Telecommuting and Environmental Policy: Lessons from the ecommute Program[∈]

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ABSTRACT

In 1999 US Congress passed the National Air Quality and Telecommuting Act. This Act established pilot telecommuting programs (ecommute) in five major US metropolitan areas with the purpose of studying the feasibility of addressing air quality concerns through telecommuting. The major goal of the ecommute program was to examine whether a particular type of economic incentive, tradable emissions credits from telecommuting, represents a viable strategy for reducing vehicle miles traveled (VMT) and improving air quality. Under the ecommute program, companies could generate emissions credits by reducing the VMT of their workforce through telework programs. They would then be able to sell the credits to firms that needed the reductions to comply with air quality regulations.

The paper provides analysis of the results of the ecommute program. First, we establish some context for evaluating whether the envisioned trading scheme represents a feasible approach to reducing mobile source emissions and promoting telecommuting and review the limited experience with mobile source emissions trading programs. We find that from a regulatory perspective, the most substantial drawback to such a program is its questionable environmental integrity, resulting from difficulties in designing sufficiently rigorous quantification protocols to accurately measure the emissions reductions from telecommuting. And perhaps more importantly, such a program is not likely to be cost-effective since the emissions reductions from a single telecommuter are very small.

The paper also presents the first analysis of data collected from the ecommute program. Using two-and-one-half years of data, we look at telecommuting frequency, mode choice, and emissions reductions as well as at reporting behavior and dropout rates. Finally, we use the program's emissions reductions findings to calculate how much telecommuting would be needed to reach an annual volatile organic compounds emission reduction target in each city.

Keywords: telecommuting, emissions, emissions trading, mode choice, air quality

JEL codes: R4, Q53, Q58

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1. Introduction

Although the concept of telecommuting has been around since the 1970s, only in the middle of the 1990s has it become a part of everyday life. With arrival of broadband connection, the idea of remote work has become much more operational. Yet, even the most optimistic accounts of the current scale of telework have left its proponents at a loss. The “fathers” of telecommuting predicted that by the year 2000, 50% of US workers would be telecommuting[1], yet only a small fraction actually does. While many companies implement telecommuting programs for their employees because such programs allow them to reduce turnover, increase productivity and cut down on energy and even real estate costs, many workers enjoy increased flexibility and travel time and cost savings. At the same time, it is be now clear that telecommuting is not for everybody, and not only because of the nature of some jobs. Telecommuting tends to increase management costs for employers and could deprive workers of social interaction with co-workers and even negatively affect their careers.

Because of these costs and because telecommuting can provide social benefits in the form of reduced traffic congestion and emissions, it might make sense for the government to provide incentives to telecommute. In the 1980s and 90s, the only significant incentive government agencies provided were telecommuting education and training offered by many US states. Also, some states had telecommuting programs for state employees that were supposed to serve as examples to be followed by other employers in the states. However, as time went by, telecommuting approached a saturation point – while most employers and employees have become familiar with telecommuting, only a small percent of the US workforce actually works remotely, and that percentage is stagnant.

Only a few states provide financial incentives for telecommuters. The Oregon Department of Energy has been offering firms that employ telecommuters tax credits. More recently, some other states have made moves in the same direction. Georgia, New Jersey and Virginia are already providing or seriously considering financial incentives to employers of telecommuters[2].

In 2000 such an incentive was proposed at the Federal level. Sen. Rick Santorum's bill, the Telework Tax Incentive Act, offered to provide a $500 tax credit for every worker who telecommutes at least 75 days per year. The credit was supposed to go to the party that pays for setting up the home office -- either the employee or employer. However, government agencies at all levels are so far reluctant to provide significant incentives to encourage more telecommuting. In the meantime, recent interest has arisen in telecommuting’s potential to reduce emissions. Many metro areas include some emissions reductions from telecommuting in their state implementation plans (SIPs).

The ecommute program started with “National Telecommuting and Air Quality Act”, signed into law in 1999. The Act started a pilot program supported by the Department of Transportation (DOT) and the Environmental Protection Agency (EPA). According to the legislation, the purpose of the ecommute program was to develop and evaluate methods for calculating reductions in emissions due to telecommuting. Then, as a part of the pilot project, employers who encouraged their workers to telecommute, were supposed to receive credits reflecting the amount of achieved emissions reductions. The received credits were supposed to be traded with the firms that, for the purposes of compliance with the Clean Air Act, would like to purchase such credits. The ecommute pilot program was to be carried out in 5 pilot cities – Los Angeles, Philadelphia, Houston, Chicago, and Washington, DC. The pilot program was supposed to test and evaluate the emissions credit mechanism to award telecommuting efforts[3].

An obvious advantage of this program compared to explicit financial incentives – tax credits, subsidies, etc. – is that the government entity does not need to allocate budget funds to reward

[1] See J, Nilles et al. (1976)

[2] University of South Florida Telecommuting Clearinghouse www.nctr.usf.edu/clearinghouse/statestatutes.htm

[3] However, due to a lack of regulatory basis, emissions trading mechanism has not been implemented in the course of the ecommute project.

employers encouraging telecommuting; employers are supposed to be able to trade emissions credits on the relevant market. The major purpose of the program was to evaluate and to sharpen the mechanisms that can be used later at the national scale.

In this paper, we describe the results of the program, discuss the institutional and regulatory background to emissions trading and the challenges of using telecommuting for emissions trading purposes.

The rest of the paper is structured as follows. In section 2 we provide a brief review of the literature on telecommuting from the trip and emissions reduction perspective. Section 3 outlines the regulatory and institutional framework for emissions trading. In section 4 we outline the structure of the ecommute program and describe the data collection process. In section 5 we present the results, quantitative as well as qualitative, of the ecommute program. Section 6 concludes and discusses possible future directions of policy and research.

2. Literature review

The literature on telecommuting has covered an array of topics– practical as well as theoretical issues, benefits and costs for both employees and employers, the impact of telecommuting on business structure and even the relationship between telecommuting and family relations. However, in this paper we will limit our literature review to the possible trip and emission reductions due to telecommuting. Because telecommuting has the potential to reduce vehicle trips, VMT, and thus emissions of various pollutants, there have been several studies that have tried to quantify these benefits.

We review six studies here that have this as their focus[4]. An early paper by Kitamura, Pendyala, and Goulias (1991) analyzes before and after behavior of 219 State of California employees who telecommute. Three studies by Mokhtarian and coauthors rely on travel diaries in which workers filled out detailed information about their commute and non-commute travel patterns, and they include telecommuters who use telework centers as well as those who work from home. Unfortunately, however, the studies have very small sample sizes. Choo, Mokhtarian, and Salomon (2003) take the unusual approach of looking at aggregate time-series data on VMT and telecommuting, thus their study lends a new perspective to the issue. Finally, a recent working paper by Collantes and Mokhtarian (2003) looks at VMT and PMT (person-miles-traveled) of telecommuters and non-telecommuters in a California sample over time, focusing on the links between residential location, VMT, and telecommuting. We review each of these studies in turn.

Kitamura, Pendyala, and Goulias (1991) is one of the earliest studies to use travel diary information. It gathered such data from participants in the State of California telecommuting study in the late 1980s. Employees and their household members filled out travel diaries before and after they started telecommuting; the sample includes a control group – also state government employees and their household members – who did not telecommute. The authors find that before the program began, those employees who eventually chose to telecommute made about the same number of trips per day as their counterparts who did not telecommute. Household members from the two groups also made about the same number of trips per day.[5] Once they begin telecommuting, however, those employees make far fewer trips per day than the control group – an average of 1.94 versus 3.95 trips/day. Household members also made fewer trips per day, though the difference was smaller – 3.08 versus 3.30 trips/day. Kitamura et al. find that, contrary to their expectations, there was no increase in non-commute trips by telecommuters. Most of the reduction in trips occurs during peak periods. The authors found that

[4] Here we discuss only empirical studies by recognized experts in the field. Due to space limitations, we omit analyses of the data outside of the US, theoretical papers, and do not cover other demand management strategies for reducing travel.

