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FREEZING CARBON DIOXIDE (CO_2) EMISSIONS: AN OFFSET POLICY FOR SLOWING GLOBAL WARMING

Gary E. Marchant*

EXECUTIVE SUMMARY

Increased scientific attention to the problem of global warming has stimulated a vigorous search for appropriate policy responses at both the domestic and international levels. This paper examines one such response --- carbon dioxide (CO_2) offsets --- and analyzes various options for designing and implementing such a program. CO_2 offsets are a special type of emissions trading program - that allocates emission rights to existing sources and requires all incremental emissions to be offset either by the purchase of the equivalent number of rights or by increasing emission sinks.

Recent studies have pointed out that emission trading programs generally result in significant cost savings relative to "command and control" approaches. They also have demonstrated that the effectiveness of emission trading programs vary depending on their legal, administrative, and technical details.

The magnitude of the cost savings depends on the difference in the marginal costs of pollution control between different technologies and facilities. If the marginal costs vary significantly, the cost savings will be large, but if the costs are relatively uniform, there will be little potential for savings. The evidence indicates that there are large differences in the marginal costs of different methods for reducing CO_2 emissions. For example, removing CO_2 by investing in energy efficiency may cost $19 per ton, while depending on wind or solar technologies may cost more than $100 per ton.

Market mechanisms also provide a dynamic incentive for firms to develop new technologies and methods for larger and more cost effective reductions in emissions. Furthermore, they shift the locus of decision-making from government regulators to individual firms. Market mechanisms take advantage of the superior knowledge of company officials about the costs and opportunities of emission reductions, rather than trying to duplicate this knowledge in the staff of environmental regulatory agencies.

Emissions trading is an attractive policy option for reducing CO_2 emissions. However, there are several obstacles to the immediate adoption of an international CO_2 emission trading program. These include:

i) A lack of international institutions or machinery to monitor and enforce emission trades. International oversight of trading involving potentially thousands of private companies would be an administrative nightmare.

ii) The opposition of countries with centralized economies to an international trading program.

iii) Equity concerns voiced by developing countries about the ability of wealthy nations to buy-up the emissions rights from their poor brethren, thus limiting the latter's capacity for economic growth.

iv) Getting all countries to accept specific reduction targets may be difficult - at least

initially.

This paper recommends consideration of an offset program implemented domestically by each developed nation. An offset program differs from a typical emissions trading program in three ways.

First, the total number of emission rights allocated under an offset policy would be equal to current total emissions. There would be no attempt initially to require reductions. Second, emissions rights would be distributed to existing sources according to their current emission levels. Thus an offset program would begin with the status quo, and only new sources would be required to purchase additional emission rights from existing sources. Thirdly, sources would have the option of offsetting new emissions by either purchasing emission rights from existing sources or by creating new emission rights by increasing emission sinks.

Under this scheme every U.S. firm above a certain size that emits CO_2 would be subject to the offset program and would be responsible for ensuring that it had sufficient emission rights to cover its emissions for a given year. Owners of emission rights of X tons per year would be entitled to emit X tons of CO_2 every year. Sources that reduce their emissions could sell or lease their surplus rights to new sources or to existing sources planning to increase their annual emissions.

Designing an effective CO_2 offset program will require decision makers to weigh numerous policy and implementation choices. This paper examines those choices in detail and concludes the following:

A CO_2 offset policy should be initially implemented as a national, not an international program.

- It should only be implemented after an international agreement has established a U.S. emission quota.

- The program should be implemented primarily by the states with some federal assistance for functions such as record-keeping of emissions trades.

- Emission levels should be calculated based on well-established emission factors, and self-reporting by firms should be the primary mechanism for monitoring industry compliance.

- Initially the offset policy should apply only to CO_2.

- The program should apply to the consumers rather than the producers of fossil fuels.

- For motor vehicles, however, the manufactures should be held responsible for the CO_2 producing potential they put on the market each year. If the vehicles sold in a given year result in an increase in CO_2, the manufacturers would be have to purchase additional emission rights: if the vehicles resulted in a decrease in annual CO_2 producing potential, the manufacturer could sell their excess emission rights.

- Emission rights should be grandfathered based on current emission rates of a facility.

These and other policy choices are designed to make a CO_2 offset program a practical and attractive approach for implementing any future decision by the United States to reduce CO_2 emission levels.

INTRODUCTION

The threat of global warming has rapidly emerged as a leading environmental issue in the United States and internationally. Current worldwide emissions (sources) of carbon dioxide ("CO_2"), the major greenhouse gas, exceed the capacity of the ocean and vegetation (sinks) to absorb CO_2 from the atmosphere. As a result, the atmospheric concentration of CO_2 has increased by about 25 percent in the past 100 years,[1] and is currently increasing at a rate of about 0.4 percent per year.[2]

The current imbalance between sources and sinks of CO_2 is expected to increase in the future as CO_2 emissions continue to grow. One recent study estimated that unconstrained global emissions of CO_2 from fossil fuel combustion will increase from 5.7 billion tons of carbon per year in 1990 to 26.9 billion tons per year in 2100.[3] Annual U.S. emissions are projected to increase in this same period from 1.2 to 4.0 billion tons of carbon per year.[4] Other studies have estimated that U.S. CO_2 emissions will increase in the shorter-term at a rate of approximately 1.3 percent per year.[5]

Given these trends of increasing CO_2 emissions and a growing imbalance between sources and sinks of CO_2 in the atmosphere, the atmospheric concentration of CO_2 is expected to double its 1900 level of about 300 parts per million by the middle of the next century. This increased concentration of atmospheric CO_2, combined with even more rapid build-ups in the atmosphere of other greenhouse gases,[6] may result in significant global warming and sea-level rise with serious economic and environmental consequences.[7]

The increased scientific attention to the potential for and consequences of global warming has stimulated policy responses at both the domestic and international levels.[8] Domestically, several bills have been introduced in Congress that seek to reduce U.S. CO_2 emissions by twenty percent.[9] Internationally, the Intergovernmental Panels on Climate Change were established in 1988 to study various aspects of the global warming problem and issued their reports late in the summer of 1990.[10] Anticipating the release of these reports, the United Nations Environmental Programme has begun preparations for negotiations on an international framework convention on greenhouse gases.[11] A resolution adopted at a recent high-level meeting of government officials from many countries, including the United States, recognized the need to "stabilize" emissions of CO_2 and other greenhouse gases.[12] Many industrial nations, including the twelve European Community nations, Australia, Austria, Canada, Finland, Iceland, Japan, New Zealand, Norway, Sweden and Switzerland, have taken unilateral initiatives to at least stabilize their greenhouse gas emissions at current levels by the year 2000.[13]

Given the increasing domestic and international pressure for reductions in CO_2 emissions, it is important for the U.S. to begin examining possible regulatory mechanisms for allocating and enforcing U.S. greenhouse gas emission reductions. National mechanisms to reduce greenhouse gas emissions can be of two general categories. The first category consists of various policies and programs that <u>indirectly</u> result in indeterminate reductions of greenhouse gas emissions. Examples include funding research into alternative energy sources, encouraging and subsidizing energy conservation, and imposing higher standards for appliance and fuel efficiencies. Most of the proposed legislation on global warming that has been introduced so far in Congress consists of a collection of such indirect controls and incentives to reduce CO_2 emissions. The second category of regulatory mechanisms seeks to reduce CO_2 emissions <u>directly</u> through emission standards, pollution taxes, or tradeable emission permits. Direct controls will likely be required to meet specific and significant emission reduction quotas under a future international agreement.

One possible regulatory mechanism that has been suggested by various commentators for reducing greenhouse gas emissions is a CO_2 offset program.[14] Such a program would require sources that produce new or increased emissions of CO_2 to offset these emissions by obtaining equivalent reductions of CO_2 emissions from other sources. Increasing the sequestration of CO_2 by new carbon sinks may also be an acceptable method of offsetting new emissions. An offset program might go a long way towards freezing CO_2 emissions at current levels.[15]

Offsetting new emissions is one type of emissions trading. The United States has had significant but limited experience in implementing several emissions trading programs for different pollutants.[16] Several empirical studies have recently been published that evaluate the effectiveness of these various emissions trading programs.[17] Two major lessons can be drawn from these studies. The first is that emissions trading programs generally result in significant cost savings relative to "command and control" approaches.[18] The second lesson is that the effectiveness of the various emissions trading programs varies considerably depending on the legal, administrative, and technical details of each program. These lessons suggest that a CO_2 offset program may be a cost-effective approach for reducing CO_2 emissions, but careful attention must be given to the legal and practical design and implementation of such a program in order to maximize its effectiveness.

This paper will use the lessons learned from the experience of other emissions trading programs to assess the effectiveness and evaluate the design of a CO_2 emissions policy**.** Part I will examine the relative effectiveness of a CO_2 offset program compared to traditional regulatory standards, a carbon tax, and emissions trading programs for other air pollutants. In Part II, the optimal design of a CO_2 offset program will be developed. A total of twenty policy choices in the design of such a program will be evaluated and the best option for each policy choice will be identified. The twenty policy choices and the options for each policy choice are shown in Table I. The analysis is intended to identify the important issues in designing and implementing a CO_2 offset policy, and to outline the most feasible and effective blueprint for such a program.

1. RELATIVE EFFECTIVENESS OF A CO_2 OFFSET PROGRAM

1. Advantages of Market Approaches for Reducing CO_2 Emissions

The two major types of market mechanisms for reducing pollution - pollution taxes and emissions trading - offer three key advantages over traditional command and control approaches. The first advantage is that market approaches allow firms to achieve emission reductions at a lower overall cost than uniform standards.[19] The cost savings from market approaches have two components. Within each facility, a firm is permitted to select the cheapest methods of emission reduction. By comparison, command and control regulations often mandate specific pollution control methods or technologies, which may not be the least expensive means for reducing emissions in each facility. Between facilities, firms with lower marginal costs of reducing pollution will reduce more emissions than a firm with higher marginal costs under a pollution tax or emissions trading program. Each firm will undertake reductions that cost less than the tax rate on emissions or the market price for emissions rights. This differential emissions reduction, based on the marginal cost of reduction for each facility, results in cost savings compared to reducing emissions to equal levels for all facilities under a command and control approach.

The magnitude of the cost savings from using market approaches to reduce emissions depends on the differences in marginal costs of pollution control between different technologies and facilities. If marginal costs vary significantly, the cost savings will be large; but if the

marginal costs are relatively uniform, there will be very little potential for cost savings from market approaches. While there is considerable uncertainty about the methods and marginal costs of reducing CO_2 emissions, the available evidence suggests that there are large differences in the marginal costs of different methods for reducing CO_2 emissions. Several researchers have attempted to estimate the marginal cost of reducing CO_2 emissions by various methods, and some of these results are shown in Table II. Although the estimates are crude and vary from researcher to researcher, they suggest that the marginal costs of CO_2 reduction may vary by as much as three orders of magnitude.[20] These large variations in marginal costs suggest that the flexibility afforded by market mechanisms may provide substantial cost savings, particularly given projections that the total costs of stabilizing CO_2 will be enormous.[21]

The second advantage of market mechanisms is that they provide a dynamic incentive for firms to develop new technologies and methods for larger and more cost-effective reductions in emissions. By reducing the cost of emission controls below the tax rate or the market price of emission rights, new technologies create immediate economic benefits for firms that make additional emission reductions. In contrast, command and control regulations deter innovation by companies because they receive no credit for reductions below regulatory standards, and the discovery of new technologies that make further reductions feasible may prompt regulatory agencies to impose even stricter standards. The cost-effective control of CO_2 emissions will require creative new solutions, and therefore the dynamic incentives generated by market mechanisms to develop new technologies and methods is an important advantage of these approaches.

The third advantage of market mechanisms is that they shift the locus of decisionmaking from government regulators to individual firms. Each firm must determine its own least-cost methods to reduce emissions, as well as its optimal level of emission reductions. Market mechanisms take advantage of the superior knowledge of company officials about the costs and opportunities of emission reductions, rather than trying to duplicate this knowledge in the staff of regulatory agencies in order to set appropriate emission standards. Given the large numbers and wide variety of sources of CO_2 emissions, the decentralized decisionmaking of market approaches will greatly reduce the information burden on regulators and lead to diverse and innovative strategies for reducing CO_2 emissions.

2. A Comparison of CO, Emissions Trading and Taxes

The general advantages of market mechanisms described above apply to both emissions trading and taxes. Significant attention has thus far been given to the potential of a "carbon tax," which would tax fossil fuels in proportion to their carbon content.[22] A carbon tax has several attractive features. One important advantage of a carbon tax is that it would be relatively easy to administer, since the tax could be levied on fossil fuels at the point where they enter the economy. A relatively limited bureaucracy would be required to implement a carbon tax. Another advantage of a carbon tax is that it would explicitly establish the price of continuing to emit CO_2, thereby making the costs clear to industry, regulators, and the public. For example, government regulators would know the financial burden they are imposing on firms when they set the tax rate.[23] This is not the case with regulatory standards or emissions trading. Accurate and advance knowledge of regulatory cost burdens is particularly important when the cost curves of reducing emissions increase sharply, as appears to be the case for CO_2.[24] Finally, a carbon tax would generate large government revenues that could be used to fund additional government programs to further reduce CO_2 emissions.

Despite these potential advantages of a carbon tax, there are other important

considerations that may make CO_2 emissions trading a more effective mechanism than a carbon tax for controlling CO_2 emissions. Although this section does not attempt a complete and com-comprehensive comparison of a carbon tax and an emissions trading program, the following five factors suggest that an emissions trading program may have important advantages over a carbon tax for controlling CO_2 emissions.

