 1,413 2,049	0.4 1,413 2,049
Latvia	37 9,424 35,369	37 9,407 35,369	37 9,341 35,369	23 7,666 28,869	23 7,666 28,829	23 7,641 28,869
Lithuania						

Poland	7 36,548 105,146	5 31,601 93,263	2 11,133 23,782	0.2 25,676 25,676		
Romania	19 47,966 187,525	19 47,542 187,525	18 47,565 177,882	6 37,988 124,830	6 37,629 124,830	6 38,073 124,830
Russian Federation	9 279,298 1,377,631	6 232,643 1,377,631	2 244,450 980,216	1 318,015 632,846	1 318,985 632,846	0.2 632,846 632,846
Sensitivity scenario	24 454,408 1,756,005	24 454,408 1,756,005	24 454,408 1,756,005	9 321,966 1,263,062	9 321,966 1,263,062	9 321,966 1,263,062
Slovakia	4 4,628 11,101	1 5,929 11,101	0.4 2,363 2,605	1 2,984 4,139		
Slovenia						
Ukraine	1 39,621 64,262	1 39,621 64,262	1 37,597 64,262			

Notes:
1. The top figure in each cell is the percentage of the 500 random runs in which sales of surplus quota are temporarily restricted.
2. The middle figure in each cell is the average quantity of surplus quota in runs where sales are temporarily restricted (1,000 tCO_2 equivalent). To get the average quantity of surplus quota sales temporarily restricted for all 500 runs multiply the average by the percentage (expressed as a decimal). For example, for the Ukraine under the X = 105% and Y = 98% specification, the average for the 85% of the runs where sales are temporarily restricted are 162,749. The average for all 500 runs is 162,749 * 0.85 = 138,337 (1,000 tCO_2 equivalent).
3. The bottom figure in each cell is the maximum quantity of surplus sales temporarily restricted in 1,000 tCO_2 equivalent.

Table B-5
Least-Cost, Full-Compliance Case with
Reference Scenario Emissions Projection for the Russian Federation
(million metric tons of carbon equivalent)

	2008	2012	Total (2008-2012)
OECD			
BAU Emissions	3,730	3,827	18,907
Domestic Reductions	149	200	915
Actual Emissions	3,580	3,611	17,991
CDM	221	314	1,344
JI	12	18	75
IET	120	52	438
Assigned Amount	3,227	3,227	16,135
Rest of Annex B			
BAU Emissions	1,321	1,424	6,858
Domestic Reductions	40	59	248
JI	12	18	75
Actual Emissions	1,269	1,348	6,550
Assigned Amount Issued	1,410	1,410	7,049
Assigned Available for IET	141	62	499
Non-Annex B			
BAU Emissions	2,629	2,879	13,747
CDM	221	314	1,344
Actual Emissions	2,408	2,565	12,403
Prices -- (US1995$/tC)			
	$11.00	$19.00	
Costs -- Present Value in 2008 (billion US1995$)			
OECD compliance	$4.33	$7.01	$28.67
Rest of Annex B compliance*	-$1.16	-$0.92	-$5.05
Non-Annex B compliance*	-$1.82	-$3.66	-$13.70
Total compliance	$1.35	$2.42	$9.93
Note: * Negative values indicate net revenue rather than a net cost.			

Table B-6
Least-Cost, Full-Compliance Case with
Sensitivity Scenario Emissions Projection for the Russian Federation
(million metric tons of carbon equivalent)

	2008	2012	Total (2008-2012)
OECD			
BAU Emissions	3,730	3,827	18,907
Domestic Reductions	62	110	435
Actual Emissions	3,667	3,716	18,471
CDM	97	166	663
JI	5	9	34
IET	339	315	1,640
Assigned Amount	3,227	3,227	16,135
Rest of Annex B			
BAU Emissions	1,064	1,119	5,451
Domestic Reductions	16	29	113
JI	5	9	34
Actual Emissions	1,044	1,082	5,311
Assigned Amount Issued	1,410	1,410	7,049
Assigned Available for IET	366	328	1,738
Non-Annex B			
BAU Emissions	2,629	2,879	13,747
CDM	97	166	663
Actual Emissions	2,532	2,713	13,084
Prices -- (US1995$/tC)			
	$3.00	$7.00	
Costs -- Present Value in 2008 (billion US1995$)			
OECD compliance	$1.33	$2.93	$10.77
Rest of Annex B compliance*	-$0.96	-$2.08	-$7.20
Non-Annex B compliance*	-$0.22	-$0.71	-$2.29
Total compliance	$0.15	$0.13	$1.28
Note: * Negative values indicate net revenue rather than a net cost.			