[5] The employees who ended up telecommuting and their household members actually made slightly fewer trips per day but the difference is not statistically significant.

telecommuters made 73% fewer morning-peak departures after they began telecommuting and 54% fewer afternoon-peak departures.

The reduction in number of daily trips translates into a reduction in VMT as well. The average distances traveled per day by those employees who signed up for telecommuting dropped from 53.7 miles to 13.2 miles on telecommuting days. Compared to non-telecommuters, telecommuters are found to drive more miles per day, on average, when they are not telecommuting – 56 versus 45 miles. This is consistent with the findings in many other studies that suggest that people with longer commutes tend to be the ones who participate in telecommuting programs.

Finally, the Kitamura et al. study also looked at the mode choice of telecommuters and non-telecommuters. The percentage of total trips made per day that are car trips increases for the telecommuting employees once they begin telecommuting but holds the same over time for the control group – telecommuting employees' share of daily trips made by car rises from 81% to 91% when they start telecommuting.

Koenig, Henderson, and Mokhtarian (1996) look at home-based telecommuters who participated in the State of California Telecommuting Pilot Project in the early 1990s. All individuals in the sample worked for the state government and filled out travel diaries before and one year after they began telecommuting. The study analyzed 40 people who chose to telecommute at home and 58 who didn't telecommute at all – i.e., a control group. The authors find that the people who telecommuted reduced the average number of daily vehicle-trips they took by 27% and reduced average VMT by 77%. Using California's EMFAC7 emissions model, the authors calculate that these reductions in driving resulted in substantial emissions reductions: 48% in total organic gases, 64% in carbon monoxide, 69% in NO_x, and 78% in particulate matter. Comparing the telecommuters to the control group, the authors find that telecommuters, prior to joining the telecommuting program, averaged higher total VMT than non-telecommuters. This result appears to be due to higher non-commute VMT for this group, as telecommuters reported lower commute VMT than non-telecommuters. Most studies find that telecommuters have longer average commutes thus the participants in this study appear to differ from those in other studies.

Mokhtarian and Varma (1998) use data from another California telecommuting program, the Neighborhood Telecenters Project, which focused on the effectiveness of telework centers in reducing VMT and emissions. The Project established 15 centers and, as in the previous study, participants and a control group of nonparticipants filled out travel diaries, both before and after the telecommuting program began. For this analysis, however, the authors found that the sample size quickly became too small if they tried to analyze both groups before and after, thus the study focuses only on the telecenter users and compares travel on days on which they use the center to days on which they do their regular commute to work. The final sample included 72 people. They find that total VMT is 53% lower on telecommuting days than on non-telecommuting days, but the number of trips increased. This is because people apparently drive home for lunch from the telecenter. The authors use the EMFAC7 emissions model and find that emissions on telecommuting days are lower than those on non-telecommuting days by 15% (ROG), 21.5% (CO), 35% (NO_x), and 51.5% (PM).

Henderson and Mokhtarian (1996) also focus on telecenters. Their data are from the Puget Sound Telecommuting Demonstration Project sponsored by the Washington State Energy Office in 1990-91. The sample in this study includes 71 telecommuters – 8 center-based and 63 home-based – and 33 non-telecommuters. The individuals worked for both government and private companies and as in the other studies, extensive travel diaries were kept on all commute and non-commute travel. Henderson and Mokhtarian find that total VMT for telecenter users dropped by nearly 54% on days on which they used the telecenters compared with non-telecenter days. By comparison, home-based telecommuters reduced their VMT by 66.5% by working at home. The telecenter users had the highest total daily VMT of the three groups, prior to the start of the telecommuting program, 91% greater than the control group. Home-based telecommuters had daily VMT 54% greater than the control group. Again in this study, emissions reductions are calculated. All pollutants are reduced, but NO_x and PM are reduced more than total organic gases and CO since they are more directly linked to miles traveled.

Choo, Mokhtarian, and Salomon (2003) take a very different approach to looking at the VMT impacts of telecommuting. They use national aggregate data to estimate an econometric time-series model of VMT as a function of economic variables; they then use the residuals from that regression – i.e., the unexplained part of annual aggregate VMT – and regress them on telecommuting data. In the first stage regression, the authors include as explanatory variables GDP per capita, the price of gasoline, average miles per gallon of the vehicle fleet, a consumer price index (CPI) for all commodities and a CPI for transportation. They have 33 years of annual data, from 1966 to 1999, and their dependent variable is VMT per capita.[6] In the second stage, in which the authors estimate the first-stage residuals as a function of a constant term and the natural log of the number of telecommuters, results show the coefficient on the telecommuters variable as negative and significant.[7] The size of the estimated coefficient suggests that VMT during the sample period would have been approximately 2.12% higher than observed VMT in the absence of any telecommuting. The range across all the different VMT models estimated is 1.78% to 3.31%.

The Choo, Mokhtarian, and Salomon study is interesting for its unique approach to estimating the VMT effects of telecommuting but the aggregate data and simple version of the VMT model leave much unexplained. The residuals from the first-stage VMT model are likely to include quite a number of omitted variables, thus the telecommuting variable in the second-stage regression could be proxying for a number of other factors that affect VMT.

In a recent working paper, Collantes and Mokhtarian (2003) analyze data from 218 employees of the state of California. The survey of these employees, completed in 1998, included retrospective responses to questions about telecommuting frequency, commute distances, residential relocations and job relocations for a 10-year period, 1988-1998, on a quarter-by-quarter basis. The point of the survey is to obtain some information on the relationship between travel behavior, telecommuting, and residential location decisions. In this paper, the authors do not econometrically model telecommuting choice or frequency or location decisions. They do, however, look at patterns of telecommuting over time and distances commuted and calculate total VMT and PMT for telecommuters and non-telecommuters.[8]

The authors find that average commute lengths, which have increased over the 10-year period, are generally longer for telecommuters than non-telecommuters and that the difference between the two has increased over time. The authors speculate that two processes could be at work to cause these results: (1) relocations made for a variety of reasons could lead to longer commutes thus prompting more telecommuting, and/or (2) increased availability of telecommuting might cause people to relocate farther from their jobs. The authors try to use their data to separate out these two possibilities. The second scenario – the availability of telecommuting leading people to move farther from their jobs – does not appear to hold. Current and former telecommuters in the dataset have shorter commutes, on average, after a move while nontelecommuters have longer ones. The longer distance moves tend to be those that take place before telecommuting begins. The authors claim that this suggests that telecommuting is a consequence of a move rather than the cause of it. When survey respondents were asked what factors were important in their three most recent moves, telecommuting was only listed at all in 12 of 97 cases and even in these, it was not listed as an important factor.

In terms of frequency of telecommuting, the data in this study shows that people telecommute, on average, approximately 1.5 times/week. This average has fallen over time, according to the survey responses, and the authors explore different possible explanations for this decline. The most likely reason, according to the authors, has to do with the fact that the early adopters of telecommuting are

[6] They estimate three versions of a VMT model and five versions of a VMT per capita model. The model we describe here is the one that they feel provides the best overall results.
[7] Regardless of the first-stage model used, the telecommuters variable is always significant in the second-stage model.
[8] The two measures of miles traveled will differ to the extent that a person carpools.

those people who do it most often. The workers who adopt later are thus pulling down the average in the later years.