First, an emissions trading program, unlike a pollution tax, can be reasonably certain to achieve a specified quantity of emission reductions. An emissions trading program can directly control total emissions by determining the number of emission rights that are allocated, whereas under a pollution tax regulators must guess the appropriate magnitude of a tax that will result in a given level of emission reductions. Two commentators who have been integrally involved with EPA's emissions trading program under the Clean Air Act ("CAA") recently wrote:

> Emission fees cannot secure specific tonnage reductions by fixed deadlines, since such fees require complete knowledge of industry control costs and constant adjustment to avoid under- and over-control. Emissions trades can guarantee such reductions by fixing their amount and letting the market determine who can produce those reductions most cheaply .... [25]

Because regulators have imperfect knowledge of the cost structures and price elasticities of firms, they will have difficulty setting a carbon tax rate that can be sure to achieve a national quota for CO_2 emission reductions that the U.S. may undertake under a future international agreement. Regulators will be forced to either intentionally over-tax emissions to ensure that the national quota is achieved; or risk having to continually adjust the tax rate if it is not resulting in sufficient emission reductions.

In fact, if CO_2 emissions are projected to increase with time,[26] and the goal of a carbon tax program is to stabilize emissions at current or lower levels, then the tax will have to be gradually increased with time. This is because the tax rate will have to be made progressively steeper to compensate for the increased quantity of projected emissions that will have to be averted in each successive year. Implementing an escalating tax is likely to be difficult because of problems such as imperfect information and administrative inertia.[27]

The second advantage of an emissions trading program is that it will ensure stable emission reductions in the face of inflation and economic growth, while a carbon tax will not. Inflation erodes the real value of a tax, and so firms find it relatively more attractive to increase emissions and pay the tax. Economic growth increases the number of firms willing to pay taxes in order to emit CO_2, and so total emissions will again grow. In contrast, inflation and economic growth do not increase total emissions under an emissions trading program, since the total quantity of emission rights stays fixed. In the words of Richard Stewart, an emissions trading program “will ensure that we run faster and faster to keep in place.” [28]

Third, while both emissions trading and pollution taxes reduce the overall cost of reducing emissions, a tax would impose additional financial burdens on industry. Firms would be required to pay both the costs of reducing emissions and the tax liabilities for remaining emissions. Thus, a tax would result in substantial transfer payments from industry and its customers to the government. Although in theory these transfer payments are not a net cost to society as a whole, in practice there will be some deadweight loss due to the transaction and administrative costs of the tax scheme.

The large transfer payments from the private sector to government entailed by a carbon

tax program will also substantially increase the cost of doing business. Since the costs of reducing CO_2 emissions is likely to be very expensive, the additional cost to firms from emission tax payments are likely to be quite burdensome and strongly opposed by industry. Large transfer payments from industry to government are not necessary under an emissions trading program in which emission rights are allocated without charge to firms.

Fourth, the United States has had some (albeit limited) experience in implementing emissions trading programs, but has had almost no practical experience with pollution taxes.[29] Thus, the EPA has already developed some of the expertise and administrative machinery that will be necessary to implement an emissions trading program, but lacks the expertise and administrative systems necessary to assess, collect, and enforce taxes. Similarly, the staff of the Congressional tax committees that would oversee a tax program have no experience or expertise on environmental matters.[30] These bureaucratic realities suggest that the federal government may be able to implement a CO_2 emissions trading program much more smoothly and efficiently than a carbon tax program.

Finally, taxes are politically unpopular. Estimates of the magnitude of a carbon tax needed to stabilize CO_2 emissions suggest that such a tax would be very hefty. One recent estimate is that a carbon tax would have to be about $250 per ton to stabilize CO_2 emissions, which would increase gasoline prices at the pump by about seventy-five cents per gallon.[31] Such a large tax would probably be politically impossible to enact in at least the near future.

3. Comparison with Emission Trading Programs for Other Pollutants

In addition to the advantages that a CO_2 emissions trading program has over command and control regulations and a carbon tax, such a program has important advantages compared to similar emissions trading programs that have been implemented for other pollutants. In particular, some of the serious problems that have plagued the emissions trading program under the CAA will not hamper CO_2 emissions trading. The most serious of these problems is that most air pollutants have local effects. Therefore, under the CAA, emissions trades were not allowed if they resulted in local ambient air concentrations exceeding the standards. Consequently, trading was limited to sources within the same air region,[32] and proposals for local trades often had to be accompanied by complex and expensive modeling data that showed that ambient air standards would not be exceeded. The concern over ambient air quality placed substantial administrative burdens and transaction costs on emissions trading and seriously reduced the overall trading level and potential cost savings of the program.[33]

Ambient air quality is not a problem for CO_2 because emissions have only a global and not a local effect. Thus, expensive and burdensome safeguards to protect ambient air quality are not necessary for a CO_2 emissions trading program. Furthermore, since the effects of CO_2 emissions are not dependent on location, trades can take place between sources located far apart without any net effect on atmospheric CO_2 buildup.

A related problem with the CAA trading program is "thin markets" that consist of very limited numbers of sources buying or selling emission rights, in large part because of the small size of trading zones.[34] Thin markets result in high transaction costs because of the difficulty in identifying and negotiating with potential trading partners. Given the large number of sources of CO_2 emissions, and a nation-wide or even international trading zone, thin markets should not be a problem for a CO_2 emissions trading program.

Another concern that arises under the CAA is the potential for anti-competitive behavior

in trading zones where one or two firms buy or sell the majority of emission rights.[35] Such firms can use their market power to extract profits by artificially restricting trading, or to prevent the entry of new firms into the market. Again, given the large number of sources and industries that emit CO_2, and the large trading zones, this type of harmful anticompetitive is unlikely with a CO_2 emissions trading program.[36]

An important lesson learned from other emissions trading programs is that: the resource problem must be defined so that the tradeable rights have economic value and that incentives to buy and sell them exist. They will have value when the demand for the rights to develop or to pollute significantly exceeds the supply of rights that society chooses to permit. [37] Again, this should not be a problem for a CO_2 emissions trading program. CO_2 emissions are projected to increase steadily in the future if they remain unconstrained,[38] and so an emissions trading program that stabilizes emissions at current levels will produce a "hot" market in which emission rights are very valuable. Furthermore, under an offset program, all new sources of emissions will be required to purchase emission rights in order to operate, and thus there will be a guaranteed demand for emission rights.

Finally, the CAA emissions trading program was subject to considerable political opposition by environmentalists. A key reason for this opposition was that EPA's emission trading program was not intended to result in any additional environmental improvements. The CAA already specified air quality standards, and the emissions trading program was an environmentally-neutral add-on to achieve the existing standards at a lower cost. Environmentalists were suspicious of a program that benefited firms without creating additional environmental improvements, and which allowed firms to trade "unused" rights when the existing standards were not being met.[39] By comparison, EPA's lead trading program was relatively uncontroversial. The key difference compared to the CAA was that the lead trading program was tied to a decision to substantially reduce the lead content of gasoline.[40] The lesson seems to be that emissions trading programs are more acceptable when accompanied by significant reductions in current emissions. A CO_2 emissions trading program would satisfy this criterion for success if the decision to reduce CO_2 emissions is tied to the decision to use emissions trading as the mechanism to control emissions at the lowest possible cost.

The previous three sections have outlined the relative advantages of a CO_2 emissions trading program compared to a command and control regulatory approach, a carbon tax, and emissions trading programs for other air pollutants. These potential advantages suggest that an emissions trading program may be an effective approach for reducing CO_2 emissions. Indeed, the Intergovernmental Panel on Climate Change (IPCC) Response Strategies Working Group has recently begun studying an emissions trading program and an initial report by the Working Group suggests that such a system "looks to be a particularly promising policy option." [41] However, as discussed earlier, the effectiveness of an emissions trading program depends largely on the legal, administrative, and technical specifics of such a program. Therefore, a specific CO_2 emissions trading program, in the form of an offset policy, is proposed in the next part of this paper.

4. A CO_2 EMISSIONS OFFSET PROGRAM

1. Overview

An offset program is a special type of emissions trading program. A typical emissions trading program involves an initial allocation or auctioning of a designated number of emission permits to firms, and then requiring each firm to reduce emissions to match the permits it

received or else trade for additional permits. An offset program differs from this typical structure in three main ways. First, the total number of emission rights allocated under an offset policy is equal to current total emissions. Second, emission rights are distributed to existing sources according to their current emission levels. Thus, an offset program begins with the status quo, and only new sources are required to purchase additional emission rights from existing sources. An existing source can choose to continue business as usual without participating in emissions trading. The third difference is that sources may have the option of offsetting new emissions by either purchasing emissions rights from existing sources or by creating new emission rights by increasing emission sinks.[42]

Before turning to the specific policy choices needed to flesh out an emissions offset policy, it is necessary to begin with a brief description of the basic skeleton of such a program. Every firm that emits CO_2 and is subject to the offset program would be responsible for ensuring that it had sufficient emission rights to cover its emissions for a given year. Emission rights would be defined in terms of tons of CO_2 per year. In other words, owners of emission rights of x tons per year would be entitled to emit x tons of CO_2 every year for the duration of the rights. Existing sources would be allocated emission rights equal to their current annual emission levels. Sources that reduce their emissions could sell their surplus rights, known as emission reduction credits ("ERCs"),[43] to new sources or existing sources planning to increase their annual emissions. A sale of emission rights would transfer the ownership of the rights for the duration of the offset program. Sources could also agree to lease ERCs for a limited period of one or more years. A source that exceeded its allowable emissions in any given year would be required to compensate for its excess emissions by leasing short-term ERCs.

There are many important variables that must be considered in designing an effective and workable offset program. In the next section, twenty policy choices for the design of a CO_2 offset program are identified and discussed. The twenty policy choices are grouped into five categories: (A) Scope and Timing of Program; (B) Administrative Issues; (C) Types of Sources; (D) Allocation of Emission Rights; and (E) Operation of the Emissions Trading System. Each of the policy choices presents two or more possible options. Options will be evaluated for their effectiveness in stabilizing CO_2 emissions in a cost-effective and equitable manner that is also administratively feasible. The option that best meets these criteria for each policy choice will be selected.

5. Policy Choices for a CO_2 Offset Program

(A) Scope and Timing of Program

(i) Geographical Scope: Since the environmental consequences of CO_2 emissions are independent of source location, there are strong reasons to extend the geographical scope of an offset program as widely as possible to take advantages of variations in marginal costs of reductions in different geographical regions. Several studies have suggested that there is great potential for relatively cheap reductions in many developing countries,[44] and these findings have been used to support the idea of an international offset program.[45] An international agreement would set initial emission quotas for each signatory country and then private sources could trade emission rights within and between countries.

However, this type of international offset program allowing private trades between sources in different countries presents several insurmountable problems. The most serious problem is the lack of international institutions or machinery to monitor and enforce emissions trades. Without adequate oversight, an international offset program is unlikely to be workable. It

is hard enough to monitor and enforce the compliance of national governments with international environmental agreements, but oversight of international trading by potentially thousands of private companies would be an administrative nightmare. A second problem with an agreement allowing private international emission trading is that some countries with centralized economies have expressed their opposition to participation in an emissions trading program.[46] Thus, as a recent IPCC report concluded, emissions trading may be "particularly relevant domestically" in those countries that favor such programs.[47]

Finally, an international offset program would raise equity concerns about the ability of industrialized nations to buy-up the emissions rights of developing countries:

> In the case of carbon emissions it is all too easy to *see* that permits to emit carbon would rapidly accumulate in the richest nations, while the developing world would soon be in a position of having to try and buy back permits from the richest nations in order to develop. Since the price might well escalate with time as global targets were tightened, the result could be very regressive.[48]

For these reasons, an international CO_2 offset program with private trading is probably not administratively feasible or politically acceptable to some. Thus, an offset program should be implemented domestically within the United States.[49]

The remaining question is whether emissions trading should be permitted across state lines. An offset program implemented on a state-by-state basis could take advantage of much of the existing state administrative machinery for implementing the CAA. [50] There are two strong arguments for allowing interstate emission trading. First, the marginal cost of emission reduction may differ between states, resulting in additional cost savings from interstate trading. Second, limiting trading to within states would freeze the current state-by-state distribution of CO_2 emissions, and would unfairly disadvantage economic growth in states with relatively low current emissions. As discussed later, the administrative problems of monitoring interstate trading can be overcome, and therefore an offset policy should be implemented as a national program that permits interstate trading.

(ii) <u>Timing of An Offset Program:</u> The U.S. could adopt a CO_2 offset program as part of a unilateral decision to reduce CO_2 emissions, or to meet U.S. obligations under a future international agreement. Given the projected rapid growth of CO_2 emissions in developing nations,[51] unilateral action by the United States would not be effective in slowing global warming unless it catalyzes similar reductions by many other countries, most likely in the form of an international treaty. An international agreement or even the potential for such an agreement could destabilize a pre-existing U.S. CO_2 offset program that was adopted unilaterally prior to international negotiations.

One of the serious problems that has hampered the CAA emissions trading program has been uncertainty about the security of emission rights.[52] Firms feared that emission rights would be confiscated by the government if further reductions were required. Insecure emission rights resulted in reduced trading, decreased cost savings, and higher transaction costs. Similar adverse consequences could result from the potential for an international agreement that could significantly alter emission rights under an existing U.S. CO_2 offset program. To avoid such disruption, it would probably be preferable to implement a CO_2 offset program after an international agreement to reduce CO_2 emissions has been completed and a U.S. national emissions quota has been established. [53]

B. Administrative Issues

(iii) Level of Government: One of the major findings of recent empirical studies of the CAA emissions trading program is that state-administered trading programs functioned much more effectively than federal programs.[54] The key difference between the two types of programs is that trades under the EPA-administered program must be approved by the state, the regional EPA office, and the EPA Administrator. Additional levels of bureaucracy increase the approval period and transaction costs of trades and therefore deter trading. Another relevant consideration is that states usually have primary responsibility for issuing operating permits for sources under the CAA.[55] To avoid duplication of regulatory requirements, it would be advantageous to take advantage of the existing state CAA administrative machinery to oversee a CO_2 offset program.