Table B-7

Relative Costs and Non-Compliance for Different Specifications of the Commitment Period Reserve Rule

		Average		Minimum		Maximum	
		Excess	Compliance	Excess	Compliance	Excess	Compliance
X	Y	Emissions	Cost	Emissions	Cost	Emissions	Cost
105	100	3.9%	101.1%	-29.0%	54.9%	34.8%	169.6%
	98	4.8%	99.7%	-24.6%	53.7%	34.8%	166.2%
	95	6.3%	97.3%	-18.9%	52.3%	34.8%	162.4%
	90	10.8%	89.6%	-11.4%	45.4%	40.1%	148.0%
	85	18.0%	79.4%	-0.9%	34.9%	43.2%	124.2%
	80	29.1%	63.4%	10.5%	22.1%	49.6%	104.1%
	70	54.6%	28.0%	33.3%	6.0%	76.0%	67.1%
100	100	11.1%	90.9%	-18.2%	47.3%	36.4%	144.8%
	98	11.6%	90.1%	-17.6%	47.3%	38.1%	144.8%
	95	12.7%	88.2%	-15.5%	45.2%	38.1%	143.1%
	90	15.6%	83.0%	-6.1%	42.8%	40.1%	139.7%
	85	20.8%	75.6%	1.6%	32.7%	1.6%	32.7%
	80	30.1%	62.2%	12.6%	22.5%	53.2%	104.1%
	70	54.8%	27.8%	33.3%	6.0%	76.0%	67.1%
98	100	14.2%	86.6%	-13.8%	43.3%	40.0%	138.0%
	98	14.6%	85.9%	-13.1%	43.5%	40.6%	138.0%
	95	15.4%	84.2%	-11.6%	42.0%	41.1%	136.2%
	90	17.8%	80.1%	-4.2%	36.3%	42.7%	134.4%
	85	22.5%	73.2%	3.0%	31.5%	45.7%	124.2%
	80	30.7%	61.3%	13.3%	22.5%	54.8%	102.6%
	70	54.5%	27.7%	33.3%	6.0%	76.8%	67.1%
95	100	18.7%	80.2%	-9.7%	34.8%	45.1%	146.3%
	98	19.0%	79.3%	-9.0%	34.8%	46.8%	145.2%
	95	19.7%	78.3%	-8.3%	33.6%	46.2%	130.6%
	90	21.4%	75.3%	-3.3%	32.0%	47.9%	130.6%
	85	25.2%	69.1%	4.6%	30.2%	50.6%	117.2%
	80	32.1%	59.4%	13.8%	21.3%	54.8%	99.5%
	70	55.0%	27.5%	33.3%	6.0%	76.8%	67.1%
90	100	27.3%	67.6%	-1.5%	23.8%	54.9%	129.8%
	98	27.4%	67.4%	-1.5%	23.8%	54.9%	119.9%
	95	27.7%	66.9%	-1.5%	23.8%	54.9%	118.3%
	90	28.7%	65.1%	0.6%	22.4%	56.4%	106.7%
	85	31.0%	61.2%	7.4%	22.4%	56.7%	102.6%
	80	35.6%	54.5%	15.1%	17.8%	58.0%	92.8%
	70	55.4%	27.0%	33.3%	6.0%	77.6%	65.6%
85	100	36.7%	53.8%	6.3%	14.9%	66.0%	110.8%
	98	36.7%	53.7%	6.3%	14.9%	66.0%	110.8%
	95	36.8%	53.6%	6.3%	14.9%	66.7%	110.8%
	90	37.3%	52.8%	8.9%	14.9%	66.8%	99.7%
	85	38.4%	51.0%	11.7%	13.9%	67.5%	91.7%
	80	41.2%	46.8%	18.5%	12.6%	68.3%	91.7%
	70	56.2%	25.8%	33.3%	6.0%	77.6%	65.6%
80	100	46.8%	39.3%	17.4%	6.0%	78.6%	89.6%
	98	46.8%	39.3%	17.4%	6.0%	78.6%	89.6%
	95	46.9%	39.3%	17.4%	6.0%	78.6%	89.6%

	90	46.9%	39.2%	17.4%	6.0%	78.3%	89.6%
	85	47.3%	38.5%	19.1%	6.0%	78.3%	89.6%
	80	48.5%	36.6%	23.7%	6.0%	79.0%	83.4%
	70	58.5%	22.8%	33.3%	6.0%	82.4%	62.6%
70	100	65.4%	13.6%	33.3%	6.0%	100.0%	59.3%
	98	65.4%	13.6%	33.3%	6.0%	100.0%	59.3%
	95	65.4%	13.6%	33.3%	6.0%	100.0%	59.3%
	90	65.4%	13.6%	33.3%	6.0%	100.0%	59.3%
	85	65.4%	13.6%	33.3%	6.0%	100.0%	59.3%
	80	65.5%	13.5%	33.3%	6.0%	100.0%	59.3%
	70	66.9%	11.6%	33.3%	6.0%	100.0%	59.3%

Note. Excess emissions are expressed as a percentage of the maximum non-compliance 2,988 GtC. Specifications that lead to over-compliance have negative values for excess emissions. Compliance cost is the Annex II compliance cost expressed as a percentage of the Annex II compliance cost for the least-cost, full-compliance case, $28.67 billion (US$1995 in 2010). Specifications with over-compliance tend to have costs in excess of 100%, while specifications with excess emissions tend to have costs less than those for the least-cost, full-compliance case, hence, costs less than 100%.