Combining the commute length with the frequency with which the commute is made leads to an estimate of commute PMT. Average PMT has increased slightly over time, for both telecommuters and non-telecommuters. This is a result of longer commutes. Non-telecommuters have higher average PMT than telecommuters but the difference declines in the later part of the sample period until the final three quarters when PMT is the same for the two groups. The same trends hold for VMT, but the difference between VMT for telecommuters and non-telecommuters is greater than the difference between PMT for the two groups. The authors look at VMT for respondents who reported "drove alone" as their commute mode and also at VMT for respondents who reported any commute mode that included use of a personal vehicle. Trends are the same for both measures of VMT.

Unfortunately, the study does not include travel diaries so there is no measure of driving other than for commute purposes. Also, drawing conclusions on data based on survey respondents' memories of their commute modes, distances, times traveled, and telecommuting behavior for each quarter up to ten years ago is likely to be problematic. The attempt to obtain a time series of telecommuting and other data is laudable since no other study, to our knowledge, includes such information, but it would be better to survey workers contemporaneously over a period of time rather than rely on memories.[9]

Overall, the studies support the hypothesis that telecommuting reduces VMT and emissions. However, there is very little evidence to address the question by how much. However, for the purposes of quantification of the telecommuting emissions credit, this is a critical question. Unfortunately, in order to accurately quantify travel and emissions reductions, one needs data from detailed travel diaries or from a complete record of motorist's movements. To the best of our knowledge, such data have not yet been applied to studies of telecommuting behavior.

3. Regulatory and institutional framework for mobile source emissions trading

We begin by briefly discussing the past US experience with emissions trading in general, and with emissions trading of mobile sources in particular. As evident from the description below, since government regulation is a prerequisite for the market of emissions, a clear regulatory framework is a necessary, but not a sufficient condition of emissions trading success.

3.1. Introduction to Emissions Trading

Emissions trading is a fairly simple concept, even though in practice many complexities arise. Because firms differ in their ability to reduce pollution, there are potential benefits from specialization through gains from trade. Instead of forcing high-cost firms to reduce emissions by some fixed amount or to install expensive technology, it is more cost-effective to allow them to purchase needed reductions from those who can reduce emissions cheaply. By improving the allocation of costs, emissions trading should enable a given environmental goal to be achieved at a lower total cost to society. In theory, the efficient outcome will occur when the marginal cost of abatement is equalized across polluters.

The intellectual origins of emissions trading date back to Coase's (1960) argument for assigning transferable property rights for "bads," such as pollution. The explicit application of this approach to environmental policy was developed separately by Crocker (1966) and Dales (1968). An advantage of emissions trading is that it frees the regulator from the substantial informational requirements associated with command-and-control regulation or a system of pollution fees. The value of the emissions rights is determined through the market rather than by a centralized authority, and the regulatory agency can simply set the desired emissions target without reference to the various firms' abatement cost functions or pollution damage functions.

[9] This is one virtue of the pilot Ecommute program. See section 5 of this paper and Walls and Nelson (2004) for analysis of three years of daily commute logs of participants in this program.

The direct benefits of emissions trading arise from the lower total costs of compliance. Trading per se does not reduce aggregate emissions; those remain a function of goals or standards set by regulation. However, indirect environmental benefits can result from trading. The federal emissions offset program, for example, requires maintaining "trading ratios" so that firms must in effect purchase "extra" emissions reductions to achieve compliance. In addition, credits and allowances can be retired—that is, purchased by or donated to an entity (often an environmental group) that opts not to use them to comply with regulations. Finally, if a trading program lowers the costs of regulation, the government may be able to set more aggressive environmental targets than would otherwise be the case.

In the United States, two basic types of interfirm trading regimes are currently used in air pollution policy: *allowance-based cap and trade* and *emissions reduction credit trading*. Emission credits are generally used in two types of programs: *emissions offset* and *open-market trading* programs.

3.2. Allowance-Based Cap and Trade

In a cap-and-trade system, an overall limit is placed on aggregate emissions during a specified compliance period. Emissions allowances that entitle the holder to emit a set amount of a pollutant are allocated to firms, with the total number of allowances set equal to the cap.[10] Allowances may be traded among eligible sources, but at the end of the compliance period, each firm must hold sufficient allowances to cover its emissions for the period. Usually, there are provisions for limited banking of allowances for later use. The attraction of a cap-and-trade system is that it retains the certainty of a hard target through the cap on total emissions while allowing firms flexibility in reaching the target.

The flagship cap-and-trade program is the SO_2 allowance market created under Title IV of the 1990 Clean Air Act Amendments. The program, designed to reduce emissions that lead to acid rain, caps annual SO_2 emissions from electric utilities' generation facilities at 8.95 million tons (approximately 50% of 1980 levels). Firms possessing surplus allowances may either sell them or bank them for future compliance needs. The program is widely considered a major success. A review of published estimates reveals a general consensus that the SO_2 trading system has resulted in, and will continue to account for, substantial cost savings over a command-and-control regime (Burtraw and Palmer 2003).

The program's success is attributed to many factors, but foremost among these is the flexibility it allows in compliance options and the timing of reductions. The fact that the regulation does not mandate a specific technological approach has enabled firms to take advantage of alternative ways of reducing emissions, such as using low-sulfur coal from Montana and Wyoming (made more available through rail deregulation). The program is also credited with spurring more process innovation than would have occurred under mandated technology standards.

Besides SO_2 allowance trading, other prominent examples of cap and trade include programs to control regional emissions of nitrogen oxides (NO_x) in the Northeastern US and state programs in California, Illinois, and Texas.

In 2005, the European Union will inaugurate a highly ambitious cap-and-trade program covering CO_2 and other greenhouse gases.[11] In the United States, there are competing proposals to extend cap and trade for further SO_2 reductions and the national regulation of NO_x. Several northeastern states have NO_x and carbon cap-and-trade programs that are slated to begin in the next few years. The cap-and-trade approach has also been proposed for addressing mercury emissions and CO_2 in the US at the national level.

3.3. Emissions Reduction Credit Trading

Unlike cap-and-trade programs, in which the emissions cap establishes the level of pollution allowed by the polluting industry, emissions reduction credit programs rely on other regulatory policies,

[10] The number of allowances equals the emissions cap if 1 allowance is equal to 1 ton of emissions, as is often the case (as in the SO_2 program), but any fixed ratio between emissions and allowances is acceptable.

[11] See Kruger and Pizer (2004) for an overview and potential pitfalls in the program.

such as rate-based emissions standards, to establish a baseline level of pollution. Credits are generated when firms reduce emissions below this baseline. The credits can then be used for other compliance purposes, such as offsetting pollution from a new source, dealing with penalties, or avoiding requirements to install reasonably available control technology (RACT). In the United States, there are two major types of emissions credit programs: *offset* programs, which are used for compliance with the Clean Air Act requirements for new large stationary sources in nonattainment areas; and *open market* programs, adopted by some states to give firms flexibility in complying with certain state and federal regulations. Offset programs primarily use emissions reduction credits (ERCs), which are denoted in a mass of emissions per unit of time (e.g., tons of NO_x per year). In contrast, open-market programs use discrete emissions reduction (DER) credits. These are mass-based (e.g., tons of NO_x) and are usually generated from a one-off emissions reduction.