While states could monitor the compliance of sources within their jurisdiction, they would lack information about inter-state emissions trades. This is where the EPA could be most useful. EPA could establish and operate a nationwide database that registers all emission trades. A trade would only become effective when it has been listed in the EPA database.[56] Such a system is not without precedent. The acid rain provisions of the new Clean Air Amendments would permit interstate trading of sulphur dioxide emission permits, and the bill requires the EPA to "establish a system for issuing, recording, and tracking allowances."[57] A similar system could be established for tracking CO_2 trades, and the database would be available to all state air quality agencies responsible for monitoring the compliance of sources within their jurisdiction.[58] This division of responsibilities between state agencies and the EPA should minimize bureaucratic overlap and administrative costs and delay.

(iv) Measuring Emissions: Under the CAA emissions trading program, sources participating in emission trades often have to quantify emission reductions using emissions monitoring or air modeling.[59] This information is expensive to obtain, and therefore serves as a deterrent to emissions trading. Quantifying emissions for many air pollutants is complicated by two problems. First, the effect of emissions on ambient air quality is important and therefore must be measured. Second, most sources have installed pollution control equipment that partially removes pollutants from emissions, and hence pollution emission levels cannot be simply calculated from the amount of pollutant produced per ton of fuel that is burned. Fortunately, a CO_2 offset program will not have to deal with either of these problems. As explained previously, the environmental consequences of CO_2 emissions are not source dependent, and so local ambient levels are not important.

Second, technologies for scrubbing CO_2 from flue gases are currently not economically feasible.[60] CO_2 emissions can therefore be calculated from the amount and type of fuel burned, and there are well-established emission factors that describe the pounds of carbon produced per pound of fossil fuel consumed.[61] Standardized emission factors for the combustion of fossil fuels could be established nationally and revised as necessary by EPA rulemaking.[62] Another significant source of CO_2 emissions is cement manufacturing, and again a fairly well-established CO_2 emission factor is available to calculate CO_2 emissions per ton of cement manufactured.[63]

The final major industrial source of CO_2 emissions in the U.S. is municipal incinerators, and a crude CO_2 emission factor can also be calculated for these sources.[64] Thus, these fairly well-established emission factors could be used to estimate CO_2 emissions from sources. Since company business records will already contain information on the amount of fossil fuels purchased by a facility, firms will not have to generate expensive, new information, such as actual emission measurements, before engaging in CO_2 emissions trading.

(v) Compliance Monitoring: An emissions trading program can rely primarily on self-reporting by firms, or it can require agency approval of each emissions trade. The lead trading program relied primarily on self-reporting, while the CAA emissions trading program imposed burdensome approval requirements on trades. This difference is believed to be partly responsible for the success of the lead trading program.[65] The total amount of lead put in gasoline by a particular refiner could be easily determined by the amount of lead additive the refiner purchased. Therefore, EPA monitored compliance with the lead reduction program by requiring quarterly reports from refiners on the amount of lead rights they used or traded.[66] Company self-reporting could be verified by EPA from reports of sales of lead additives by lead manufacturers. This effective but relatively simple self-reporting requirement imposed very small transaction costs on lead trading.

By comparison, EPA imposed very complex administrative requirements for approval of emissions trading under the CAA. As discussed previously, emission monitoring of air pollutants was very difficult because of the concern about ambient air quality and the presence of pollution control equipment that made infeasible the use of simple emission factors based on fuel consumption. Because emission levels were uncertain, EPA imposed strict safeguards on emissions trading that included lengthy approval procedures and burdensome information requirements.[67] The result was increased transaction costs and reduced trading:

> If monitoring is difficult then the measurement and allocation of property rights are also likely to be difficult, controversial and expensive. Because this is likely to cause regulators to impose additional regulatory requirements on trading of rights, increase difficulty of monitoring will generally be associated with decreases in trading. [68]

Fortunately, a CO_2 offset program would be more like the lead trading program than the CAA emissions trading program. CO_2 emissions can be relatively easily calculated from fossil fuel consumption and emission factors, and therefore a self-reporting system similar to that of the lead trading program can be used. Each firm would be required to submit an annual report of its CO_2 emissions to the appropriate state agency. The report would include business records of all fossil fuel purchases, as well as a statement of all emission rights bought or sold.

The state agency would check that annual emissions did not exceed the firm's baseline emission rights plus any additional rights the firm had purchased.[69] The state agency could verify all claimed or unclaimed trades using the EPA emissions trading database. The state could also verify fuel consumption data with information available from fuel producers and importers. A firm that exceeded its allowable emission limits in any one year would be required to lease ERCs to compensate for its exceedance in that year.[70] The firm would also have to buy permanent ERCs or reduce its emissions to avoid further penalties in upcoming years. This self-reporting system should minimize administrative burdens on firms and will not deter emission trading with high transaction costs.

(C) Types of Sources

(vi) Type of Greenhouse Gas: So far, the offset program has been described as applying only to CO_2 emissions. However, CO_2 is only responsible for about 55 % of the current commitment to global warming.[71]A regulatory program that attempts to control all greenhouse gases, not just CO_2, will have a larger impact on reducing the potential for global warming. Furthermore, a piecemeal approach that only addresses CO_2 may result in firms shifting to processes or fuels that result in reduced CO_2 emissions but increased emissions of other greenhouse gases.[72] Thus, without a comprehensive program that includes all greenhouse gases, the benefits of CO_2

emission reductions may be diminished by increased emissions of other gases.[73] Finally, since there are likely to be significant differences in the marginal costs of reducing the various greenhouse gases, an offset program that allows trading between different gases has the potential for additional cost-savings.[74]

Despite these potential advantages of a comprehensive approach, it would probably be best to focus an offset program solely on CO_2, at least to begin with. The major reason for excluding other greenhouse gases is that there are currently major information gaps with respect to these other gases. There are major uncertainties about the sources and sinks of greenhouse gases such as methane and nitrous oxides.[75] There is also significant uncertainty in the conversion factors that would be needed to compare the relative global warming potential of the various greenhouse gases.[76] While attempts have been made to calculate conversion factors,[77] these calculations will probably change significantly as more information becomes available. Such changes could have a disruptive effect on a comprehensive emissions trading program. Finally, there are not well-established emission factors for greenhouse gases other than CO_2, and there are large source-by-source variations in the emission rates of these gases.[78]

Thus, an emissions trading program that included these other gases could not use the simple, inexpensive self-reporting system described above, but would require costly monitoring data that would increase administrative and transaction costs and consume most if not all of the efficiency gains from allowing trading between gases.[79] In addition to these information problems, emissions of some other greenhouse gases such as methane are source dependent, and thus the geographical location of sources would be important.[80] This problem would require additional restrictions on trading, further reducing the benefits of a trading program.

The disadvantages of including other greenhouse gases in an emissions offset program would seem to outweigh the advantages at this time.[81] CO_2 is by far the single most important contributor to global warming potential, and the relatively well-known sources and emission factors for CO_2 make possible a very efficient emissions trading program. Therefore, it would be best to begin with a program involving only CO_2 emissions, and adding in other gases if and when sufficient information became available that would allow these gases to be included in the program without greatly increasing administrative and transaction costs. In the meantime, alternative regulatory approaches for controlling other greenhouse gases could be considered, especially if an international agreement includes controls on these gases as well as CO_2.

(vii) <u>Producers v. Consumers:</u> A CO_2 offset policy could apply to the producers or the consumers of fossil fuels. The advantage of requiring producers of fossil fuels to offset increased production of CO_2-producing fuels is that there are fewer producers than consumers, and thus the administrative costs would be lower. This approach of "going upstream" to producers was adopted by the EPA in its decision to distribute permits for CFCs to manufacturers rather than end users.[82] However, there are several factors that argue against a CO_2 offset program targeted at fossil fuel producers.

First, the administrative costs of an offset program for fossil fuel consumers can be kept quite low for the reasons described previously, and thus the cost savings from the more simple administrative system for producers might not be that great. Second, a producer-based offset program may suffer from some of the problems encountered in other emissions trading programs with relatively small numbers of permit buyers and sellers, such as "thin" markets and anti-competitive behavior.[83] Third, distributing all CO_2 rights to the relatively small number of fossil fuel producers would create an enormous windfall for these firms, especially as the value of CO_2 rights increases with time.[84] The transfer of such large windfall profits to a small

number of CFC producers created considerable political controversy that eventually resulted in Congress passing a statute that imposed a tax on producers to recover some of the windfall.[85]

A fourth argument against a producer-based offset program is the gap between the production and consumption of fossil fuels. Approximately eight percent of oil produced or imported into the U.S. is used for a variety of non-fuel purposes such as paving materials, plastics, synthetic fibers, and lubricants.[86] Smaller proportions of natural gas and coal are also used for non-fuel purposes.[87] Most of the carbon in these fossil fuels used for other purposes will not be oxidized to CO_2 in the near future, and therefore should not be subject to a CO_2 regulatory program. Thus, a producer offset program would either have to exempt fuels used for non-fuel purposes, which would add administrative complexity and costs, or inappropriately subject these fuels to the offset requirement.

A related problem is that some sources of CO_2 emissions, such as cement production and incinerators, do not use fossil fuels. Yet another problem is that fossil fuels produced in the U.S. but exported to other countries would have to be exempted from a producer offset requirement, since the CO_2 emissions produced by U.S. exported fuels would not count as part of the U.S. CO_2 quota under an international agreement.[88] Again, this would create administrative problems.[89] These problems could be avoided by an offset program that focused directly on sources of CO_2 emissions: consumers of fossil fuels and other industries that emit CO_2.

(viii) Mobile Sources: A CO_2 offset program obviously could not apply to individual automobile owners because of the large number and small per unit emissions of automobiles. The two options, therefore, are to either: (1) only include stationary sources in an offset program;[90] or (2) subject automobile manufacturers to a modified offset requirement. The transportation sector accounts for over 30% of U.S. CO_2 emissions, most of which is produced by motor vehicles.[91] Thus, excluding mobile sources from a CO_2 offset program will seriously reduce the impact of the program in stabilizing CO_2 emissions. Furthermore, it may be that there are relatively cost-effective methods for reducing CO_2 emissions from automobiles, such as by increasing fuel efficiency or using alternative fuels. Therefore, by including automobiles in an emissions trading program, the overall CO_2 emissions reduction goal may be achieved at a lower total cost. For these reasons, an CO_2 offset program should include mobile sources.

A motor vehicle manufacturer does not produce the CO_2 emissions from automobiles directly, but rather manufactures and sells a product that itself produces CO_2. One possible way to adapt an offset program to motor vehicle manufacturers would be to hold them responsible for the CO_2-producing potential they put on the market each year. CO_2-producing potential for a given line of cars in a particular year would be calculated by multiplying five factors:
(1) the number of units sold in that year; (2) the fuel mileage of the model in miles per gallon; (3) the amount of CO_2 produced per unit of fuel; (4) the average miles driven per car per year; and (5) the average lifetime of a car. The sum of the products of these five factors for all models in a particular manufacturer's fleet would be the total annual CO_2-producing potential of that manufacturer. Each manufacturer's baseline would be the CO_2-producing potential put on the market by the manufacturer in the baseline year.[92] If the annual CO_2 producing potential put on the market by a manufacturer increases, it would be required to purchase additional emission rights; if the annual CO_2-producing potential decreases, a manufacturer could sell its excess emission rights. The emission rights bought or sold by motor vehicle manufacturers would be equivalent to the emission rights of stationary sources. The only other difference that would be required for mobile sources would be the system for annual reporting. Each company would be required to report its annual CO_2-producing potential to the government. Since the reporting

would be on a company-wide basis, and automobile manufacturers have facilities in many states or in other countries,[93] it would be appropriate to designate a federal agency such as the EPA to receive and review annual reports by motor vehicle manufacturers. Since the number of such manufacturers is fairly small, this should not create a very large administrative burden for the EPA.

(ix) Minor Stationary Sources: Many requirements of the CAA only apply to "major" sources and major modifications of existing sources.[94] It is very expensive to administer and enforce environmental regulations that apply to minor sources. However, there are two important reasons for including minor sources in an emissions offset program.[95] First, very cost -effective reductions of CO_2 emissions may be possible for some minor sources, and therefore inclusion of such sources may help reduce the overall costs of achieving a given reduction in U.S. CO_2 emissions. Second, although individual minor sources emit relatively small quantities of CO_2, cumulative emissions from such sources may be very substantial. If emissions from minor sources are allowed to grow unconstrained, they could significantly nullify the emission reductions from major sources.[96]

The inclusion of minor sources in a CO_2 offset program depends on the tradeoff between the benefits of including them and the increased administrative costs from including additional sources. It will be much more feasible and efficient to regulate source categories that add a relatively small number of significant emitters of CO_2 than categories that contain a large number of very small emitters. The average CO_2 emissions for different categories of facilities are shown in Table III.[97] Although the category-averaging approach is crude in that it ignores variations in size and emission rates within categories, the data in Table III clearly show that there is tremendous variability in the average CO_2 emission rates from different categories of sources. For example, coal-fired utilities have average CO_2 emissions of over 300,000 tons of carbon per year (tC/y), while industrial sources average about 600 tC/y, commercial sources emit 40 tC/y on average, and most residential sources emit about 1 tC/y. There is also wide variations in CO_2 emission rates between different categories within the industrial, commercial, and residential groupings of source categories. The number of facilities in each source category also varies enormously.