Table B-8

Relative Costs and Non-Compliance for Different Specifications of the Commitment Period Reserve Rule, Russian Federation Sensitivity Scenario

		Average		Minimum		Maximum	
		Excess	Compliance	Excess	Compliance	Excess	Compliance
X	Y	Emissions	Cost	Emissions	Cost	Emissions	Cost
105	100	-6.7%	124.9%	-51.2%	19.1%	36.7%	295.0%
	98	-5.9%	122.4%	-51.2%	19.1%	37.0%	295.0%
	95	-4.5%	118.4%	-50.3%	19.1%	37.9%	292.6%
	90	-1.6%	109.6%	-47.3%	15.9%	40.5%	285.0%
	85	2.4%	97.1%	-40.0%	15.9%	47.2%	240.3%
	80	2.4%	97.1%	-40.0%	15.9%	47.2%	240.3%
	70	19.1%	47.3%	-17.4%	15.9%	66.5%	162.4%
100	100	1.8%	99.0%	-40.3%	15.9%	47.4%	264.7%
	98	2.3%	97.4%	-40.3%	15.9%	47.4%	264.7%
	95	3.3%	94.6%	-38.3%	15.9%	48.4%	261.5%
	90	5.3%	88.1%	-36.0%	15.9%	49.3%	258.2%
	85	8.3%	79.2%	-34.6%	15.9%	52.4%	220.3%
	80	12.5%	66.5%	-34.6%	15.9%	58.3%	181.8%
	70	21.9%	39.4%	-17.4%	15.9%	66.5%	162.4%
98	100	5.3%	88.3%	-35.1%	15.9%	51.4%	233.6%
	98	5.7%	87.1%	-35.1%	15.9%	51.4%	227.4%
	95	6.5%	84.6%	-34.6%	15.9%	52.4%	223.7%
	90	8.3%	79.0%	-34.6%	15.9%	53.5%	220.2%
	85	10.8%	71.5%	-34.6%	15.9%	55.8%	213.0%
	80	14.5%	60.7%	-34.6%	15.9%	61.1%	170.4%
	70	23.1%	36.2%	-17.4%	15.9%	66.5%	162.4%
95	100	10.6%	72.1%	-34.6%	15.9%	57.0%	189.7%
	98	10.9%	71.2%	-34.6%	15.9%	58.3%	189.7%
	95	11.5%	69.7%	-34.6%	15.9%	58.3%	186.2%
	90	12.8%	65.8%	-34.6%	15.9%	59.6%	186.2%
	85	14.9%	59.8%	-34.6%	15.9%	61.1%	178.5%
	80	17.7%	51.7%	-33.9%	15.9%	64.4%	170.4%
	70	69.1%	73.3%	-41.8%	15.9%	96.5%	178.5%
90	100	19.1%	47.5%	-32.1%	15.9%	66.5%	170.3%
	98	34.4%	179.4%	-1.9%	63.4%	69.0%	319.1%
	95	34.8%	178.0%	-1.9%	63.4%	69.0%	314.9%
	90	36.1%	173.2%	0.7%	59.7%	70.9%	284.2%
	85	39.0%	163.0%	9.3%	59.7%	71.3%	273.1%
	80	44.8%	145.2%	19.0%	47.5%	72.9%	247.1%
	70	26.6%	26.5%	-17.4%	15.9%	66.5%	121.1%
85	100	46.2%	143.1%	7.9%	39.8%	83.0%	295.0%
	98	46.2%	143.0%	7.9%	39.8%	83.0%	295.0%
	95	46.3%	142.7%	7.9%	39.8%	83.9%	295.0%
	90	46.8%	140.5%	11.2%	39.8%	83.9%	265.3%
	85	48.3%	135.8%	14.8%	37.1%	84.9%	244.0%
	80	51.8%	124.7%	23.2%	33.6%	85.8%	244.0%
	70	28.0%	23.0%	-17.4%	15.9%	66.5%	83.6%
80	100	58.9%	104.7%	21.9%	15.9%	98.8%	238.5%
	98	58.9%	104.6%	21.9%	15.9%	98.8%	238.5%

	95	58.9%	104.6%	21.9%	15.9%	98.8%	238.5%
	90	59.0%	104.2%	21.9%	15.9%	98.4%	238.5%
	85	59.5%	102.6%	24.0%	15.9%	99.3%	238.5%
	80	61.0%	97.4%	29.8%	15.9%	100.0%	222.0%
	70	28.5%	21.7%	-17.4%	15.9%	66.5%	50.5%
70	100	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%
	98	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%
	95	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%
	90	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%
	85	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%
	80	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%
	70	28.6%	21.4%	-17.4%	15.9%	66.5%	25.3%

Note. Excess emissions are expressed as a percentage of the maximum non-compliance 2,377 GtC. Specifications that lead to over-compliance have negative values for excess emissions. Compliance cost is the Annex II compliance cost expressed as a percentage of the Annex II compliance cost for the least-cost, full-compliance case, $10.77 billion (US$1995 in 2010). Specifications with over-compliance tend to have costs in excess of 100%, while specifications with excess emissions tend to have costs less than those for the least-cost, full-compliance case, hence, costs less than 100%.