Emission reductions may be converted to ERCs or DERs if certain criteria are met. These criteria have been set out in a series of EPA guidance documents dating back to the 1980s. Specifically, the reductions must be *surplus, permanent, quantifiable,* and *enforceable* (U.S. EPA 1986):

- *Surplus.* To avoid double counting, the reductions must be additional to reductions required by state and federal regulations. If the purpose of the trades is to allow for flexible compliance, it must be shown that the trades do not end up increasing aggregate emissions.
- *Permanent.* The reductions must occur for as long as they are relied on in the state implementation plan (SIP) or SIP-related requirements.
- *Quantifiable* . The emissions reductions can be reliably measured.
- *Enforceable.* Violations can be identified and liability can be determined. State and/or federal agencies are able to apply penalties and secure appropriate corrective actions if necessary.

If the above criteria are met, the emissions reductions are said to have “integrity”—that is, they do not result in emissions above what would occur in the absence of a trading program.

3.3.a. Emissions Offsets

Under the New Source Review provisions of the Clean Air Act, new large stationary sources in nonattainment areas (as well as existing sources that undergo major modifications) are required to implement lowest achievable emissions rate (LAER) technology. In addition, they must more than offset any increase in total emissions that results from their activity by securing emissions reduction credits from existing sources in the same area. For example, if a new power plant emitting 100 tons of NO_x per year is built in a nonattainment area, it must secure more than 100 tons’ worth of ERCs to meet its offset requirements. Federal law specifies trading ratios for offsets that can be as high as 1:1.5, depending on source and nonattainment status. Thus, the firm in the example might be required to purchase ERCs equivalent to 150 tons of NO_x emissions per year.

The idea behind offsets is to enable economic growth without jeopardizing progress toward attainment of air quality goals. However, new sources are required to comply with stringent technology standards before purchasing credits from elsewhere, and therefore the compliance flexibility advantage of trading is weakened. Offsets are available for a variety of pollutants, most prominently NO_x and VOCs.

Swift and Haites (2002) conclude that the use of ERCs for offset purposes has comparatively high environmental integrity because of the “semicapped” nature of emissions from large stationary sources in nonattainment areas. As long as ERCs are generated within the stationary sector (as has been typically the case), New Source Review rules work to produce an implied cap on large stationary source emissions.

3.3.b. Open-Market Trading

In recent years, some states have attempted to expand emissions trading through "open-market" trading programs.[12] These programs were developed after in 1994 EPA released its proposed open-market trading rule, which provided a framework for expanding emissions trading beyond electric utilities and other large stationary sources. This rule was never finalized, but elements of it were incorporated into EPA's guidance for economic incentive programs, released in 2000. The open-market trading programs rely on discrete emissions reductions—mass-based, one-time reductions in emissions of pollutants (usually NO_x or VOCs). DER credits are defined retrospectively, after the reductions have taken place. Whereas ERCs are necessarily a stream of reductions, DERs are usually created from activities of limited duration. An example of a DER is the reduction of NO_x emissions that would occur when a coal-fired cogeneration plant switches its fuel to natural gas. The estimated reduction could then be banked and used or traded at a later date. According to EPA guidance, shutdowns and activity curtailment are not approved methods for generating DERs; rather, DERs are generally created from over-compliance with existing regulation and represent a reduction from an estimated baseline level of emissions.

The most significant difference between open-market and offset trading is the use of the credits. DERs are designed to be used where there is no offset requirement, such as for compliance with EPA's RACT standards, which apply to all large stationary sources in non-attainment areas, or for dealing with state penalties and special circumstances.

The rationale for open-market programs has been to expand emissions trading beyond the traditional constituency of large stationary sources and to provide a vehicle for inter-sector trading, which many believe will open up new possibilities for cost savings. However, an open market does not have the firm emissions cap generally associated with allowance trading or even the implicit cap associated with New Source Review offsets. Because the open-market framework is explicitly designed for inter-sector trading and for uses other than the strict federal new source requirements, there is a higher risk that trades will lack integrity. For many types of sources often included in open-market programs (such as area or mobile sources), there is no meaningful inventory of the covered sources or reliable mechanism to monitor emissions at those sources. Thus, the universe of covered sources is not as well defined as it is for allowance trading or new sources in non-attainment areas.

Swift and Haites's (2002) survey of open-market programs contains several empirical findings concerning the performance of the programs. First, the authors find that there has been insignificant trading activity; credit generation far outweighs use, resulting in an oversupply of DERs. Second, although the primary focus of DER programs was initially permit compliance, almost half the uses of DERs have been for penalties and special circumstances. The use of DERs for permit compliance has been less than 1% of stationary NO_x emissions. Finally, in most states, more than 90% of the NO_x DERs have been created at a handful of large stationary sources. Swift and Haites conclude that open-market programs suffer from inherently weak environmental integrity unless certain best practices are instituted.

3.4 Emissions Trading with Mobile Source Credits

Although emissions reduction credits and discrete emissions reduction credits are predominantly created by stationary sources, trades involving mobile sources are permitted under federal law. EPA has allowed mobile source emissions reductions to be a source of tradable credits since 1986. According to EPA's (1993) *Interim Guidance on the Generation of Mobile Source Emission Reduction Credits*, mobile emissions reduction credits (MERCs) can be used to comply with RACT standards, to offset emissions under New Source Review, to address temporary emissions spikes or temporary noncompliance with regulations, and to satisfy emissions reduction requirements that are

[12] Texas, New Hampshire, Michigan, Connecticut, New Jersey, and Massachusetts all have programs, though New Jersey recently rescinded its program.

over and above RACT. But MERCs cannot be used to satisfy the requirements of best available control technology, lowest achievable emissions rate, or new source performance standards. Furthermore, the guidance prohibits the use of MERCs for inspection and maintenance programs and employer trip reduction programs.[13] The guidance does not address implementation issues in much detail, in particular how MERCs would be used by stationary sources.

MERCs can be generated from a range of actions, including vehicle scrappage programs, modifications of vehicle fleets, inspection and maintenance programs in areas where they are not required, clean fuel programs, and trip reduction measures. The orientation has been toward using technological approaches to create MERCs rather than relying on VMT reduction strategies. Scrappage, engine retrofit, and clean fleet programs are the most common methods for creating MERCs.

In practice, MERC trading has been very limited. Although some states have provisions for including mobile sources in their offset programs, only a few—Connecticut, New Jersey, Michigan, and three air districts in California—have approved the creation of mobile emissions reduction credits. In those states, MERC trades have accounted for a tiny fraction of the emissions trades that have taken place. For example, according to Haites and Haider's (1998) review, MERCs have been involved in less than 1% of the offset trades in California. The most significant current MERC project in California created offsets for PG&E National Energy Group's Otay Mesa Generating Project in San Diego County. The offsets were generated from the conversion of diesel-fueled trash trucks to compressed natural gas, and the conversion of ferries to clean diesel technology (Diesel Technology Forum 2003). Houston has had a MERC program but is only now preparing to authorize the creation of its first MERC, involving a marine source. Several states allow credits to be created through trip reduction activities, but no MERCs have yet been created this way.

Possible reasons for the limited use of MERCs include (1) the inherent difficulty of applying emissions trading to a sector with large numbers of relatively low-emitting sources. Because potential emissions reductions from any individual vehicle are relatively small, the costs of monitoring and certifying individual emissions reductions will tend to dwarf the potential value of the credit generated. Another important reason (2) is a mismatch between the nature of mobile source credits and the needs of credit buyers. By their nature, mobile source emissions reductions are temporary. For this reason, states and air districts have required that MERCs be considered temporary. Firms requiring offsets, on the other hand, must take steps to reduce emissions indefinitely. Finally, one more reason (3) lies in problems of demonstrating that MERCs meet EPA's criteria for integrity. Of the integrity criteria, the requirements that reductions be quantifiable and surplus present the biggest challenge for mobile source reductions. It is more difficult to quantify emissions reductions from many mobile sources than those from a few large stationary sources. Stationary source emissions can be directly monitored, thus providing a high degree of assurance that reductions are actually occurring. There exists no corresponding monitoring regime for automobiles, and MERC programs frequently rely on emissions factor approaches rather than on monitored emissions.[14]

There are other potential uses for credits generated from telecommuting besides interfirm trading programs of the sort discussed above. The most obvious regulatory uses are for achieving compliance with rideshare programs, helping demonstrate transportation conformity, and contributing to voluntary mobile source emissions reduction programs (VMEPs) in the SIP.