Table IV shows the relationship between the number of sources and the contribution to total non-transportation CO_2 emissions. The data in Table IV show that the number of regulated sources would increase dramatically if smaller sources are included in an offset program. A program that included only the 1,268 sources (all coal-fired utilities) that emitted more than 100,000 tC/y would control approximately 45 percent of all non-transportation CO_2 emissions.[98] If all sources emitting more than 10,000 tC/y were included in the program, almost 9,000 sources would be regulated, and about 57 percent of total emissions would be controlled. In this range, over 500 additional sources would have to be regulated for every additional one percent of total current emissions that is included in the program.

If the regulatory threshold was reduced to 1,000 tC/y, over 34,000 sources would be regulated, which together would account for almost 70% of total current emissions. The additional cost of including each additional one percent of current emissions would be to add over 2,300 additional facilities to the offset program. If the regulatory threshold is even lower, the number of facilities that would have to be regulated would quickly overwhelm regulatory agencies. Given that only about 15,000 major sources are regulated under the CAA,[99] a CO_2 offset program should be restricted to sources that emit over 10,000 tC/y (8,909 sources) or at least 1,000 tC/y (34,415 sources). Sources that emit less than this threshold would be classified as minor sources and would be exempt from the offset program.

An alternative approach for regulating minor sources, and to avoid the threat of unconstrained growth of emissions from these sources, would be to use a similar approach as for motor vehicle manufacturers that focuses on the manufacturers of the sources rather than the source themselves. Manufacturers of CO_2-producing products, such as gas furnaces, water heaters, and ranges, would be required to offset any increases in the annual CO_2-producing potential they put on the market in a given year. This requirement would also correct counter-productive incentives that might be created by an offset program that applies only to major sources. For example, households with electrical furnaces will be required to "pay the price" of an offset program because the utility that generates their electricity will be subject to the offset requirement. If gas or oil furnaces are not covered by an offset requirement, these furnaces will have an unfair cost advantage over electric furnaces. Furthermore, some consumers may shift from furnaces that use electricity (that may come from non-CO_2 producing sources such as nuclear power) to furnaces that use fossil fuels and produce unregulated CO_2 emissions.

(x) Credit for CO_2 Sinks: While no one believes that reforestation could be a comprehensive solution for controlling CO_2 emissions, it may be a cost-effective method of offsetting new CO_2 emissions from some facilities.[100] One recent study calculated that a 385 square mile tract of land planted with moderately growing trees could absorb all the CO_2 emitted by a large coal-fired power plant over its lifetime.[101]Another study estimated that the increase in CO_2 emissions from the production of electricity projected for the period from 1987 to 1996 could be offset by planting roughly 11.1 million acres of forest. [102] Cost comparisons with other methods of offsetting CO_2 emissions suggest that reforestation may one of the most cost-effective options available. A serious obstacle to awarding credits for reforestation projects is the administrative difficulty of calculating and monitoring CO_2 reductions by reforestation projects. There are many uncertainties about the rate of CO_2 absorption from forests, and the rate will vary depending on a large number of site-specific factors, such as the species of trees and local soil and climatic conditions. Also, reforested areas must be maintained for the period for which credits are claimed. These problems create administrative complexities that clash with the relatively straightforward reporting system described previously.[103]

One possible solution would be to require that emission reduction credits will only be awarded for reforestation projects contracted out to federally-licensed professional treeplanting organizations. These licensed organizations would be held to high standards of objectivity and professional competence. They could be counted on to adequately maintain a site for the duration of the specified period, and would be responsible for professional standards of performance and accurate record-keeping. They would also be required to calculate and report the estimated CO_2 absorption from particular reforestation projects using accepted scientific data and procedures. Credit would only be given for reforestation efforts that were undertaken and certified by one of these organizations. Thus, firms seeking to offset new CO_2 emissions with a reforestation project would be required to hire one of these licensed organizations. Professional reforestation organizations would shift much of the administrative costs and burdens of measuring and verifying reforestation efforts from the government to the private sector.

D. Allocation of Emission Rights

(xi) Allocation Mechanism: The two main options for the initial allocation of emission rights are an auction or to give them away for free. The main arguments for an emissions rights auction are: (1) firms do not receive a windfall but rather have to pay for their emission rights; (2) all firms are given an equal opportunity to purchase emission rights; and (3) it raises revenue for the government that can be used to fund additional global warming programs. However, the relative disadvantages of an auction would appear to outweigh the advantages. First, an auction results in

large transfer payments from firms to the government. This raises many of the same problems that were previously discussed with regard to an emissions tax, such as the strong political opposition of industry. In addition, since the large transfer payments by firms are eventually passed on to customers, they are likely to be regressive. [104]

A second problem with auctions is that they can result in large economic disruptions and dislocations. An auction could distribute CO_2 emission rights very differently than the current distribution of emissions. Companies that were unsuccessful in acquiring enough rights in the auction would be forced to shut-down or cutback their production. Foreign firms might buy a disproportionate share of emission rights and thereby displace some current American producers from their own market. An auction could also drastically alter the current industry-to-industry or state-to-state distribution of CO_2 emissions, again resulting in economic displacement and disruption. Also, concern has been expressed that large firms with "deep pockets" would be able to buy up a disproportionate share of rights under an emissions auction.[105]

A third disadvantage of an auction is that it would be expensive to auction the rights to hundreds of millions of tons of CO_2 emissions to thousands of firms located across the nation. The alternative approach of simply allowing firms continue to operate at their current emission levels would be relatively easy and inexpensive to administer. Finally, the federal government's experience with auctions is limited to auctioning government property, including oil and gas land leases or surplus property.[106] The government has no experience in auctioning pollution rights, and a first-time auction program is likely to result in a whole host of unexpected problems.

In addition to these disadvantages of an emissions auction, some of the suggested benefits of an auction would be diminished for a CO_2 offset program. First, while the free allocation of emission rights would give firms windfall profits, these profits would be spread very thinly, because rights will be allocated to consumers rather than producers of fossil fuels. Thus, unlike the very large and visible windfall profits given to the five domestic producers of CFCs under the stratospheric ozone protection program, the windfall profits from the free allocation of CO_2 emission rights will be diluted over thousands of firms.

Second, while it is true that allocating emissions based on historical emission levels favors existing firms, this preference is quite different from the highly criticized bias against new sources under the CAA. Under the CAA, new sources are subject to much more stringent regulatory requirements than existing sources, and existing facilities have no incentive to reduce emissions. Furthermore, the strict requirements for new sources creates an incentive for firms to extend the lifetimes of heavily polluting existing sources. While existing sources have nothing to gain by reducing emissions under the CAA, under a CO_2 emission offset program such sources will be able to sell their excess emission rights if they reduce their CO_2 emissions. Thus, the opportunity costs of not reducing emissions under an offset program will eliminate many of the inefficiencies and perverse incentives that result from new source bias under the CAA.

Furthermore, there are several additional factors that justify favoring existing sources by allocating emission rights based on historical emission levels. First, existing firms have sunk costs which constrain their flexibility to produce less CO_2 and to trade emission rights. In contrast, new sources will be able to include minimization of CO_2 emissions as a goal in their planning stages. Second, from a moral perspective, production of CO_2 has not previously been thought of as a "bad." In fact, society has long encouraged and required automobile manufacturers and stationary sources to achieve more complete combustion to produce CO_2 rather than carbon monoxide and other hydrocarbons that are dangerous to human health.

Finally, from a practical and political perspective, only existing firms "vote," and thus the grandfathering existing emissions will encounter much less political opposition than an auction.

(xii) Total Quantity of Allocated Rights: The total quantity of emission rights allocated could be equivalent to or less than current emissions. For example, if the goal is to reduce current emissions by ten percent, current producers of CO_2 might be allocated rights to ninety percent of their current emission levels. The quantity of emission rights allocated will largely depend on the U.S. national quota if an international agreement is in force. However, if there is flexibility in setting the U.S. emissions goal, it would be preferable to allocate emissions rights equivalent to current emissions. Such an allocation will minimize the disruption of existing production activities. A sudden reduction of allowable emission levels by ten percent would cause serious economic shock and disruption as firms scramble to quickly reduce emissions. [107] Allocating emission rights equal in quantity to existing emissions will result in a much smoother adjustment to a CO_2 emissions offset program.

(xiii) Basis for Allocation to Firms: There are two approaches for allocating emission rights to firms based on historical levels. The first option is to allocate rights based on the historical level of production, and then calculate emission rights using an industry average ratio for emissions per unit of activity. The second approach is simply to base emissions rights on the historical level of emissions. The new Clean Air Amendments use the first approach and allocate sulphur dioxide emission rights based on a utility's historical level of energy generation multiplied by an industry average emission rate.[108] The chief advantage of this approach is that it does not reward high polluters with additional emission rights, and it does not penalize firms that have taken prior action to reduce emissions unilaterally.

However, there are three reasons why the second approach of allocating rights based on past emissions should apply to a CO_2 offset program. First, this approach is much simpler to implement. It would be complicated and burdensome to calculate the CO_2 emission rights for firms based on industry average emission rates. While the sulphur dioxide trading program is limited to just over 100 facilities that are all in the same industry, the CO_2 offset program will apply to thousands of sources in many different industries. Thus, the administrative costs of using industry average emission rates will be much higher.

Second, the potential unfairness of using actual emissions rather than average emission rates for allocating emission rights will be less important for CO_2 sources. Few if any sources have undertaken unilateral CO_2 control programs to date, and so there will not be a problem of firms that have taken such action being punished by receiving fewer emission rights. While firms do differ in energy efficiency, these differences are not the result of different responses to the objective of reducing CO_2 emissions.

Finally, allocating emission rights based on existing emissions will be less disruptive of current production activities than an approach that allocates emissions based on industry averaging, which would give some firms more emission rights than they need while giving other firms less. For these reasons, emission rights should be grandfathered based on existing emission levels.

(xiv) Definition of Baseline: So far, emission rights have been defined in terms of total emissions from a facility. An alternative approach would be to define emission baselines in terms of unit of output. For example, the emissions baseline of an electric utility would be defined as the utility's historical level of CO_2 emissions per kilowatt-hour of electricity generated; and a motor vehicle manufacturer's emission baseline would be defined in terms of

CO_2-producing potential per automobile. The advantage of this approach is that it is not affected by a firm's market share. When emissions are defined in terms of total emissions per facility, it has the tendency to freeze the status quo with respect to market shares.

However, the alternative approach of calculating emissions per unit of output has three flaws, which make it unattractive for a CO_2 offset program. First, it is administratively more complicated because emission levels would have to be divided by output. This can be quite costly given the large number of different types of output that involve CO_2 release. Another complicating factor is that many manufacturing facilities produce more than one type of output (i.e. products). Second, it is not clear how emission rights could be traded among different types of output. For example, how would rights for one ton of CO_2 per unit of electricity compare to rights for one pound of CO_2 per automobile? Third, emission rights based on emissions per unit of output would not effectively control CO_2 emissions, because increases in the quantity of output, and the resulting increase in total CO_2 emissions, would be unconstrained. For these reasons, emission rights and emission baselines should be defined in terms of total emissions per facility.

(E) Operation of the Emissions Trading System

(xv) Duration of Emission Rights: Emission rights could be perpetual or of limited duration.[109] Emission rights of limited duration decrease emissions trading and industry flexibility to adopt long-term CO_2 emission control policies because of the uncertainty about emission rights after the current rights expire. The short, five-year duration of water pollution permits seriously hampered trading of water pollution rights in the Fox River, Wisconsin trading program.[110] On the other hand, there is great uncertainty about the future manifestation of global warming and the possible need for further reductions in CO_2 emissions. It is very possible that a future international agreement will have to be renegotiated every few years to revise national emission quotas in light of new scientific information. The U.S. will not have the flexibility to meet its changing national quotas if it allocates perpetual emission rights to industry. A possible solution that addresses these conflicting concerns is to make the ownership of emission rights perpetual, but the value of rights will be of limited duration. In other words, emission rights would be issued for a period of, for example, seven years. At the end of this period, the U.S. government could decide to discount all emission rights by a specified percentage. In order to enhance industry planning, the government could announce its intention to discount emission rights well in advance of the expiration date of the current emission rights. However, the owner of the rights at the time the original period expires would retain ownership of the rights, even if their value is diminished. This solution gives the government the flexibility to make additional reductions in CO_2 emissions. It also guarantees secure emission rights for industry, [111], which should facilitate emissions trading, and long- term planning.

(xvi) Emissions Trading Ratio: The offset requirement of the CAA for new sources locating in non-attainment areas requires new sources to offset every unit of new emissions with reductions of 1.2 units of emissions from existing sources.[112] A trading ratio of greater than unity is favored by some as a means for achieving further reductions of pollution emissions. However, this approach is short-sighted. If further reductions of emissions are warranted, they should be achieved by reducing the total quantity of emission rights that are allocated, not by "taxing" emissions trading with a trading ratio greater than unity. Emission trading is a mechanism for achieving a given level of emission reduction; it should not be used as a mechanism for reducing emissions further. The result of taxing emissions trading by requiring additional reductions as a pre-condition creates a disincentive for trading that increases the overall cost of reducing emissions. For example, the additional twenty percent reduction requirement of the CAA offset

program has imposed additional costs on firms and has restricted trading activity. [113]

The only situation in which a trading ratio greater than unity is justified is when there is considerable uncertainty in measuring the emission reductions at an existing source. Higher trading ratios provide a margin of safety for protecting the environment when emission reductions are uncertain. For example, in the Dillon Reservoir program in Colorado, a point source can offset one unit of effluent reduction requirements by securing two units of effluent reductions from non-point sources. [114] This two-for-one trading ratio is warranted because of the difficulty in accurately measuring the water pollution discharges from non-point sources. Nevertheless, the cost savings from reducing non-point sources, instead of point sources that are already tightly controlled, makes these two-for-one trades worthwhile. A similar situation may apply to emission reduction credits for reforestation programs under a CO_2 offset program.