Table B-9

Estimated Liquidity of the International Emissions Trading Market Under Different Specifications of the Commitment Period Reserve

X	Y	Annual Measures				
		1	**3**	**5**	**7**	**9**
105	**100**	15.19	332.08	358.75	317.48	40.11
105	**98**	22.65	333.27	359.66	318.61	40.99
105	**95**	34.28	335.44	361.33	320.69	42.60
105	**90**	54.93	340.28	364.73	325.32	45.87
105	**85**	77.45	346.97	369.02	331.71	50.01
105	**70**	150.44	352.82	362.92	337.30	44.13
100	**100**	21.88	338.34	362.65	323.46	43.87
100	**98**	28.48	338.87	363.02	323.97	44.23
100	**95**	39.15	340.21	364.01	325.25	45.18
100	**90**	58.35	343.67	366.53	328.55	47.60
100	**85**	79.22	348.72	369.87	333.39	50.82
100	**70**	150.62	372.58	382.64	356.20	63.12
98	**100**	25.21	341.21	364.53	326.21	45.68
95	**98**	36.74	346.07	367.74	330.85	48.77
95	**95**	45.78	346.42	367.96	331.19	48.99
95	**90**	63.12	348.34	369.30	333.02	50.27
95	**85**	82.44	351.91	371.61	336.44	52.50
95	**70**	150.90	372.87	382.85	356.47	63.32
95	**100**	30.96	345.74	367.57	330.54	48.61
90	**98**	47.15	353.69	372.70	338.14	53.55
90	**95**	54.94	353.84	372.75	338.28	53.59
90	**90**	69.69	354.51	373.07	338.91	53.91
90	**85**	87.09	356.47	374.28	340.80	55.07
90	**80**	106.55	360.18	376.50	344.34	57.21
90	**70**	151.39	373.35	383.20	356.93	63.66
85	**100**	55.53	361.71	377.67	345.80	58.34
85	**98**	59.61	361.72	377.67	345.81	58.34
85	**95**	66.37	333.27	349.20	318.61	30.92
85	**90**	78.91	361.94	377.72	346.03	58.39
85	**85**	93.59	362.59	378.01	346.64	58.66
85	**80**	111.07	364.61	379.13	348.58	59.75
85	**70**	152.42	374.37	383.96	357.91	64.40
80	**100**	72.85	369.82	382.49	353.56	62.98
80	**98**	75.20	369.83	382.49	353.56	62.98
80	**95**	80.01	369.84	382.50	353.57	62.99
80	**90**	90.50	369.88	382.52	353.61	63.00
80	**85**	102.90	370.04	382.56	353.77	63.04
80	**80**	117.50	370.67	382.80	354.37	63.27
80	**70**	154.85	376.78	385.63	360.21	66.00
70	**100**	124.06	386.10	392.66	369.12	72.78
70	**98**	124.06	386.10	392.66	369.12	72.78
70	**95**	124.06	332.08	338.65	317.48	20.76
70	**90**	124.60	386.10	392.66	369.12	72.78
70	**85**	129.37	386.10	392.66	369.12	72.77
70	**80**	138.86	386.13	392.67	369.15	72.78
70	**70**	165.31	386.84	392.91	369.83	73.02