4. Ecommute program

In 1999, Congress passed the National Air Quality and Telecommuting Act. This Act established pilot telecommuting programs in five major U.S. metropolitan areas with the purpose of studying the feasibility of addressing air quality concerns through teleworking. A group of key

[13] At one time, employer trip reduction programs were mandatory for severe non-attainment areas, but Congress rescinded that requirement in 1995. Some areas still have those programs.
[14] EPA's MOBILE emissions factor model and California's EMFAC model are often used.

stakeholders outlined several important goals and objectives to be achieved in the program, including the following:

- ascertaining the viability of developing, testing and promoting economic incentives, specifically including emissions credits that may be tradable;
- building partnerships within U.S. communities to address air quality, congestion and quality of life issues associated with teleworking;
- defining and sharpening regulatory and statutory issues necessary to promote air emissions trading incentives, including mechanisms for cross-sector emissions trading;
- developing and evaluating methods for calculating reductions in emissions of precursors of ground level ozone and greenhouse gases achieved as the result of vehicle miles traveled; and
- gathering important data and information about transportation, urban planning, and the environmental impacts of telework.

The original five metropolitan areas in the program were Chicago, the District of Columbia, Houston, Los Angeles, and Philadelphia. Chicago dropped out of the program in 2000 and was replaced by Denver. The "ecommute" program commenced in June 2001 and by March 2004, 49 companies with 535 employees had participated.

The collection of data on teleworking activity in the ecommute program, as well as information on other commuting modes, is done using Teletrips, a web-based commute-tracking software developed by the Canadian-based firm, Teletrips Inc. The software was designed specifically to track the emission benefits from telecommuting and other "green" commute alternatives (such as carpooling and biking). Participating employees fill out a form at the end of each week indicating for each day whether or not they went to work and their means of travel. The interface is designed to be user-friendly and participants report that the weekly log can be filled out in under a minute. Reporting is prompted by weekly e-mail reminders.

Upon entering the program, each employee provides information about their vehicle and their commute. Information about the employee's vehicle includes the year, make, and model of the vehicle, the engine type, and whether or not it has passed an emissions test. Commute information includes the distance of the journey to work, as well as the time that the employee leaves home, arrives at work, and leaves work, arrives at home. The employee reports his mode choice for each day, including driving alone to work, carpooling, using public transit, walking, biking, telecommuting at home, or telecommuting at a telework center. The employee also reports if he does not work on that particular day.

Teletrips is not a full-fledged trip diary, and therefore it does not capture the total travel behavior of individuals who telecommute. For example, it is impossible to determine from the data if individuals drive more for non-work purposes on their telecommuting days, thus offsetting some of the benefits associated with not driving to work. Furthermore, detailed information about the employees enrolled in Teletrips is not available. So, for example, we do not know the income, marital status, education, and so forth of these workers. We also do not have reliable information on the types of jobs in which these workers are employed, their length of employment, or other job status information.

Another factor limiting the scope of conclusions that can be drawn from the Teletrips data is the self-selected nature of the sample. Self-selection occurs on two levels. First, the decision to participate in the program is made at the firm level, so the sample is limited to those firms that have an interest in telecommuting and who happened to be contacted by the local organizations responsible for marketing the program. Second, even within those firms, only employees who are interested in telecommuting sign up. Therefore, information is collected about only those employees who are most likely to participate in a telecommuting-tracking program like ecommute. Unfortunately, this data set does not provide a suitable "control" group that would allow more general questions about telecommuting behavior to be answered.

On the other hand, the data gathered in the ecommute program has some distinctive features that can shed light on important questions concerning teleworking activity. The weekly commute log combined with the commute profile enables relatively accurate estimates of the emission benefits from telecommuting and other "green" commute options. Because information on commute-length and vehicle type is specific to each participant, there is no need to rely on default averages, which might overstate or understate the emissions savings from individual telecommuting behavior. Moreover, because trip activity is recorded more or less contemporaneously, the reported level of telecommuting may be more accurate than estimates obtained from one-time surveys. An additional advantage of the data is that by following individuals through the life of the program, Teletrips allows for a detailed examination of how program participation and telecommuting behavior change over time. Teletrips provides one of the few sources of information on teleworking behavior over time.

5. Program Results

5.1 Basic Information from Teletrips

We obtained the Teletrips data in March 2004, thus the most recent employee entries are for the last day of February. Table 1 shows the total number of companies that have joined the ecommute program since it began in June 2001, the total number of employees enrolled, and the average number of employees per company. It is important to understand that the 535 total employees enrolled across all cities includes all employees currently in the system, as well as those who were in the system at one time and then, for one reason or another, stopped reporting. Similarly, of the 49 registered companies, some may have dropped out of the program and some are current.

Denver has had the most active ecommute program of the five cities, with 252 employees enrolled across 13 companies. Los Angeles has as many companies signed up as Denver but far fewer employees per company. Likewise, Washington, DC, has several companies but not very many employees in each.

Table 1. Number of Companies and Number of Individual Employees Enrolled in the ecommute Program, by City

as of March 1, 2004

	Number of companies	Number of employees	Average number of employees per company
Washington, DC	11	52	4.7
Denver	13	252	19.4
Houston	7	108	15.4
Los Angeles	13	31	2.4
Philadelphia	5	92	18.4
TOTAL	49	535	10.9

As explained above, not all employees have been in the ecommute program since it began, and not all who started have remained in the program – or at least have continued to fill out a weekly commute log. Moreover, even those who have been in the system for a significant period of time do not all reliably report their commute choices each week. In the next three tables, we present some summary information on the lengths of time employees have been in the program, drop-out rates, and reporting frequency.

Table 2 shows the number of employees enrolled less than 3 months, 3-6 months, 6-12 months, and a year or more. These figures are generated by counting the number of days between the first date the employee reported to the system and the last date of reporting (as of March 1, 2004). Thus, an employee may have gaps in his commute log, but we do not consider that dropping out of the program. Over half of the 535 employees in the system, 276 people, have been enrolled for at least a year. The numbers vary significantly across the cities, however. Denver has been active in registering companies and encouraging employee participation since the program began, thus 134 people in Denver have been in the program a year or more. Denver also continues to sign up new participants, as can been seen in the other time period categories in the table. Virtually all participants in Los Angeles, on the other hand, have been in less than 3 months. Sixty percent of employees in the D.C. area have been in 6 months or less.