Although evidence suggests that these projects offer a relatively inexpensive method for reducing CO_2, there are large uncertainties in calculating the quantity of CO_2 absorbed by reforestation projects. One way to allow credit for reforestation programs without jeopardizing total emission reduction goals would be to require trading ratios of greater than unity. For example, if a new utility intended to offset new emissions of *x* tons per year with a reforestation project, it could be required to achieve an estimated 1.2x units per year of CO_2 reductions. This increased trading ratio would provide a margin of safety for the inherent uncertainties in the estimates of CO_2 reduction from reforestation projects.

(xvii) Credit for Shutdowns: One of the most controversial aspects of the CAA emissions trading program was whether a firm should receive credit for a shutdown of a facility that would have occurred anyway. [115] It can be argued that a decision to give credit for the emissions reduction from a facility shutdown that would have occurred anyway results in a net increase of total emissions. A shutdown that would have occurred anyway would result in permanent reductions, so why give credit for these reductions that can be used to increase emissions by an equivalent amount elsewhere?

There are several reasons why credit should be given for facility shutdowns. A subjective shutdown test that asks whether the shutdown would have "occurred anyway" would be unworkable. The decision to close a facility is not usually a clear black or white issue, and so it would be very difficult and burdensome for a government agency to have to decide whether each particular shutdown was inevitable or instead was motivated by the intention to earn emission reduction credits. Furthermore, even if a facility would have eventually closed anyway, offering emission reduction credits for shutdown might induce heavily polluting, marginal firms to shut down sooner. Early shutdowns of such facilities should help achieve emissions reductions at a lower overall cost. Finally, it is not clear why shutdowns should be distinguished from less drastic emissions reductions, some of which may also have been "inevitable:"

> A shutdown is nothing more than a 100 percent reduction in output. If a 99 percent reduction can qualify as an ERC, then so should a 100 percent reduction. A shutdown is merely one end of a continuum from no reduction to total reduction, and every point along that continuum deserves similar treatment. [116] For these reasons, full credit should be given to the emissions reductions from facility shutdowns.

(xviii) Emissions Banking: Another controversial issue similar to credit for shutdowns is emissions banking. Emissions banking consists of a state-operated registry of available emission reduction credits. Banking helps broker emissions trading by making it easier for buyers and sellers of emission credits to identify each other, thereby lowering transaction costs.

Participation in banking is voluntary, and even with banking it is still up to the buyer and seller to negotiate the price of an emissions trade. Emissions banking has been opposed by some environmentalists because it gives legitimacy to the concept of property rights in pollution. [117] However, it is widely agreed that banking can lower barriers to emissions trading and thus lower compliance costs for industry, therefore making deeper cuts in emission levels economically feasible. [118] Therefore, emissions banking should be permitted and encouraged.

A more controversial issue is whether a firm should receive credits for the time that an emission right is not used, whether it be banked or not. For example, suppose a firm has excess emission rights and deposits them in bank, and they are not sold for two years. The buyer would be entitled to exercise the rights for all future years, but should the seller receive credit for the two years the rights were in the bank and therefore unused? A similar situation is when a facility unexpectedly emits less CO_2 than usual in a particular year because of some temporary slowdown. Should the firm receive credit for this temporary one-year reduction in emissions below its allowable limit?

The CAA emissions trading program and the lead trading programs adopted different solutions to this kind of problem. Under the CAA, if an emission right is not used in a particular year, the right to emit in future years will survive intact, but the firm will receive no credit for the year in which the emission rights were not used. Thus, emission rights are treated as "in the air" for the period in which they are banked.[119] In contrast, under the lead trading program, a firm that does not use all of its lead rights in a particular year can bank its unused allowances from that year and either use them or trade them for use in a future year. [120]

Giving credit for emission rights not used in a particular year would result in increased emissions, since foregone emissions could be added on to the emission totals in future years. Therefore, the question is whether there are advantages to be gained from allowing firms to receive credit for unused emission rights that were not used that would justify the increase in emissions that would result. There are such reasons. First, it should be stated that the resulting increase in emissions would not cause the national emissions goal to be exceeded, because the foregone emissions were included in the national quota in the first place.

Second, giving credit for emissions that were not used in a particular year could help achieve the national emissions goal at lower overall cost. For example, consider a hypothetical example in which a firm plans to undertake major renovations of its facility in two years. The renovations will allow the firm to significantly increase production while holding CO_2 emissions constant. It may be that there are some very inexpensive steps the firm could take in the meantime to reduce CO_2 emissions for the last two years of operation of the current, inefficient facility. However, since the firm will need all of its emission rights for its renovated facility in two years, it would not be willing to permanently sell any of its emission rights. The firm would only undertake the relatively inexpensive steps to reduce its current emissions if it could receive credits for not using all of its current emission rights in the two year period. It could then sell these credits to a firm that would otherwise have to reduce its emissions for those two years using much more costly methods. Both firms would benefit from this type of arrangement, and the total cost to society of reducing CO_2 emissions would be reduced.

A third reason for giving credit for unused emission rights is that it has the effect of deferring emissions from the present year to future years. The concern about global warming is not just with the potential magnitude of climate change, but also with the rate of change. [121] Delaying emissions from the present year to a future year slows the rate of atmospheric CO_2 build-up, and is therefore beneficial.

(xix) Credit for Emission Reductions: Under an offset program as presented so far, only sources receive emission reduction credits for emission reductions. However, what happens when the emission reductions result from the action of some party other than the source? For example, an environmental organization may undertake an energy conservation awareness program in a community that results in significant reductions in demand for electricity from a nearby coal-fired electric utility. It seems unfair that the utility should get credit for the emission reductions that result from the actions of the environmental group. However, any other rule would likely be unworkable. It is not possible to assign with precision and certainty the factors responsible for increases or decreases in electricity demand in a particular community. In the hypothetical example, the environmental organization might claim that its energy conservation advertisements on television were responsible for decreased electricity demand, while the utility might argue that the leaflet it inserted in electricity bills urging people to turn off unused lights was responsible for the decreased energy demand. It would be impossible for an administrator to decide between these and other claims for credit for the decline in energy demand and the consequent reduction of CO_2 emissions.

The simpler rule would be to give the credit for all emission reductions to the source at which the reductions occur. Organizations that undertake actions that may result in emission reductions at a utility or other source could negotiate in advance with the source for a share of the profits from the resulting emission reduction credits.

There will be some situations where the normal rule of giving the credit for emissions reduction to the emissions source will not work. Most of these situations will involve mobile sources. For example, the United Parcel Service recently initiated a program in New York to retrofit its delivery vehicles to use natural gas. Emissions tests indicate that CO_2 emissions are reduced by 13 percent in the retrofitted vehicles. [121] It does not seem appropriate to give the vehicle manufacturer the credit for these emission reductions, since it was not involved in any way. Therefore, in situations such as this where emissions reductions are achieved in motor vehicles after they have left the manufacturer, emission reduction credits could be given to the responsible party when the emissions reductions are permanent, quantifiable, and verifiable.

(xx) Complementary Programs: The final policy choice is whether a CO_2 offset program should be adopted alone or in conjunction with other programs to reduce CO_2 emissions. At best, a CO_2 offset program as described in this paper would stabilize U.S. CO_2 emissions at current levels. However, the EPA estimates that CO_2 emissions will have to cut by more than 50 percent to stabilize atmospheric concentrations of CO_2. Other greenhouse gas concentrations are also increasing steadily, and these gases may also have to be controlled. It is likely, therefore, that additional programs may be needed in addition to a CO_2 offset program to control global warming.

If additional regulatory programs are adopted, care should be taken to choose programs that complement rather than conflict with the offset program. Several lessons can be learned from previous emissions trading programs. One of the key lessons from the CAA is that the "effectiveness of [an emissions trading] system is undermined when that system is complemented by additional regulations compelling some high minimum level of treatment on the part of all emitters.[124] Performance standards conflict with an emission trading program because they sometimes prevent the least expensive emission reductions. Another lesson from the CAA is that it is better to adopt an emissions trading system at the beginning of a regulatory program, rather than adding an emissions trading system to supplement an existing regulatory program:

> Designing a market approach can be much more difficult when building on an existing regulatory program than when starting from scratch. Emissions trading, for example, was introduced after clean air parameters were fixed and stakeholders had learned to live with the devil they knew. From the start, trading was conceived as a limited supplement to the command- and-control structure, not a replacement. Therefore,, it ran headlong into such complexities of the existing regime as uncertain emission inventories, deficient air quality plans, and failed attainment deadlines . . . [A]ddressing the complexities of the underlying program made trading rules nearly as complex.

Another consideration is that if complementary regulatory programs result in actual reductions of CO_2 emissions, the emission rights under an offset program should be periodically discounted so that the quantity of emission rights will not exceed total emissions at any point.

Several types of programs could complement a CO_2 offset program. Regulatory initiatives that directly or indirectly control emissions of other greenhouse gases are unlikely to conflict with a CO_2 offset program. Government-funded research programs to develop more energy efficient technologies and alternative energy sources that do not release CO_2 would strengthen a CO_2 offset program by increasing the availability of cost-effective emission reduction methods and technologies. The development of energy conservation, mass transit, and commuter carpooling programs may also complement a CO_2 offset program. Finally, a small carbon tax may complement a CO_2 offset program. Although such a tax creates large and unpopular transfer payments to government, it would not need to be set as high in conjunction with an offset program because firms would already have incentives to reduce CO_2 emissions. A small supplementary carbon tax would add further incentives for emissions reductions, and would take back some of the windfall profits firms would receive from the grandfathering of emission rights based on historical emission levels.

CONCLUSION

In theory, a CO_2 offset program offers many potential economic, practical, and political advantages over command and control regulations, a carbon tax, or emissions trading programs for other pollutants. However, these potential advantages will only be appropriated if the legal, technical, and administrative details of the offset program are carefully selected to maximize the cost-effectiveness, administrative feasibility, and fairness of the program.

This paper has attempted to identify and discuss many of the important details in designing and implementing a CO_2 offset program. A total of twenty policy choices and a recommended option for each has been presented, and are summarized in Table V. A CO_2 offset policy should be implemented as a national program, preferably after an international agreement has established a U.S. emissions quota. The program should be administered primarily at the state level, although with some federal assistance for functions such as record keeping of emissions trades. Emission levels should be calculated based on well-established emission factors, and self-reporting by firms should be the primary mechanism for monitoring industry compliance.

The offset policy should apply only to CO_2, at least to begin with. The program would apply to the consumers rather than the producers of fossil fuels; and the requirements for mobile sources would be slightly amended to hold motor vehicle manufacturers responsible for the CO_2-producing potential they put on the market each year. Minor stationary sources would be exempt from the offset program, but manufacturers of minor sources of CO2 emissions may be subject

to an offset requirement similar to that for motor vehicle manufacturers. Finally, credit would be given for increasing sinks of CO_2, provided that adequate safeguards to ensure compliance could be established.

Emission rights would be grandfathered based on historical emission levels. Firms would be given emission rights at no cost equivalent to their emission levels in the baseline year. The baseline would be defined in terms of total CO_2 emissions per facility, rather than emissions per unit of output.

Emission rights would be of limited duration with respect to their value; but the ownership of the rights would be perpetual. Emissions would be traded on a 1:1 ratio, and credits would be given for the shutdown of facilities. Emissions banking would also be allowed, and firms would be able to store and later use emission rights that were not exercised in a particular year. Only sources of emissions would qualify for credit for emissions reductions, with some limited exceptions. It may be necessary to complement the offset policy with additional programs to reduce greenhouse gas emissions; but caution should be exercised to ensure that these programs do not conflict with or undermine the offset program. A CO_2 offset program based on these recommendations should achieve substantial reductions in the projected future growth of U.S. emissions of CO_2 at the lowest possible cost, if and when the U.S. decides that such reductions are necessary.

Footnotes

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1. Schneider, The Changing Climate, **Scientific Am**., Sept. 1989, at 70, 72.

2. D. Wuebbles & J. Edmonds, A Primer on Greenhouse Gases, at 10 (DOE/NBB0083)(Mar. 1988).

3. A. Manne & R. Richels, Global CO_2 Emission Reductions - The Impacts of Rising Energy Costs, at 16 (Feb. 1990).

4. Id.

5. E.g ., J. Edmonds & H. Cheng, A Preliminary Analysis of U.S. CO_2 Emissions Reduction Potential from Energy Conservation and the Substitution of Natural Gas for Coal in the Period to 2010, at 3 (DOE/NBB-0085) (Feb. 1989).

6. The other major greenhouse gases include methane, nitrous oxide, and chlorofluorocarbons ("CFCs"). The relative contributions of these gases to the change in radiative forcing from 1980 to 1990 are 55 % for CO_2, 17 % for CFCs 1 l and 12, 15 % for methane, 6% for nitrous oxide, and 7% for other CFCs. See Intergovernmental Panel on Climate Change, Policymakers Summary of the Scientific Assessment of Climate Change (June 1990).

7. For a discussion of the potential impacts of global warming, see **EPA, Effects of Changes in Stratospheric Ozone and Global Climate** (Aug. 1986).

8. This paper does not attempt to address issues such as the likely magnitude of global warming, whether greenhouse gas emissions should be reduced, when they should be reduced, or by how much they should be reduced. Rather, the paper focuses on mechanisms for achieving cost-effective reductions if and when a decision is made to significantly reduce greenhouse gas emissions.