X	Y	Commitment Period Measure				
		2	4	6	8	10
105	**100**	3.04	66.42	71.75	69.14	8.03
105	**98**	4.53	66.65	71.93	69.31	8.20
105	**95**	6.86	67.09	72.27	69.63	8.52
105	**90**	10.99	68.06	72.95	70.29	9.18
105	**85**	15.49	69.39	73.80	71.12	10.01
105	**70**	30.09	70.56	72.58	69.94	8.83
100	**100**	4.38	67.67	72.53	69.89	8.78
100	**98**	5.70	67.77	72.60	69.96	8.85
100	**95**	7.83	68.04	72.80	70.15	9.04
100	**90**	11.67	68.73	73.31	70.63	9.53
100	**85**	15.84	69.74	73.97	71.28	10.17
100	**70**	30.12	74.52	76.53	73.74	12.63
98	**100**	5.04	68.24	72.91	70.25	9.14
95	**98**	7.35	69.21	73.55	70.87	9.76
95	**95**	9.16	69.28	73.59	70.91	9.80
95	**90**	12.62	69.67	73.86	71.17	10.06
95	**85**	16.49	70.38	74.32	71.61	10.51
95	**70**	30.18	74.57	76.57	73.78	12.67
95	**100**	6.19	69.15	73.51	70.84	9.73
90	**98**	9.43	70.74	74.54	71.82	10.72
90	**95**	10.99	70.77	74.55	71.83	10.72
90	**90**	13.94	70.90	74.61	71.90	10.79
90	**85**	17.42	71.29	74.86	72.13	11.02
90	**80**	21.31	72.04	75.30	72.56	11.45
90	**70**	30.28	74.67	76.64	73.85	12.74
85	**100**	11.11	72.34	75.53	72.78	11.67
85	**98**	11.92	72.34	75.53	72.78	11.67
85	**95**	13.27	66.65	69.84	67.30	6.19
85	**90**	15.78	72.39	75.54	72.79	11.68
85	**85**	18.72	72.52	75.60	72.85	11.74
85	**80**	22.21	72.92	75.83	73.06	11.96
85	**70**	30.48	74.87	76.79	73.99	12.89
80	**100**	14.57	73.96	76.50	73.71	12.60
80	**98**	15.04	73.97	76.50	73.71	12.60
80	**95**	16.00	73.97	76.50	73.71	12.60
80	**90**	18.10	73.98	76.50	73.72	12.61
80	**85**	20.58	74.01	76.51	73.72	12.61
80	**80**	23.50	74.13	76.56	73.77	12.66
80	**70**	30.97	75.36	77.13	74.32	13.21
70	**100**	24.81	77.22	78.53	75.67	14.56
70	**98**	24.81	77.22	78.53	75.67	14.56
70	**95**	24.81	66.42	67.73	65.26	4.15
70	**90**	24.92	77.22	78.53	75.67	14.56
70	**85**	25.87	77.22	78.53	75.67	14.56
70	**80**	27.77	77.23	78.53	75.67	14.56
70	**70**	33.06	77.37	78.58	75.72	14.61

Table B-10

International Liquidity for Domestic Emissions Trading Programs by Country for Different Specifications of the Commitment Period Reserve

Average value and minimum value

Country	Downstream Measure 1									Downstream Measure 2		
	Y = 98%			Y = 95%			Y = 90%			Y = 98%		
	X =			X =			X =			X =		
Annex II Parties	**100**	**95**	**90**	**100**	**95**	**90**	**100**	**95**	**90**	**100**	**95**	**90**
Australia	28	28	29	70	70	71	141	141	141	23	23	24
	26	26	27	64	64	64	129	129	129	21	21	22
Austria	72	72	87	179	180	182	359	359	359	64	65	77
	51	51	61	127	127	129	255	255	255	45	46	55
Belgium	46	46	46	114	114	114	228	228	228	36	36	36
	37	37	37	92	92	92	184	184	184	29	29	29
Canada	42	42	46	105	105	106	210	210	210	34	34	37
	36	36	39	90	90	90	179	179	179	29	29	32
Denmark	34	41	59	75	79	90	145	146	151	24	30	43
	24	30	43	54	57	65	105	106	109	16	20	28
Finland	108	188	268	117	188	268	174	198	268	118	206	294
	73	127	182	79	127	182	118	134	182	80	139	198
France	705	893	***	705	893	***	705	893	***	795	***	***
	503	637	771	503	637	771	503	637	771	562	711	862
Germany	33	54	109	75	83	117	149	150	157	33	53	106
	29	48	96	66	73	103	131	131	138	28	46	92
Greece	153	205	258	153	205	258	155	205	258	169	228	286
	133	179	225	133	179	225	135	179	225	153	206	258
Iceland	***	***	***	***	***	***	***	***	***	***	***	***
	***	***	***	***	***	***	***	***	***	***	***	***
Ireland	47	77	190	117	120	191	235	235	237	45	73	181
	40	65	160	99	101	160	197	197	199	38	63	154
Italy	59	152	249	100	152	249	199	199	249	61	157	257
	51	131	214	85	131	214	171	171	214	53	135	221
Japan	37	37	37	93	93	93	186	186	186	30	30	30
	33	33	33	83	83	83	165	165	165	27	27	27
Luxembourg	***	***	***	***	***	***	***	***	***	***	***	***
	559	613	668	562	615	669	570	619	672	904	992	***
Netherlands	42	42	47	104	104	105	208	208	208	35	36	40
	36	37	41	91	91	92	182	182	182	32	32	36
New Zealand	123	123	123	307	307	307	613	613	613	104	104	104
	85	85	85	212	212	212	423	423	423	73	73	73
Norway	64	64	73	159	159	161	318	318	318	56	56	64
	52	52	59	129	129	130	257	257	257	45	45	52
Portugal	167	257	347	167	257	347	200	257	347	175	268	362
	139	213	287	139	213	287	166	212	287	145	223	301
Spain	43	69	150	101	108	156	201	201	208	40	65	142
	37	59	129	86	92	134	172	172	178	35	56	123
Sweden	63	67	116	158	159	171	316	316	317	56	59	103
	48	50	87	119	119	129	238	238	238	42	44	76
Switzerland	481	485	879	***	***	***	***	***	***	441	444	806
	321	324	587	803	803	832	***	***	***	299	301	546
United Kingdom	37	62	132	87	93	137	172	173	179	35	59	126
	32	53	114	74	80	118	148	149	154	31	51	109