Table 2. Length of Time Employees Have Been Enrolled in the ecommute Program, by City

as of March 1, 2004

	Number of employees enrolled				
	< 3 months	3-6 months	6-12 months	>12 months	Total
Washington, DC	18	13	4	17	52
Denver	63	24	31	134	252
Houston	13	8	6	81	108
Los Angeles	23	3	4	1	31
Philadelphia	15	27	7	43	92
TOTAL	132	75	52	276	535

In Table 3, we show how often employees report to the system. On average, across all five cities, employees fill out their commute logs 71% of the time. This means that they are failing to fill out the logs 29% of the time. This non-reporting is highest in Houston, where employees fill out their logs just a little over half the time, and is lowest in Los Angeles. These percentages are averages; there are some employees who are more conscientious than others. One hundred people in the Teletrips database have commute logs for every day that they have been in the system.[15]

Table 3. Employee Reporting Frequency in the ecommute Program, by City

as of March 1, 2004

	Average Number of Days that Employees Fill Out a Commute Log as a Percent of Days in the Program
Washington, DC	72.7
Denver	76.5
Houston	51.7
Los Angeles	82.5
Philadelphia	74.0
TOTAL	71.0

It is impossible to know from the data why people are not filling out their commute logs. Even if they are on vacation, they are meant to fill the log out, stating that they did not work on the particular days in question. Likewise, if they worked but did not telecommute, they are still supposed to log their commute activities. In fact, there are over 100 people in the system who report that they have never telecommuted but who fill out their commute logs. Nonetheless, we have to acknowledge the possibility that employees may be failing to report during the weeks that they do not telecommute, biasing the telecommuting results from the program.

[15] However, 52 of the 100 are people who have been in the system only 1 day.

Another issue with the data has to do with dropping out of the program. A large percentage of employees stop reporting after some period of time. It is possible that they are still teleworking, but because we have no commute logs for them, we have no way of knowing. Table 6 shows the percentage of total employees enrolled in the program over the entire program period who have *not* reported to Teletrips within the last month for which we have data, February 2004. Overall, slightly less than 35% of all employees are currently reporting, thus 65% of the sample have dropped out, or at least have not reported to Teletrips for a month. The percentages vary across the cities from only 42% in L.A. up to 73% in Philadelphia. It is not surprising that L.A.'s drop-out rate is lowest since most of the employees enrolled there have signed up only late during the ecommute program.

Tables 3 and 4 provide some useful information about tracking commute behavior over time. Even though Teletrips is reportedly easy to deal with and filling out commute logs takes very little time, there is still a high percentage of participants in the program who do not report on any given day and a very high percentage who appear to drop out completely. As we said in Section II above, one of the unique aspects of this data was the possibility it provided of observing telecommuting behavior over time. However, these observations need to be taken with a grain of salt because of the missing commute logs and limited time that some employees actively participate in the program.

Table 4. Employee Drop-Out Rates in the ecommute Program, by City

	Percentage of Registered Employees Who Have Not Reported to Teletrips in the Most Recent Month, February 2004
Washington, DC	71.2
Denver	62.3
Houston	70.4
Los Angeles	41.9
Philadelphia	72.8
TOTAL	65.4

5.2. Commute Mode Choice of Employees in the ecommute Program

For each day of the week, employees report not only their telecommuting activity but also their mode for commuting to work when they don't telework and/or whether they did not work at all. Table 5 shows, for each pilot city, the percentage of total days worked that are teleworking days (including telework centers), as well as days in which the employee drove alone to work (including motorcycles), drove or rode in a car or van pool, used public transit, or used other forms of transportation (which includes bicycling and walking, as well as a self-reported "other" category). The figures in Table 5 are calculated by simply adding up the days reported for each mode, across all employees, and dividing by the total number of days reported. Thus the reporting days are treated as equivalent regardless of *who* is reporting – i.e., we do not take into account which employee is reporting. Because employees enter and leave – or at least stop reporting to – the program on different dates and report with varying degrees of regularity, we have an unequal number of commute logs across employees. There is no single correct way to summarize the commuting data in this case, so we choose to present it in two different ways. In this section, we treat each day as equivalent to every other day, regardless of which employee filled out the log. In the next section, we compute the percentage of days in the system that each employee teleworks and uses each mode to get to work. We thus treat employees as equivalent but control for the fact that there are different numbers of days reported per employee by looking at percentages of days in the system.

Table 5 shows that, on average, across all five cities, approximately 36% of total workdays reported to the system are telework days. The rest of the time, employees reported most often that they drove alone to work; this option accounts for 49% of all workdays. The figures in Table 5 highlight the self-selection issue with this data that we mentioned in Section II above. Participants in the program are those employees who chose to sign up, and they are likely to be people who want to, and are able to, telecommute relatively often – just under 2 days per week, on average. We have no information on the general, non-telecommuting, workforce. Another problem that may come into play, and one that we mentioned above, is that people may be reporting more faithfully during the weeks in which they have some telecommuting and not reporting in other weeks. This could bias the mode choice percentages and in particular, raise the percentage of workdays that are telecommuting days above what it actually is.

Table 5. Mode Choice of Employees in the ecommute Program on All Workdays, By City

As of March 1, 2004

	Percentage of Total Workdays Reported That are Days on Which Employees				
	Drove Alone[1]	Drove or Rode in a Car/Vanpool	Used Public Transit	Walked or Other[2]	Teleworked[3]
Washington, DC	55.4	3.3	1.9	3.7	35.7
Denver	46.8	7.9	3.1	3.9	38.3
Houston	62.9	9.2	2.4	7.2	18.3
Los Angeles	39.3	2.2	17.4	6.0	35.0
Philadelphia	39.5	1.3	7.3	2.0	50.0
ALL CITIES	49.0	6.6	3.8	4.2	36.4

[1]The drove-alone option includes motorcycles.
[2]The other category includes a self-reported “other” option as well as walking, bicycling, and roller-blading.
[3]Telework includes working at home and working at a telework center. Very few employees reported using a telework center.

The figures vary in some rather surprising ways across the cities. Los Angeles, the land of the automobile, has the lowest percentage of days in which employees drove to work alone and by far the highest percentage using public transit – over 17% of the time, employees in L.A. reportedly use transit. By contrast, in Philadelphia, transit is used only 7.3% of the time. Houston has the lowest reported telework days in the system at 18.3%. That city also has the highest “drove alone” percentage and the highest reported carpool and vanpool use.

It is also interesting to look at these same percentages for non-telework days. In other words, on the days that the employee worked but did *not* telecommute, what does he report as his commute mode? Table 8 shows the findings in the data. If all employees who telecommute would otherwise have driven alone to work – a typical assumption made in many studies when looking at the congestion and emission benefits from telecommuting – we would expect that the percentages in the first column of Table 6 would be roughly equal to the sum of the first and last columns of Table 5. In other words, the percentages attributable to teleworking in Table 5 would now be included in the “drove alone” option. This is not the case, however. Instead, the percentages for all modes rise. We will return to this point when we discuss the emissions reductions from the ecommute program in Section 5.3 below. Across all five cities, driving alone takes place on 77% of reported workdays when employees do not telecommute; transit accounts for 6% of all non-telecommuting workdays, and car and vanpools approximately 10%.

Table 6. Mode Choice of Employees in the ecommute Program, on All Non-Telecommuting Workdays, by City

As of March 1, 2004

	Percentage of Non-Telecommuting Workdays in Which Employees Reported That They			
	Drove Alone[1]	Drove or Rode in a Car/Vanpool	Used Public Transit	Walked or Other[2]
Washington, DC	86.3	5.1	2.9	5.8
Denver	75.9	12.7	5.0	6.4
Houston	77.0	11.3	2.9	8.8
Los Angeles	60.5	3.4	26.8	9.3
Philadelphia	78.9	2.7	14.5	3.9
ALL CITIES	77.0	10.4	6.0	6.6

[1]The drove-alone option includes motorcycles.
[2]The other category includes a self-reported “other” option as well as walking, bicycling, and roller-blading.