9. E.g. , Global Warming Reduction Act, H. R. 1078, 101st Cong., 1st Sess. (1989) (introduced by Rep. Schneider); National Energy Policy Act of 1989, S. 324, 101st Cong., 1st Sess. (1989) (introduced by Sen. Wirth).

10. Intergovernmental Panel on Climate Change, IPCC First Assessment Report: Overview (Aug. 31, 1990).

11. See Grubb, The Greenhouse Effect: Negotiating Targets, 66 **Int'l Affairs** 67, 69 (1990).

12. Ministerial Conference on Atmospheric Pollution & Climate Change, The Noordwijk Declaration on Atmospheric Pollution and Climatic Change, § 16 (Noordwijk, The Netherlands, Nov. 1989).

13. See O'Sullivan & Zurer, Global Warming: Small but Solid Progress Toward Treaty, **Chem. Eng.** *News*, Nov. 19, 1990, at 4.

14 See, e.g., Ruckelshaus, Toward a Sustainable World, **Scientific Am.,** Sept. 1989, at 166, 172; **T. Wirth & J. Heinz, Project 88,** at 15-16 (Dec. 1988); **D. Dudek, Offsetting New** CO_2 **Emissions,** (EDF, Sept. 1988); J. Swisher & G. Masters, International Carbon Emission Offsets: A Tradeable Currency for Climate Protection Services (Stan. U. Dept. of Civil Eng. Tech. Rep. #309) (Feb. 1989). Congressman Jim Cooper of Tennessee introduced legislation in the final days of the 101st Congress calling for a CO2 offset policy, and intends to reintroduce the legislation in the next Congress. H.R. 5966, 101st Cong., 2d Sess. (1990).

15. Although in theory an offset program would result in no net increase in CO_2 emissions, in practice some sources will be too small or diffuse to be controlled and therefore might cause slight increases in total CO_2 emissions.

16. Past or existing programs include: (1) EPA's lead rights trading program that allowed gasoline refiners to trade excess rights to include lead additives in gasoline; (2) the emissions trading program under the Clean Air Act ("CAA") that allows sources to use "offsets," "netting," "bubbles," and "banking" to meet regulatory requirements; (3) the Fox River effluent trading program that allows sources on the Fox River in Wisconsin to trade water pollution discharge allowances; (4) the Dillon Reservoir water pollution rights trading program in Colorado that allows point

sources of water pollution discharged into the Dillon Reservoir to meet pollution reduction requirements by acquiring pollution rights from non-point sources in a 2:1 ratio; and (5) the CFC production rights program that allows producers of CFCs to trade CFC production permits. In addition, Title V of the new Clean Air Amendments recently enacted by Congress and signed into law by President Bush will allow coal-fired electric utilities to trade sulfur dioxide emission rights.

17. See, e.g., Hahn & Hester, Marketable Permits: Lessons for Theory and Practice, 16 **Ecology** L. Q. 361 (1989) [hereinafter Hahn & Hester I]; Hahn & Hester, Where Did All the Markets Go? An Analysis of EPA's Emissions Trading Program, 6 **Yale J. Regulation** 109 (1989) [hereinafter Hahn & Hester II]; Hahn, Economic Prescriptions for Environmental Problems: How the Patient Followed the Doctor's Orders, 3 **J. Econ. Persp.** 95 (1989); Stavins, Harnessing Market Forces to Protect the Environment, **Environment,** Jan./Feb. 1989, at 5; Tripp & Dudek, Institutional Guidelines for Designing Successful Transferable Rights Programs, 6 Yale J. Regulation 369 (1989); Dudek & Palmisano, Emissions Trading: Why is This Thoroughbred Hobbled?, 13 **Col. J. Int'l** L. 217 (1988); ; Hahn & Noll, Barriers to Implementing Tradable Air Pollution Permits: Problems of Regulatory Interactions, 1 **Yale J. Regulation** 63 (1983); Brady, Emissions Trading in the United States: An Overview and the Technical Requirements, 17 **J. Envtl.** Management 63 (1983); Gonzalez, Markets in Air: Problems and Prospects of Controlled Trading, **5 Harv. Envtl.** L. **Rev.** 377 (1981); B. Cook, Bureaucratic Politics **and Regulatory Reform: The EPA and Emissions Trading** (1988); **R. Liroff, Reforming Air Pollution Regulation: The Toil and Trouble of EPA's Bubble** (1986); **T. Tietenberg, Emissions Trading: An Exercise in Reforming Pollution Policy (1985); General Accounting Office, A Market Approach to Air Pollution Control Could Reduce Compliance Costs Without Jeopardizing Clean Air Goals** (Mar. 1982); W. Foskett, Emission Offset Policy at Work: A Summary of Eight Cases (Nat'l Bureau of Standards Apr. 1980).

18. "Command and control" approaches involve setting and enforcing uniform technological or emissions standards for pollution sources.

19. For a theoretical proof of this proposition, see Montgomery, Markets in Licenses and Efficient Pollution Control Programs, 5 **J. Econ. Theory** 395 (1972).

20. Another study of the marginal costs of CO_2 emission reduction was conducted for the Dutch government by McKinsey & Company. These researchers also found wide variations in marginal costs between different methods, ranging from a marginal cost per ton of carbon avoided of -$200 per year to over $100 per year. See McKinsey & Co., Protecting the Global Atmosphere: Funding Mechanisms (June 1989).

21. For example, one set of researchers estimated that the discounted price of stabilizing U.S. CO2 emissions through the year 2100 will range from 0.8 to 3.6 trillion dollars. A. Marine & R. Richels, CO_2 Emission Limits: An Economic Cost Analysis for the USA, at 2627 (Nov. 1989) (forthcoming in The Energy Journal).

22. See, e.g., Congressional Budget Office, Carbon Charges as **a Response to Global Warming: The Effects of Taxing Fossil Fuels** (Aug. 1990); A Tax to Keep Cool, **Economist,** May 13, 1989, at 19; Menyasz, Scientists from 48 Countries View Tax on Fossil Consumption as Way of Helping Pay for Action Plan to Safeguard Global Atmosphere, 11 Int'l Env't Rep. (BNA) 414 (1988).

23. Regulators will only know the costs per unit of CO_2 emissions they will be imposing on sources of CO_2 emissions. They will not know the overall costs to industry, however, because regulators cannot be certain how much reduction in CO_2 emissions a given level of tax will achieve.

24. See supra notes 19-20 and accompanying text.

25. Levin & Elman, The Case for Environmental Incentives, **Envtl F.,** Jan./Feb. 1990, at 7, 9.

26. See supra notes 3 - 5.

27. In contrast, an emissions trading program will automatically adjust to increased demand for CO_2 emission rights. Since the supply of emission rights will be fixed, the price for the rights will increase in tandem with the growing demand for emission rights.

28. Stewart, Economics, Environment, and the Limits of Legal Control, 9 **Harv. Envtl. L. Rev.** 1, 13 (1985).

29 The one exception to this statement is the recent tax imposed on ozone depleting CFCs. S.D. Seidel & Blank, Closing an Ozone Loophole, **Envtl. F.,** Nov./Dec. 1990, at 18.

30. See S. **Breyer, Regulation and Its Reform** 282 (1982).

31. A. Manne & R. Richels, supra note 3, at 26. This estimate was of the long-run equilibrium price needed to stabilize CO_2 emissions until the year 2100. Other researchers have used a shorter time horizon and have calculated a somewhat lower tax. For example, Chandler & Nicholls estimate that a carbon tax of $85 per ton would suffice to hold CO_2 emissions constant through the year 2000. W. Chandler & A. Nicholls, Assessing Carbon Emissions Control Strategies: A Carbon Tax or a Gasoline Tax? (Am. Council for an Energy-Efficient Economy Policy Paper #3 1990).

32. The size of trading zones varied from state to state and region to region. A typical rule restricted trading to sources that were within an 85 mile radius. See W. Foskett, supra note 17, at 23.

33. See, e.g., Hahn & Hester I & II, supra note 17.

34. See, eg, Noll, Implementing Marketable Emissions Permits, 72 **AEI Papers** & **Proc.** 120, 121 (1982).

35. See Hahn & Hester I, supra note 17, at 364.

36. However, hoarding of emission rights may still be a problem if companies hold onto unused emission rights out of fear that they will not be able to purchase additional rights in the future if they need them.

37. Tripp & Dudek, supra note 17, at 376.

38. See supra notes 1 - 5 and accompanying text.

39. See Hahn & Hester I, supra note 17, at 399.

40. Id.

41. IPCC, Report of the Second Session of IPCC Working Group III/ Response Strategies Working Group (RSWG) (Geneva, Oct. 1989). The United States has recently submitted a "Concept Paper" to the IPCC Working Group that suggests an emissions trading approach. See Materials for the Informal Seminar on U.S. Experience with "Comprehensive" and "Emissions Trading" Approaches to Environmental Policy (Wash., D.C., Feb. 3, 1990). See also Sun, Emissions Trading Goes Global, 247 **Science** 520 (1990).

42. The relative advantages of these three unique aspects of an offset program are considered below in the discussion of specific policy choices for designing such a program.

43. There are many ways a firm could reduce its CO_2 emissions and receive ERCs. Utilities could increase the efficiency of primary energy generation (e.g. by heat recovery), invest in education and incentive programs for energy conservation by consumers, shift to lower carbon fuels such as natural gas, or shift to non-fossil fuel electricity generation. Manufacturers could reduce the energy intensity of manufacturing processes and improve the energy efficiency of products such as automobiles and appliances. Cogeneration plants could also result in net decreases in CO_2 emissions. As the EPA concluded, "[n]o single technology or small set of technical options offers `a solution' to greenhouse gas emissions. Only by aggregating the effects of many technical opportunities over a long time can significant reductions in greenhouse gas emissions be achieved." **EPA, Policy Options for Stabilizing** Global Climate VII-6 (Draft Feb. 1989). The diversity of possible technologies and methods for reducing CO_2 emissions is of course a strong reason for using market mechanisms to decentralize decision-making to the plant managers of the large number of facilities that produce CO_2 emissions.

44. See, e.g., McKinsey & Co., supra note 20; EPA, supra note 43, at VIII-38; J. Swisher & G. Masters, supra note 14, at 14. The conclusion that there is a large potential for cheap emission reductions in developing countries assumes that emissions in these countries will remain relatively unconstrained and thus will grow rapidly. See A. Marine & R. Richels, supra note 3, at 14. On the other hand, if emissions in these countries are tightly controlled by an international agreement, there will likely be very little excess emissions that are available for sale to the United States. Although an international agreement would likely allow much more emissions growth in developing countries (see Grubb, supra note 11, at 75), the rapid rate of economic growth projected for many developing countries makes questionable the assumption that these countries will have large surpluses of unneeded emission rights that can be sold to countries such as the United States.

45. See, e.g., J. Swisher & G. Masters, supra note 14.

46. See IPCC, Supra note 41 (noting that several nations expressed "political concerns about the `right to pollute'

and the ability of wealthy nations to procure those rights . . . [and therefore suggesting] that an international system of tradeable permits was not advisable"(emphasis added)].

47. Id.

48. Grubb, supra note 11, at 82. A related possibility is that developing country X, wanting to encourage foreign investment, will give a significant quantity of its national emissions quota to a subsidiary of a large U.S. corporation that is operating in X. A few years later, when emission rights become very scarce in the U.S., the parent company may decide to shut-down the subsidiary in country X and transfer its emission rights to the U.S., thereby depriving X of important emission allowances it needs to develop.

49. This does not foreclose the possibility that nations, as opposed to private companies, may be permitted to buy or sell emission rights from other countries under an international agreement setting national CO_2 emission quotas. Trading between nations does not raise the same administrative and political problems as international trading between private sources. However, other problems would arise. For example, given the uncertainty about future global warming, it is likely that national emission quotas would have to be periodically renegotiated in light of new scientific evidence. A country would therefore be unlikely to sell any of its emission rights to another country, knowing that at the next set of negotiations it will have a difficult time justifying why it should not have its quota reduced given that it had surplus emission rights to sell in the previous period. Regardless of whether country-to-country trading is permitted under a future international agreement, each country will have to decide the type of regulatory mechanism it will use to meet its national quota, whether it be by an emissions trading program, a carbon tax, or emission standards.

50. Under the CAA, states are responsible for designing and enforcing State Implementation Plans that include many of the regulatory requirements of the Act. 42 U.S.C. § 7410 (1988).

51. See A. Manne & R. Richels, supra note 3.

52. See Hahn & Hester I, supra note 17, at 378-79.

53. As mentioned earlier, even if an international agreement exists, there may be periodic revisions of national emission quotas in response to new scientific information. However, these fine-tuning adjustments of national quotas are likely to have a much less disruptive effect on a U.S. offset program than the original allocation of national quotas when the agreement is first entered into.

54. See Hahn & Hester II, supra note 17, at 137. For example, twice as many bubbles have been approved by state programs than approved by EPA. Id. at 127-28.

55. States with approved state implementation plans are responsible for permitting existing sources. New sources are required to obtain a pre-construction permit (commonly called "new source review") and an operating permit. Both the federal and state government are involved in new source review. The EPA regional offices usually have primary responsibility for preconstruction review of new sources locating in attainment regions, while states usually have primary responsibility for new sources locating in non-attainment areas. Since many areas are in attainment for some pollutants and in non-attainment for other pollutants, sources in these areas have to obtain one permit from the state and another permit from the EPA. See **J. Bromberg, Clean Air Act Handbook** 252-56 (2d ed. 1985). Title V of the new Clean Air Act Amendments will revamp the CAA operating permitting system to require all sources to obtain operating permits from states with approved permit programs. Pub. L. No. 101-549 (1990).

56. The reporting of trades to the EPA would involve minimal information requirements, and would include the name and location of the sources, the size and price of the trade, and the signatures of a responsible official from each party.