United States	35	35	35	87	87	87	173	173	173	27	27	27
	31	31	31	79	79	79	157	157	157	25	25	25
Rest of Annex B												
Bulgaria	62	87	127	94	112	143	154	164	182	56	79	114
	40	57	82	61	73	93	100	107	119	41	57	82
Croatia	550	653	759	553	654	759	556	660	761	674	801	930
	350	417	484	352	417	484	361	421	485	456	542	629
Czech Republic	29	41	67	57	63	81	106	109	115	26	37	60
	20	29	47	40	45	57	75	77	82	19	23	45
Estonia	308	331	354	308	331	354	308	331	354	478	513	548
	195	209	224	195	209	224	195	209	224	299	321	343
Hungary	196	259	324	202	260	325	222	269	327	214	283	355
	149	197	247	154	198	247	169	204	249	151	200	251
Latvia	857	916	976	858	917	976	861	918	977	***	***	***
	434	464	494	434	464	494	436	465	494	676	722	770
Lithuania	73	109	164	102	129	173	162	176	202	65	98	147
	58	87	131	82	103	138	129	140	161	50	74	111
Poland	84	134	172	97	130	174	129	149	181	86	136	175
	67	107	138	77	104	139	103	119	145	66	106	136
Romania	248	285	323	249	286	323	253	287	324	304	349	395
	120	138	156	121	138	156	123	139	157	135	155	175
Russian Federation	220	296	386	240	306	389	289	336	402	219	296	385
	161	217	282	176	224	284	211	246	294	165	223	290
Sensitivity Case	847	912	976	847	912	976	847	912	976	***	***	***
	538	580	620	538	580	620	538	580	620	880	947	***
Slovakia	47	60	96	57	74	99	81	91	108	45	66	93
	35	52	73	44	57	75	62	69	82	35	51	73
Slovenia	41	41	41	102	102	102	204	204	204	37	37	37
	34	34	34	85	85	85	170	170	170	31	31	31
Ukraine	335	422	508	336	422	507	339	422	507	377	474	571
	168	211	254	168	211	254	170	211	254	190	238	287
Legend: *** indicates greater than 1,000%												

Country	Downstream Measure 2						Upstream Measure 3					
	Y = 95%			Y = 90%			Y = 98%			Y = 95%		
	X =			X =			X =			X =		
Annex II Parties	**100**	**95**	**90**	**100**	**95**	**90**	**100**	**95**	**90**	**100**	**95**	**90**
Australia	58	58	58	116	116	116	15	15	16	38	38	38
	53	53	54	107	107	107	14	14	15	35	35	35
Austria	160	160	163	321	321	321	16	16	20	41	41	41
	114	114	115	227	227	227	14	15	17	36	36	37
Belgium	90	90	90	181	181	181	13	13	13	32	32	32
	73	73	73	147	147	147	12	12	12	29	29	29
Canada	86	86	86	171	171	171	15	15	16	37	37	37
	73	73	74	146	146	146	13	13	14	32	32	32
Denmark	54	57	65	105	107	109	18	23	32	41	43	49
	36	38	43	69	70	72	14	17	24	31	32	37
Finland	128	206	294	190	217	294	42	72	103	45	72	103
	86	139	198	128	146	199	36	62	88	38	62	88
France	795	***	***	796	***	***	121	153	185	121	153	185
	562	712	862	563	712	862	110	139	168	110	139	168
Germany	74	81	115	146	146	154	14	22	45	31	34	48
	64	70	99	126	127	133	12	20	39	27	30	43
Greece	169	228	286	172	228	286	86	116	146	86	116	146
	153	206	258	155	206	258	77	103	129	77	103	129
Iceland	***	***	***	***	***	***	16	16	27	40	40	42
	***	***	***	***	***	***	14	14	24	35	35	37
Ireland	112	114	181	223	223	226	19	31	76	47	48	76
	95	97	154	189	189	191	17	28	70	43	44	70
Italy	103	157	257	206	206	257	20	52	84	34	52	84
	89	135	221	177	177	221	19	48	78	31	48	78
Japan	75	75	75	150	150	150	12	12	12	30	30	30
	68	68	68	136	136	136	11	11	11	27	27	27
Luxembourg	***	***	***	***	***	***	191	209	228	192	210	228
	910	995	***	922	***	***	102	112	122	103	113	127
Netherlands	88	88	89	177	177	177	14	14	15	34	34	34
	80	80	80	159	159	159	12	12	14	30	30	31
New Zealand	260	260	260	519	519	519	31	31	31	77	77	77
	182	182	182	364	364	364	28	28	28	70	70	70
Norway	140	140	142	280	280	280	20	20	23	49	49	50
	113	113	114	225	225	226	17	17	20	43	43	43
Portugal	175	268	362	209	268	362	67	103	140	67	103	140
	145	223	301	174	223	301	59	90	122	59	90	122
Spain	95	102	148	190	190	197	15	24	53	36	38	55
	83	88	128	165	165	170	14	22	48	32	34	50
Sweden	140	141	152	280	280	281	13	14	24	32	32	35
	104	104	113	208	208	208	11	12	21	28	28	30
Switzerland	***	***	***	***	***	***	13	13	24	33	33	34
	746	746	773	***	***	***	12	12	23	31	31	32
United Kingdom	83	90	132	165	165	172	14	24	51	33	36	53
	72	77	114	143	143	149	13	21	46	30	33	48
United States	67	67	67	135	135	135	12	12	12	31	31	31
	62	62	62	123	123	123	11	11	11	28	28	28
Rest of Annex B												