We can compare the figures in Tables 5 and 6 with mode choice numbers from other sources. Table 7 shows estimates for the year 2000 from the Federal Highway Administration’s Journey to Work survey for the five ecommute cities.[16] This is a broad survey across employees, some with access to telecommuting options but many more without. Thus, compared with employees in the ecommute program, we would expect far fewer respondents to report working at home. The last column of Table 7 confirms this expectation. Thus, it is probably best to compare the percentages in Table 7 with those in Table 6, the mode share figures on non-telecommuting days. The “drove alone” percentages in the ecommute program for Denver and Houston are almost identical to those obtained from the Journey to Work survey; Philadelphia’s “drove alone” percentage is also quite close. The figures for Washington, DC, and Los Angeles, however, differ significantly. In Washington, far more employees in the ecommute program report driving alone and far fewer use public transit than in the large sample surveyed in the "Journey to Work" study. This is likely due to the fact that the companies enrolled in the ecommute program are primarily suburban Northern Virginia companies and not D.C. firms with ready access to Metro. The Los Angeles results, as expected, do not match the Journey to Work findings at all. Less than 5% of people in L.A. use transit and nearly 73% drive alone to work, according to the Journey to Work, but in the ecommute program those percentages, on non-telecommuting days, are 27% and 60%, respectively.

Table 7. Commute Mode Choice, from 2000 Journey to Work Survey, by CMSA

	Average Number of Survey Respondents Who Report that They Use Each Mode as Percentage of Total Survey Respondents				
	Drove Alone[1]	Drove or Rode in a Car/Vanpool	Used Public Transit	Walked or Other[2]	Worked at Home[3]
Washington, DC	70.8	12.8	9.2	3.8	3.5
Denver	75.8	11.5	4.3	3.7	4.7
Houston	77.3	14.2	3.2	2.9	2.5

[16] The areas covered in the FHWA study are Consolidated Metropolitan Statistical Areas (CMSAs) that include a broader geographical area than the ecommute program.

Los Angeles	72.7	15.2	4.6	4.0	3.6
Philadelphia	73.5	10.3	8.6	4.8	2.8

[1]The drove-alone option includes motorcycles.
[2]The other category includes a self-reported "other" option as well as walking and bicycling.
[3]This survey uses the term "work at home" rather than teleworking or telecommuting.

In Table 8 below, we summarize the ecommute mode choice and telework data in a slightly different way. We calculate the *proportion* of days that each employee telecommutes, drives alone to work, and so forth, and then report averages across employees. So although employees have different numbers of days reported, we make employees comparable by looking at the proportion of their days in the system that they undertake each activity. In Table 8, we show only the drove alone, transit, and telecommuting options.

The telework percentage across all five cities is roughly the same as it was in Table 5: on average, employees have telecommuted 35% of the days that they have worked and reported to Teletrips. The percentages for the individual cities are also comparable to those in Table 5, with the exception of Washington, DC. According to Table 5, 36% of the total days reported in DC are telecommuting days but according to Table 7, the average employee has telecommuted only 22% of his workdays. This must mean that there are a few heavy teleworkers in the DC area who have been with the program for a while, or at least reported to Teletrips relatively more than have others in that region. This brings up the average in Table 5 relative to Table 8. Similarly, the "drove alone" percentage for DC is lower in Table 5 than in Table 8. In both Tables 5 and 8, the percentage of workdays telecommuted in Philadelphia is quite high, 50.8% in Table 8. This high number appears to be primarily a result of a set of 17 employees at Amtrak who report that they telework nearly every day.

Table 8. Average Number of Days Employees in the ecommute Program Used Each Commute Mode, as Percentage of Total Work Days

As of March 1, 2004

	Drove Alone[1]	Used Public Transit	Teleworked[2]
Washington, DC	62.3	3.4	21.9
Denver	47.2	3.4	38.6
Houston	63.5	1.4	17.9
Los Angeles	45.2	12.5	32.4
Philadelphia	33.9	11.4	50.8
ALL CITIES	49.2	4.9	35.0

[1]Drove alone option includes motorcycles.
[2]Teleworked includes telework centers, as well as working at home.

5.3. Estimates of Emissions Reductions from the ecommute Program

As we explained in Section 4 above, participants in the ecommute program report the age, make, and model of the vehicle in which they commute each day, as well as the distance traveled to and from work. This means that, armed with emissions factors by vehicle age for each individual city, we can compute a fairly reliable estimate of the emissions avoided by telecommuting, on an individual employee basis. We obtain these emissions factors, in grams per mile, from runs of EPA's MOBILE model for four of the five cities and from runs of California's EMFAC2002 model for Los Angeles. Both models have very detailed emission factors, specific to both vehicle type (passenger car, motorcycle, large and small trucks, etc.) and vehicle age. Vehicle age is a crucial piece of information for estimating emissions benefits from avoided trips, because technological improvements have dramatically reduced the emission rates of new cars over the past 20 years. As a result, the emissions savings from averting a vehicle trip of a new car are much lower than the savings of averting a trip using an old car.

Table 9 begins by showing the average one-way distances commuted from home to office. The average one-way distance traveled by employees in the ecommute program is just over 22 miles. Not surprisingly, Los Angeles has the highest average commute length at nearly 34 miles; Denver's is the lowest at approximately 20 miles. In each of the cities, however, the range is wide. Some employees report that they commute only a mile each way, while the longest one-way commute is 146 miles.[17] The mean is greater than the median in each of the cities because of these few participants with very long commutes.

The average one-way distance of 22 miles appears somewhat high. In a report on telecommuting and emissions trading and the potential of the ecommute program by the National Environmental Policy Institute (NEPI, 2000), estimates of average distance to and from work, net of miles traveled for non-work trips during the day, were given for each of the five cities. These averages are as follows: 19 miles (DC), 15 miles (Denver), 27.5 (Houston), 16.5 (Los Angeles), and 12.5 (Philadelphia). With the exception of Houston, these averages are all below the averages in the first column of Table 9.

Table 9. Distribution of One-Way Distance Commuted by Participants in the ecommute Program, by City

as of March 1, 2004

(in miles)

	Mean	Median	Std. Dev.	Minimum	Maximum
Washington, DC	24.1	20.0	21.2	3	115
Denver	19.7	15.0	14.7	1	85
Houston	22.3	16.5	19.5	1	146
Los Angeles	33.6	30.0	20.6	5	80
Philadelphia	25.3	20.0	19.2	1	100
ALL CITIES	22.4	17.0	17.9	1	146

An analysis of a telecommuting survey done by the Southern California Association of Governments (SCAG) shows that the average commuting distance of a teleworker is 21 miles in Los Angeles and the surrounding region. The SCAG number is useful as a comparison since it is an average only of people who telecommute and not the general population. The Houston figure in Table 14 is reasonably close to the NEPI estimate: the average one-way distance for participants in the ecommute program is 22 miles, while the NEPI report estimates a distance of 27.5 miles. The medians reported in Table 9 are actually closer to the averages reported by NEPI, at least the median distances in Denver and Washington, DC, match up well. Again, the relatively few participants in the ecommute program who live a long way from their workplace appear to be driving up the means in Table 9.

Tables 10 and 11 show the distribution of vehicle types and ages among the 535 employees in the ecommute program. Table 10 shows that most employees, 67%, own light-duty gasoline vehicles. The next highest percentage is mid-size trucks at nearly 18%, followed by full-size trucks (>8,500 pounds) at 7.5%. Table 11 indicates that most of the employees in the ecommute program own relatively new vehicles. Only 5.6% of the vehicles in use by ecommuters are pre-1990 vehicles. Fully 41%, on the other hand, are model year 2000 or newer. The average vehicle is 5.4-years-old.[18]

[17] The distances were missing or erroneously reported as zero for a few employees in the dataset. When we had the zip codes available, which we did in most cases, we looked up on the Internet distances between zip codes.