57. Pub. L. No. 101-549, Title IV (1990). Interstate emission trading would only be permitted in the second phase of the acid rain reduction program. EPA also currently maintains other databases on air pollution sources. The National Emission Data system ("NEDS") contains data on criteria pollutant emissions by major and minor sources across the country. The Compliance Data System ("CDS") maintains records of the compliance status of all major and many minor sources of air pollution. It is possible that record-keeping of CO_2 emission trading could be integrated into one of these two existing databases.

58. The database could also be accessible to private parties. Companies could use the database to check the going price of emissions trades, and also to check-up on the compliance of competitors. Environmentalists could also use the database to monitor industry compliance.

59. EPA, Emissions Trading Policy Statement; General Principles for Creation, Banking and Use of Emission Reduction Credits; Final Policy Statement, 51 Fed. Reg. 43,832 (1986) [hereinafter EPA Emissions Trading Policy].

60. See M. Steinberg, An Analysis of Concepts for Controlling Atmospheric Carbon Dioxide (DOE/CH/00016-1)(Dec. 1983).

61. Average emission factors for the major fossil fuels are, in pounds of CO_2 per pound of fuel:

Bituminous Coal	2.59
Fuel Oil & Gasoline	3.14
Natural Gas	2.75

See M. Steinberg, H. Cheng & F. Horn, A Systems Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S., at 6 (DOE/CH/000162) (Dec. 1984).

62. The carbon content of petroleum and natural gas is quite consistent between different samples, and therefore a single emission factor could be established for each type of fuel. However, the emission factor for coal varies considerably depending on the type of coal. A recent analysis of 491 coal samples found that the carbon content varied from 48.2 to 85.9 percent. G. Marland &R. Rotty, Carbon Dioxide Emissions from Fossil Fuels: A Procedure for Estimation and Results for 1950-1981, at 57 (DOE/NBB-0036) (June 1983). However, the U.N. has developed a system for rating different types of coal in energy units of "tons coal equivalent" based on heating value. The carbon content of coal can be calculated from the heating value at 56. Therefore, this rating system could be used to establish CO_2 emission factors for different types of coals. "Coal equivalent" contains about 70.7 percent carbon. Id, at 57.

63. Cement manufacturing involves the calcination of calcium carbonate ($CaCO_3$) into calcium oxide (CaO) and CO_2. The production of one metric ton of cement results in the release of 0. 136 tons of carbon into the atmosphere as CO_2. R. Griffin, CO_2 Release from Cement Production 1950-1985, at 8 (Inst. for Energy Analysis, Aug. 1987).

64. Typical municipal refuse that is burned in incinerators contains 25.54% carbon by weight. See **S. Williamson, Fundamentals of Air Pollution** 290 (1973). Most of this carbon is released as CO_2. See Santoleri, Incineration: Introducing the Technical Issues, 9 **Envtl. Impact. Assessment Rev.** 163, 173-74 (1989). However, a standard national CO_2 emission factor would be very crude because the content of refuse varies significantly with location. Although some of the CO_2 produced by incinerators is from the combustion of organic matter that would have released much of its carbon into the atmosphere anyway by natural processes, much of the CO_2 produced is from plastics and other synthetic products.

65. See Hahn & Hester I, supra note 17, at 388-90.

66. 40 C.F.R. § 80.20(d) (1988).

67. See Dudek & Palmisano, supra note 17, at 240.

68. Hahn & Hester I, supra note 17, at 405.

69. The baseline would be established by a firm's emissions in a designated year prior to the beginning of the program. The baseline year should be before the program comes into existence so that firms will not intentionally boost their emissions to establish a higher baseline; but on the other hand the baseline year should be chosen as close to the beginning of the program as possible to minimize changes from the status quo. Using a single year to calculate baselines may be unfair to firms that had an unrepresentative year due to a prolonged labor strike or an extended maintenance shutdown. To avoid such problems, it may be preferable to establish baselines based on a three year average of emissions, as is done in the acid rain provisions of the new Clean Air Amendments.

70. An exemption would probably be allowed for de minimis exceedances. In order to deter exceedances, a firm may be required to compensate exceedances with leased ERCs in more than a 1: 1 ratio. For example, if a firm exceeded its allowable limit of 1000 tons of CO_2 per year by 100 tons in a particular year, it may have to make up this exceedance by leasing 200 additional tons of emission rights for a one-year period. The question of whether a firm would be entitled to credit when it emitted less than its allowable limit in a given year is discussed later in section (E).

71. See supra note 6.

72. For example, a CO_2 offset policy may cause firms to shift to natural gas, but the increased emissions of

methane from leaks in natural gas pipelines would not be considered. See D. Victor, Tradeable Permits and Greenhouse Gas Reductions: Some Issues for U.S. Negotiators, at 45 (M.I.T. Feb. 1990).

73. On the other hand, since fossil fuel consumption also produces other greenhouse gases such as methane and tropospheric ozone, reductions in the use of fossil fuels that result from a CO_2 offset program may simultaneously result in net reductions of other greenhouse gases. Id. at 53.

74. These and other arguments for a comprehensive approach are summarized in a discussion paper prepared by the U.S. Department of Justice for the IPCC Response Strategies Working Group. See Materials for the Informal Seminar on U.S. Experience with "Comprehensive" and "Emissions Trading" Approaches to Environmental Policy.

75. See D. Wuebbles & J. Edmonds, supra note 2, at 4 ("Of particular concern is the relatively primitive evaluation of the relationship between energy activities and emissions of these gases ...").

76. The greenhouse potential of a gas is a function of two factors: (i) residency time, or the time that a given molecule of a gas remains in the atmosphere; and (ii) radiative forcing, or the effectiveness of a given molecule of a gas in preventing energy from leaving the earth's atmosphere.

77. See, e.g., McKinsey & Co., supra note 20.

78. See D. Victor, supra note 72, at 37.

79. Id. at 42.

80. IL at 7.

81. CFCs, the third largest contributor to global warming, are already regulated by international agreement to control ozone depletion. Although some of the substitutes that will replace the regulated CFCs will also contribute to global warming, the regulation of CFCs should have a net positive impact on global warming and partially reduce the need to include CFCs in a greenhouse gas offset program.

82. 53 Fed. Reg. 30,566 (1988). In the U.S., there are only five CFC manufacturers but about 200,000 end users. See Shapiro & Warhit, Marketable Permits: The Case of Chlorofluorocarbons, 23 **Nat. Resources J**. 577, 587 (1983).

83. See, e.g., Noll, supra note 34, at 121.

84. An EPA consultant estimated that the permit allocation system would produce $1.8 to $7.2 billion in windfall profits for producers. 53 Fed. Reg. 30,606 (1988). This assumes that emission rights are allocated free of charge. A fossil fuel consumer offset program would also result in windfall profits for firms that use fossil fuels, but the benefits would be spread over a much larger number of firms.

85. P.L. 101-239, 103 Stat. 2106 (1989). See also Proposals to Control the Manufacture, Use, and Disposal of Ozone-Depleting Substances. Hearings before the SubComm. on Envtl. Protection of the Senate Comm. on Env't and Public Works, 101st Cong., 1st Sess. (1989).

86. G. Marland & R. Rotty, supra note 62, at 573.

87. Some natural gas is used for ammonia and methyl alcohol production and as a petrochemical feedstock. Id. at 15. Some of the coal used for coking ends up as non-oxidized byproducts. Id at 45-47.

88. For example, in 1987 the U.S. produced 17.7 quadrillion Btus (QBtu) of oil and exported approximately 1.6 QBtu (9.0%), and produced 20.2 QBtu of coal of which 2.1 QBtu (10.4%) was exported. Energy Information Admin., **Annual Energy Outlook, Long-Term Projections 1989,** at 45 (1989).

89. Fossil fuels imported into the U.S. would be treated the same way as fuels produced in the U.S. and therefore would be subject to the offset requirement.

90. For example, at least one commentator has proposed a CO_2 offset program that would originally include only stationary sources. See **D. Dudek,** supra note 14, at 4.

91. See supra note 5.

92. The total CO_2 -producing potential of a motor vehicle manufacturer would include not only automobiles but also trucks, buses, motorcycles, and all other types of motor vehicles. Manufacturers of locomotives and airplanes may also be subject to a similar offset requirement.

93. The offset requirement for mobile sources would apply to all motor vehicles sold in the United States. Therefore, foreign importers of automobiles would be responsible for the CO_2 -producing potential they sell in the U.S. market.

94. A "major" source is defined as a facility that emits more than 100 or 250 tons per year of regulated pollutants, depending on the industry classification. See 42 U.S.C. § 7479(1) (1988).

95. Unlike the CAA, minor modifications of major sources need not be exempt from a CO_2 offset program, since these sources would have to comply with the annual reporting requirements anyway. In other words, a modified source will not have to go through any extra procedures than would an unmodified source under an offset program, and so there is no argument of administrative burden to justify exempting minor modifications, unless the CO_2 emission increases are truly de minimis.

96. A good example of the dangers of ignoring minor sources is the CAA offset program, which required new sources locating in non-attainment areas to offset new pollutant emissions. However, the offset requirement only applied to major sources. In the Los Angeles area, 3,959 new sources escaped the offset requirement in the decade between 1976 and 1986 because they were classified as minor. Together, these minor sources increased emissions of hydrocarbons by 200,000 pounds per day. By comparison, the total level of new emissions by major sources that were required to be offset was only 27,000 pounds per day. Thus, 88% of new pollutants went unregulated. See Tripp & Dudek, supra note 17, at 385 n.53.

97. Table III does not include data for incinerators. EPA projects that the number of municipal incinerators will increase from 111 incinerators burning 48,971 tons per day currently to over 310 facilities burning over 200,000 tons per day by the year 2000. See Santoleri, supra note 64, at 166, 193.

98. Since only average emission levels are calculated for each category of sources, some sources within the category will obviously emit less than the category average. However, for purposes of simplification, all sources within a category will be treated as identical in this discussion.

99. **Council on Environmental Quality, Environmental Quality 1982**, at 75 (1982).

100. Other types of carbon sinks, such as scrubbing CO_2 from emission stacks and sequestering the carbon deep in the ocean, may be possible and should also be eligible for emission reduction credits. While such methods are unlikely to be technologically or economically feasible in the near future, the availability of credits for new types of sinks will encourage innovation to develop such technologies.

101. See M. Steinberg, supra note 60, at 46. See also G. Marland, The Prospect of Solving the CO_2 Problem Through Global Reforestation (DOE/NBB-0082) (Feb. 1988).

102. **D. Dudek,** supra note 14, at 8.

103. New developments such as remote sensing and recent efforts by the U.S. Forest Service to track forested lands may ease some of the administrative difficulties of the proposed scheme.

104. See D. Harrison, Policy Approaches for Controlling Greenhouse Gases, at 19 (NERA, May 1989).

105. Dudek & Palmisano, supra note 17, at 250.

106. **General Accounting Office, EPA's Safety Assessment of Substitutes for Ozone- Depleting Chemicals and Legal Issues Relating to CFC and Halon Production Rights,** at 45 (GAO/T-RCED-89-45)(May 1989).

107. Even freezing U.S. CO_2 emissions at current levels may be very difficult to achieve given the projected growth of unconstrained emission levels. See supra notes 3 - 5. An alternative option would be to allocate emission rights equivalent to current emissions, plus provide a small additional pool of emission rights that would be auctioned off by the government. This would allow some growth of total U.S. CO_2 emissions, but at a slower rate than if emissions were unconstrained. A policy to retard the growth of CO_2 emissions in the short-term may be more economically feasible than an immediate freeze on emissions. A longer-term goal could be to stabilize and then reduce emissions, provided that utilities and industry are given enough lead time to plan for the necessary innovation and investment. An offset program would also be compatible with this type of long-term goal if emission rights have finite duration and can be discounted in the future. See infra § (xv).

108. Pub. L. No. 101-549, Title IV (1990).

109. This discussion only refers to regular emission rights which give a firm a right to emit a specified quantity of CO_2 every year for the duration of the rights. The offset system will also involve a second type of emission rights. Temporary emission credits give a company the right to emit a given amount of CO_2 for one year only. For example, if a firm temporarily reduced its emissions for a single year, it would earn temporary credits that could be sold to firms that experienced a one-time exceedance of its allowable limits.

110. See Hahn & Hester I, supra note 17, at 392-93.

111. Even if the value of emission rights are discounted in the sense that fewer quantity of emissions allowed, the market value of the rights will increase because of the increased scarcity of emission rights.

112. EPA Emissions Trading Policy, supra note 59, at 43,816.

113. See Hahn & Hester II, supra note 17, at 146.

114. See Hahn & Hester I, supra note 17, at 394.

115. EPA Emissions Trading Policy, supra note 59, at 43,819.

116. **EPA, Emission Reduction Banking Manual**, at 15 (Sept. 1980).

117. See Hahn & Hester II, supra note 17, at 143.

118. See, e.g., EPA Emissions Trading Policy, supra note 59, at 43,825.

119. EPA Emissions Trading Policy, supra note 59, at 43,825.

120. 50 Fed. Reg. 13,117 (1985).

121. See **EPA**, supra note 43, at 1-23 ("The rate at which climate may change must be of particular concern to policy makers.").

122. See Dazunja, Natural Gas in the Big Apple, **E Magazine,** March/April 1990, at 11.

123. **EPA,** supra note 43, at I-9.

124. Tietenberg, Transferable Discharge Permits and the Control of Station Source Air Pollution: A Survey and Synthesis, 56 **Land Economics** 391, 413 (1980).