Bulgaria	85	102	129	139	148	164	36	50	73	54	65	83
	61	74	94	101	107	119	25	35	50	37	45	57
Croatia	678	802	930	694	809	932	166	197	228	167	197	229
	459	543	629	469	547	631	120	142	165	121	143	165
Czech Republic	51	57	72	95	97	103	16	23	38	32	36	46
	38	43	54	71	73	77	14	19	32	27	30	38
Estonia	478	513	548	478	513	548	259	278	297	259	278	297
	299	321	343	299	321	343	140	150	160	140	150	160
Hungary	221	285	356	243	294	358	89	117	147	92	118	148
	156	201	251	172	207	252	70	92	116	72	93	116
Latvia	***	***	***	***	***	***	358	383	407	358	383	407
	677	723	770	679	724	771	179	192	204	180	192	204
Lithuania	92	115	155	145	157	181	52	78	117	73	92	123
	70	88	118	110	119	137	28	42	63	39	49	66
Poland	99	132	177	132	151	184	50	79	102	57	77	103
	76	102	137	102	117	143	37	59	76	43	57	76
Romania	306	350	396	310	352	396	77	203	230	177	203	230
	135	155	176	138	156	176	117	135	152	118	135	152
Russian Federation	239	305	388	289	336	401	70	95	124	77	98	125
	181	230	292	218	253	302	52	69	90	56	72	91
Sensitivity Case	***	***	***	***	***	***	271	292	313	271	292	313
	880	947	***	880	947	***	173	186	199	173	186	199
Slovakia	56	72	96	79	88	104	42	62	87	52	67	90
	43	56	74	61	69	81	32	47	66	40	51	68
Slovenia	92	92	92	183	183	183	15	15	15	38	38	38
	76	76	76	153	153	153	13	13	13	33	33	33
Ukraine	377	474	571	381	474	571	140	176	212	140	176	212
	190	238	287	192	238	287	80	101	121	80	101	121
Legend: *** indicates greater than 1,000%												