125. Levin & Elman, supra note 25, at 10.

APPENDICES

A-1

Table I Policy Choices in Designing a 002 Offset Program

A. Scope and Timing of Program:

i. Geographical Scope:
- a. International
- b. U.S. - national
- c. U.S. - state-by-state

ii. Timing of an Offset Program:
- a. Any time
- b. Only after an international agreement

B. Administrative Issues:

iii. Level of Government:
- a. State
- b. Federal

iv. Measuring Emissions:
- a. Monitoring/modeling
- b. Emission factors

v. Compliance Monitoring:
- a. Approval of trades
- b. Self-reporting

C: Types of Sources:

vi. Type of Greenhouse Gas:
- a. CO_2 only
- b. All greenhouse gases

vii. Producers/Consumers of Fossil Fuels:
- a. Producers
- b. Consumers

viii. Mobile Sources:
- a. Stationary sources only
- b. Stationary and mobile sources

ix. Minor Stationary Sources:
- a. All new sources
- b. Major new sources only

x. Credit for CO_2 Sinks:
- a. Source reductions only
- b. Source reductions or increased sinks

(cont'd)

A-2

Table I (cont'd)

Policy Choices in Designing a CO_2 Offset Porgram

D. Allocation of Emission Rights:

xi. Allocation Mechanism:
- a. Auction
- b. Give emission rights away

xii. Total Quantity of Rights Allocated:
- a. Equivalent to current emissions
- b. Less than current emissions

xiii. Basis for Allocation to Firms:
- a. Historical emission levels
- b. Industry averaging

xiv. Definition of Baseline:
- a. Total facility emissions
- b. Emissions per unit of output

E. Operation of the Emissions Trading System:

xv. Duration of Emission Rights:
- a. Limited
- b. Perpetual

xvi. Emissions Trading Ratio:
- a. Unity
- b. Greater than unity

xvii. Credit for Shutdowns:
- a. Yes
- b. No

xviii. Emissions Banking:
- a. Allowed
- b. Not allowed

xix. Credit for Emission Reductions:
- a. Any party
- b. Sources only

xx. Complementary Programs:
- a. Offset program only
- b. Offset with complementary programs.

TABLE II

Estimates of Marginal Costs of CO_2 Emissions Reduction*

Emissions Reduction Method	**Annualized Marginal Cost** ($ per Ton of C)
Reforestation	0.67 – 88[1]
Increasing Energy Efficiency	12- 19[2]
Nuclear Power	44- 617[3]
Natural Gas	60-100[4]
Wind Power	107[5]
Steam- Injected Gas Turbine	109- 200[6]
Geothermal Power	123[7]
Wood Power	141[8]
CO_2 Scrubbing	150[9]
Solar Thermal(with Gas)	216[10]
Combined-Cycle Coal	814[11]
Phtovoltaics	921[12]

Sources:

1. D. Dudek, Offsetting New CO_2 Emissions, at 10 (EDF, Sept. 1988), estimates the marginal cost of sequestering one ton of carbon at $0.67 to $1.34 depending on the species of tree used. U.S. Department of Agriculture, Tree Planting and Forest Improvement To Reduce Global Warning, at 13 (Oct. 1989), estimates that the cost of sequestering 5% of U.S. CO_2 emissions would be $5.3 billion, which works out to an average cost of about $88 per ton of carbon absorbed. This estimate probably represents an upper bound of the marginal cost of reforestation, since the cost of sequestering smaller amounts of CO_2 is probably cheaper per ton.

2. D. Dudek, supra, estimates the marginal cost of reducing carbon using energy conservation to range from $12.30 to $18.45 per ton, white C. Flavin, Slowing Global Warning: A Worldwide Strategy, at 46 (Worldwatch Paper 91, Oct. 1989), estimates the marginal cost of energy efficiency to be $19 per ton of avoided carbon.

3. The $44 estimate is from Congressional Research Service, Controlling Carbon Dioxide Emissions, at 25 (Apr. 1989); while the $617 estimate is from C. Flavin, supra, at 47. The large difference between these estimates is probably due to different assumptions about the widely varying capital costs of nuclear power plants.

4. Congressional Research Service, supra, at 18. The cost estimate varies depending on the natural gas electricity generating technology that is used.

5. C. Flavin, supra, at 47.

6. Id.

7. Id.

8. Id.

9. Id. at 34. This estimate does not include the costs of permanent disposal of the CO_2 collected by the scrubbers, which is likely to be substantial.

10. Id. at 47. 11. Id.

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*Estimates of marginal costs are the cost of avoiding one ton of carbon emissions from an existing coal-fired power plant using existing technologies.

Table III

Average CO_2 Emission by Type of Facility

Mo. of Type of Facility[1]	Facilities[2]	Total CO_2 Emissions[3] (mil.tC/y)	Avg. CO_2 Emissions[4] (tC/y)
ALL UTILITIES	6,587	*512.1*	*77,744*
Cost-Fired	*1,268*	*436.2*	*344,032*
Oil-Fired	*3,353*	*33.7*	*10,049*
Natural Gas-Fired	*1,966*	*42.2*	*21,479*
ALL INDUSTRIAL	*350,757*	*210.2*	*599*
Food & Kindred Products	*22,130*	*12.2*	*403*
Tobacco Products	*163*	*0.4*	*2,220*
Textile Mill Products	*6,630*	*2.9*	*441*
Other Apparel	*24,391*	*0.3*	*12*
Lumber L Wood Products	*32,984*	*1.0*	*30*
Furniture & Fixtures	*10,003*	*0.6*	*62*
Paper & Allied Products	*6,381*	*45.4*	*7,111*
Printing L Publishing	*53,406*	*0.7*	*12*
Chemicals L Allied Products	*11,901*	*31.5*	*2,643*
Petroleum & Coat Products	*2,322*	*54.2*	*23,342*
Rubber & plastic Products	*11,597*	*2.1*	*184*
Leather Products	*2,735*	*0.2*	*60*
Stone L Glass Products	*16,545*	*16.5*	*997*
Primary Metals	*7,061*	*29.7*	*4,211*
Fabricated Metals	*35,560*	*3.3*	*92*
Machinery	*52,912*	*2.9*	*55*
Electric Equipment	*16,453*	*1.9*	*114*
Transportation Equipment	*9,443*	*3.6*	*385*
Instruments	*8,045*	*0.5*	*68*
Misc. Manufacturing	*15,871*	*0.3*	*21*
ALL COMMERCIAL	*3,539,000*	*140.4*	*40*
Assembly	*452,000*	*11.2*	*25*
Education	*177,000*	*14.3*	*81*
Food Sates & Service	*380,000*	*12.4*	*33*
Wealth Care	*61,000*	*13.4*	*220*
Lodging	*106,000*	*10.5*	*99*
Mercantile/Services	*1,055,000*	*23.3*	*22*
Office	*575,000*	*28.2*	*49*
Warehouse	*387,000*	*14.8*	*38*
Other	*167,000*	*7.2*	*43*
Vacant	*180,000*	*5.1*	*28*
ALL RESIDENTIAL	*76,289,000*	*104.5*	*1*
Single Family Detached	*60,607,000*	*70.3*	*1*
Single Family Attached	*4,514,000*	*5.6*	*1*
2-4 Units	*3,885,000*	*13.4*	*4*
>5 Units	*1,189,000*	*12.5*	*11*
Mobile Homes	*6,094,000*	*2.7*	*1*

Table III (cont'd) Average CO_2 Emissions by Type of Facility

NOTES:

1. Type of Facilities: Industrial facilities are categorized according to their SIC codes. The available data on residential facilities listed the total number of units in residential buildings of various sizes. The number of buildings were calculated by assuming that buildings with 2-4 units averaged 3 units per building, buildings with 5 to 9 units averaged 7 units per building, buildings with 10 to 19 units averaged 15 units per building, buildings with 20 to 49 units averaged 35 units per building, and buildings with more than 50 units averaged 75 units per building. These estimates were then used to convert the statistics on the total member of units in buildings of various sizes into the number of buildings of those sizes. Buildings with more than five units were then aggregated to be consistent with the available data on fuel use in residential buildings.

2. Number of Facilities: The sources for the data on the number of facilities were: (a) Utilities: Energy Information Admin., Electric Power Annual 1988, at 18 (DOE/EIA-0348 1988); (b) Industrial: Bureau of the Census, Statistical Abstract of the United States 1989, at 720-24 (1989) [hereinafter Statistical Abstract 1989); (c) Commercial: Statistical Abstract 1989, at 561; (d) Residential: Statistical Abstract 1989, at 705.

3. Total CO_2 Emissions: Results are presented in units of millions of tons of carbon per year. Total CO_2 emissions were calculated from data on fuel consumption by facilities and CO_2 conversion factors for fossil fuels. Data on fuel consumption for the various types of facilities were obtained from the following sources: (a) Utilities: Energy Information "in., Arrival Energy Review 1968, at 205 (DOE/EIA-0384 1988); (b) Industrial: Statistical Abstract 19x9, at 562; (c) Commercial: Statistical Abstract 1989, at 561; (d) Residential: Statistical Abstract 1969, at 559. The conversion factors to convert fuel consumption into CO_2 emissions were taken from M. Steinberg, N. Cheng & F. Morn, A System Study for the Removal, Recovery and Disposal of Carbon Dioxide from Fossil Fuel Power Plants in the U.S., at 6 (D0E/CN/00016-2 Dec. 1954). The conversion factors, in pounds of CO_2 per 1000 Btu, were: Coat - 0.204; Oil - 0.160; Natural Gas - 0.115. Since the more common measure of CO_2 emissions is ponds of carbon rather than pounds of CO_2, the results for CO_2 emissions were converted to units of pounds of carbon per year by multiplying by a conversion factor of 12/44.

4. Average CO_2 Emissions: Results are presented in units of tons of carbon per facility per year. Average CO_2 emissions were calculated by dividing total CO_2 emissions for a category of facilities by the number of facilities in the category. Note that some facilities in a given category use only electric power, yet were included in the averaging. Thus, for industrial, commercial, and residential buildings, the number of facilities actually emitting CO_2 will be somewhat smaller than shown, and the average emissions per facility will be higher. Also, this crude averaging method takes no account of the variance in emission levels between facilities within a given source category. Thus, for example, a particular category of facilities may have moderate average CO_2 emissions, but it may be that a few facilities in the category have very high emissions while the other facilities have low emissions. Nevertheless, this crude averaging approach probably presents a fairly accurate representation of the variations between categories with respect to variations in CO_2 emissions and number of facilities.

TABLE IV

Relationship Between Number of Facilities and CO_2 Emission Levels[1]

Size of facilities (tons of C per facility per year)	Number of Facilities	Percent of All Non-Transportation CO_2 Emissions	Marginal S of Facilities Added Per Percentage Increase of Total CO_2 Emissions[2]
100,000 + up	1,268	45.1%	28
10,000 + up	8,909	58.6%	566
1,000 + up	34,415	69.6%	2,319
100 + up	178,213	75.1%	26,145
10 + up	5,082,120	90.5%	318,435
1 + up	80,182,120	100.0%[3]	7,905,263

NOTES:

1. The results of this table are derived from the data in Table III.

2. This column measures the marginal number of additional facilities that must be included to increase the total amount of emissions that are included by one percent of total non-transportation CO_2 emissions. For example, consider the step on line two of including all sources with average annual emissions of 10,000 to 99,999 tons of carbon per year. A total of 7,641 additional facilities are added (8,909 - 1,268 : 7,641). Including these facilities increases the total percentage of all non-transportation CO_2 emissions from 65.1% to 58.6%, or an increase of 13.5%. Thus, for each additional 1% of total emissions that are included, 7,641/13.5 = 566 additional facilities must be added to the program.

3. The result that 100% of total non- transportation CO_2 emissions are accounted for by sources emitting more than one ton of carbon per year is an artifact of: (1) the averaging approach for each category of facilities; and (2) the fact that total non-transportation CO_2 emissions was defined as the total emissions from all the facilities included on the table. Therefore, while there is undoubtedly many small sources of CO_2 emissions that emit less than one ton of carbon per year, these sources are relatively insignificant and therefore can be left out of the calculations in this table without substantially affecting the results.

Table V
Policy Choices and Recommended Options for a CO_2 Offset Program

	POLICY CHOICE	RECOMMENDED OPTION
i.	Geographical Scope:	Limited to sources within U.S.; interstate trading allowed.
ii.	Timing of an Offset Program:	Preferably after an international agreement setting national emission targets has been completed.
iii.	Level of Government:	Primarily administered at the stat level: with some federal assistance.
iv.	Measuring Emissions:	Fossil fuel consumption and emission factors.
v.	Compliance Monitoring:	Based on self-reporting and national emissions trading database.
vi.	Type of Greenhouse Gas:	Only CO_2, at least to begin with.
vii.	Producers/Consumers of Fossil Fuels:	Fossil fuel consumer- based program.
viii.	Mobile Sources:	Include mobile source by holding manufacturers responsible for annual CO_2 -producing potential they place on market.
ix.	Minor Stationary Sources:	Apply offset requirement to major source only; and perhaps to manufacturers of minor sources.
x.	Credit for CO_2 Sinks:	Allow credit for reforestation projects with proper safeguards.
xi.	Allocation Mechanism:	Give emission rights away for free.
xii.	Total Quantity of Rights Allocated:	Equal to current total emissions level.
xiii.	Basis for Allocation to Firms:	Historical emissions level.
xiv.	Definition of Baseline:	Total emissions per facility.
xv.	Duration of Emission Rights:	Ownership of rights perpetual; but value can be discounted.
xvi.	Emissions Trading Ratio:	One-for-one.
xvii.	Credit for Shutdown:	Yes.
xviii.	Emissions Banking:	Yes, including credit for unused rights.
xix.	Credit for Emission Reductions:	Sources only, with limited exceptions.
xx.	Complementary Programs:	Yes, providing they do not conflict with or undermine the offset program.