Country	Upstream Measure 3			Upstream Measure 4								
	Y = 90%			Y = 98%			Y = 95%			Y = 90%		
	X =			X =			X =			X =		
Annex II Parties	**100**	**95**	**90**	**100**	**95**	**90**	**100**	**95**	**90**	**100**	**95**	**90**
Australia	77	77	77	13	13	13	32	32	32	63	63	63
	70	70	70	12	12	12	29	29	29	58	58	58
Austria	81	81	81	15	15	18	36	36	37	73	73	73
	72	72	72	13	13	15	32	32	32	64	64	64
Belgium	64	64	64	10	10	10	25	25	25	51	51	51
	58	58	58	9	9	9	23	23	23	46	46	46
Canada	73	73	73	12	12	13	30	30	30	60	60	60
	63	63	63	10	10	11	26	26	26	52	52	52
Denmark	79	80	82	13	16	23	29	31	36	57	58	60
	60	60	62	10	12	18	22	24	27	44	44	45
Finland	67	76	103	46	79	113	49	79	113	73	83	113
	57	65	88	39	68	97	42	68	97	63	72	97
France	121	153	185	136	172	209	136	172	209	136	172	209
	110	139	168	123	156	189	123	156	189	123	156	189
Germany	61	62	65	14	22	44	30	33	47	60	60	63
	54	54	57	12	19	39	27	29	42	53	53	56
Greece	88	116	146	96	129	161	96	129	161	97	129	161
	78	103	129	87	117	147	87	117	147	89	117	147
Iceland	79	70	79	14	15	24	36	36	38	71	71	71
	70	70	70	12	13	21	31	31	33	62	62	62
Ireland	93	93	94	18	29	72	44	45	72	89	89	90
	86	86	87	16	27	66	41	42	66	82	82	83
Italy	67	67	84	21	53	87	35	53	87	70	70	87
	62	62	78	19	49	81	32	49	81	65	65	81
Japan	59	59	59	10	10	10	24	24	24	48	48	48
	53	53	53	9	9	9	22	22	22	44	44	44
Luxembourg	194	211	229	280	306	334	281	307	335	285	310	336
	104	113	123	151	166	180	152	166	181	154	167	181
Netherlands	68	68	68	12	12	13	29	29	29	58	58	58
	61	61	61	10	10	12	26	26	26	52	52	52
New Zealand	154	154	154	26	26	26	65	65	65	131	131	131
	141	141	141	24	24	24	60	60	60	121	121	121
Norway	88	99	99	17	17	20	43	43	44	87	87	87
	86	86	86	14	15	17	36	36	37	72	72	72
Portugal	81	103	140	70	108	146	70	108	146	84	108	146
	71	90	122	62	95	128	62	95	128	74	95	128
Spain	71	71	74	14	23	51	34	36	53	68	68	70
	64	64	66	13	21	45	30	33	47	61	61	63
Sweden	64	64	64	11	12	21	28	29	31	57	57	57
	56	56	56	10	11	19	26	26	28	51	51	51
Switzerland	67	67	67	12	12	22	30	30	32	61	61	61
	62	62	62	11	11	21	29	29	30	57	57	57
United Kingdom	66	67	69	14	23	49	32	34	51	64	64	66
	60	60	62	12	21	44	29	31	46	58	58	60
United States	62	62	62	10	10	10	24	24	24	48	48	48
	56	56	56	9	9	9	22	22	22	44	44	44
Rest of Annex B												

Bulgaria	89	94	105	32	45	66	49	59	75	80	85	95
	61	65	72	24	34	50	37	44	56	60	64	71
Croatia	171	199	229	203	241	280	204	242	280	209	244	281
	123	144	166	142	168	195	142	169	196	146	170	196
Czech Republic	61	62	66	15	21	34	29	32	41	54	56	59
	50	51	55	12	17	28	24	27	34	45	46	49
Estonia	259	278	297	401	430	460	401	430	460	401	430	460
	140	150	160	227	244	261	227	244	261	227	244	261
Hungary	101	122	148	97	129	161	100	129	162	111	134	163
	79	96	160	71	93	117	73	94	117	80	97	118
Latvia	359	383	408	579	619	659	580	619	659	582	620	660
	180	192	204	281	301	320	281	300	320	282	301	320
Lithuania	115	125	144	46	70	104	65	82	110	103	112	129
	62	67	77	24	36	54	33	42	57	53	57	66
Poland	77	88	107	51	81	104	58	78	105	78	90	109
	57	66	80	37	59	76	43	57	77	57	65	80
Romania	180	204	230	215	247	280	216	247	280	219	249	280
	119	136	153	137	158	179	138	158	179	140	159	179
Russian Federation	93	108	129	70	95	123	77	98	124	92	108	128
	68	79	94	54	72	94	58	74	95	70	82	98
Sensitivity Case	271	292	313	428	461	493	428	461	493	428	461	493
	173	186	199	286	308	330	286	308	330	286	308	330
Slovakia	74	83	98	41	60	85	50	65	87	71	80	95
	56	63	74	32	46	66	39	51	67	56	62	74
Slovenia	76	76	76	14	14	14	34	34	34	69	69	69
	65	65	65	12	12	12	29	29	29	59	59	59
Ukraine	142	176	212	157	198	238	158	198	238	159	198	238
	81	101	121	87	110	132	87	110	132	88	110	132
Legend: *** indicates greater than 1,000%												

Appendix C

Production of Class I Ozone Depleting Substances in the United States, 1989 through 1996

Table C-1

Production of Class I Ozone Depleting Substances in the United States, 1989 through 1996

(ODP tons)

Year	Main CFCs	Halons	Other CFCs	Carbon tetrachloride	Methyl chloroform	Total[a]
1989	320,436	61,229	577	56,036	31,517	381,665
1990	199,697	51,401	?	?	29,453	251,098
1991	172,164	41,565	?	?	27,525	213,729
1992	152,730	25,843	75	12,126	25,723	216,497
1993	127,712	18,915	106	16,225	20,637	183,595
1994	78,208	0	101	15,225	5,795	99,329
1995	34,728	0	38	8,932	4,599	48,297
1996	676	0	0	11	448	1,135

Note: [a] Total regulated production of Class I ozone-depleting substances, CFCs and halons only for 1989 through 1991 and all groups of substances for 1992 through 1996.

Source: Oberthür, 1999, Table 2, p. 51; Table 4, p. 55; Table 10, p. 83; Table BI.1, p. 157; and Table BII.1, p. 168.