[18] This is actually an overestimate of vehicle age. We calculated this figure by subtracting the vehicle model year for each employee from 2003 and then computing the average age. However, some participants were in the program prior to 2003 and dropped out (or stopped reporting), thus their vehicles were newer in those years than they were in 2003. We do not adjust for this.

According to the Federal Highway Administration (FHWA), the average car on the road in 2000 was 9-years-old, nearly 4 ½ years older than the vehicles owned by participants in the ecommute program (U.S. FHWA, 2003). This could be significant. If telecommuters own newer – and thus cleaner – than average vehicles, the emissions benefits of telecommuting may not be that great.

Table 10. Distribution of Types of Vehicles Owned by Employees in ecommute Program

as of March 1, 2004

Vehicle type	Percentage of employees in ecommute program
Light-duty gasoline vehicles (i.e., passenger cars)	67.5
Light-duty gasoline trucks (6,000-8,500 lbs gross vehicle weight)	17.8
Light-duty gasoline trucks (>8,500 lbs gross vehicle weight	7.5
Light-duty gasoline trucks (<6,000 lbs gross vehicle weight	5.2
Motorcycles	0.9
Light-duty diesel vehicles (i.e., passenger cars)	0.6
Light-duty diesel trucks (under 8,500 lbs gross vehicle weight)	0.6

Table 11. Distribution of Ages of Vehicles Owned by Employees in ecommute Program

as of March 1, 2004

Vehicle Model Year	Percentage of employees in ecommute program
1984 – 1989	5.6
1990 – 1994	15.3
1995 – 1999	37.8
2000 & 2001	27.1
2002 & 2003	14.0

To generate specific emission factors for NO_x and VOC for each city, we use the assumptions employed by local planners for their regulatory demonstrations. This means that assumptions about temperatures, traffic congestion, inspection and maintenance programs, and the like are consistent with those used by the cities for purposes of demonstrating transportation conformity and other regulatory uses. The scenario run for all cities except Denver was a Summer day in 2005. For Denver a winter run was used because unlike the other cities Denver has a greater problem with carbon monoxide (which is worse in the winter) than ozone (which is worse in the summer).

Two important issues emerge for calculating total emissions reductions: (1) whether we assume that the employee would have driven alone to work had they not telecommuted, and (2) whether we assume that there is any change in non-work trips as a result of working at home. Since we do not have any travel information on the individuals in the program other than their journeys to work, we cannot speak to (2). We simply assume there is no change in non-work travel as a result of telecommuting. With respect to (1), we show emissions results under two assumptions. In the first scenario, we assume that everyone who telecommuted would otherwise have driven alone to and from work in the vehicle they report that they own. The emissions reduction from telecommuting is then the emissions factor, in grams/mile, multiplied by the reported round-trip commute mileage from home to office.[19] In the second scenario, we use the information on mode choices that employees report to Teletrips and adjust this figure downward. Specifically, for each employee the emissions reduction is the emissions factor, in grams per mile, multiplied by round-trip mileage multiplied by the percentage attributable to the "drove alone" option. This second scenario thus assumes that some of the telecommuting workers would otherwise have used public transit, walked or biked, or ridden in a car or vanpool.[20]

Table 12 shows total VOC and NO_x emissions reductions for each city under the two mode choice assumptions. Emissions reductions are greater under Scenario 1 because credit is taken for the full mileage from home to office (or telework center to office) on every day that the employee reports that she teleworks. Thus emissions benefits shown in the first two columns are approximately 18% greater than those shown in the latter two columns. Under both scenarios, Denver shows the greatest total emissions benefits because employees there have been in the program longer and thus report more days telecommuting. Los Angeles shows the least benefit because of fewer employees who have enrolled later. Emissions reductions across all cities since inception of the program through February 2004 total approximately 2 tons each of VOC and NO_x.

Table 13 provides more information by showing emissions reductions *per telecommuting day* – in other words, the numbers in Table 12 are divided by the total number of days of telecommuting for each city.

Table 12. Total Emissions Reductions from ecommute Program

June 1, 2001 – Feb. 29, 2004

(in pounds)

	Scenario 1[1]		Scenario 2[2]	
	VOCs	NO_x	VOCs	NO_x
Washington, DC	260	237	218	203
Denver	2992	2319	2539	1981
Houston	316	289	228	226
Los Angeles	49	24	39	19
Philadelphia	907	1055	794	892
ALL CITIES	4524	3925	3818	3321

[1]Under Scenario 1, it is assumed that employees would have driven alone to work every telecommuting day had they not telecommuted.
[2]Under Scenario 2, it is assumed that employees would have driven alone to work some fraction of the time based on reported mode choices.

Table 13. Emissions Reductions from ecommute Program, Per Telecommuting Day

June 1, 2001 – Feb. 29, 2004

(in pounds per day)

[19] When the employee uses a telework center and reports the distance to the telework center, we account for that in our mileage calculations. If the distance is unreported, which it was for approximately 50 employees, we multiply the reported home-to-office distance by the average ratio of the home-to-telework-center distance to home-to-office distance, across employees, to obtain an estimate of the home-to-telework center distance.
[20] For those few employees who report that they telecommute every day, we have no information on what their mode choice would have been had they not telecommuted. In these cases, we use the average "drove-alone" percentage for the rest of the sample, 77% (see Table 9 above), to adjust their emissions reductions.

	Scenario 1[1]		Scenario 2[1]	
	VOCs	NO_x	VOCs	NO_x
Washington, DC	0.139	0.126	0.116	0.108
Denver	0.157	0.122	0.134	0.104
Houston	0.107	0.097	0.077	0.076
Los Angeles	0.123	0.062	0.100	0.048
Philadelphia	0.120	0.140	0.105	0.118
ALL CITIES	0.142	0.124	0.120	0.105

[1]Scenarios as defined in Table 12.

Some interesting results show up in a comparison of Tables 12 and 13. The emissions reductions in Table 12 are strongly determined by the overall number of participants in the program. Thus, the emissions reductions in Philadelphia, in scenario 1, are more than 18 times the reductions in Los Angeles. On a per telecommuting day basis, however, Table 13 shows that the two cities yield approximately the same emissions reduction. This result is driven by the relatively high number of telecommuting days in Philadelphia, which is caused, in turn, by the fact that the average participant in the ecommute program in Philadelphia telecommutes a large percentage of his total workdays. Denver, which has the largest total emissions reductions (Table 12) because of the large number of people enrolled, also has the largest reductions on a per telecommuting day basis as well (Table 13). This result appears to primarily result from emissions factors. The overall average emissions factors for VOC and NO_x across all five cities are 1.308 g/mi and 1.109 g/mi, respectively. In Denver, the averages are 1.530 g/mi (VOC) and 1.242 g/mi (NO_x).

In general, a combination of factors comes into play in Tables 12 and 13: number of participants in the program, number of days each participant telecommutes, emissions factors of the vehicles owned by those participants, and distances traveled to work. It is impossible to sort out all of the conflicting influences on emissions reductions and emission reductions per telecommuting day. Overall, across all the pilot cities, an average of slightly more than one-tenth of a pound each of VOC and NO_x is reduced per day of teleworking.

We can use these figures in Table 13 to calculate the number of teleworkers that would be needed to achieve a hypothetical target annual emissions reduction from telecommuting. Table 14 shows the results of this calculation, assuming a target of 25 tons of VOCs.[21] Results in the first column are obtained assuming that each worker telecommutes the percentage of days given in Table 9. These percentages range from 17.9% for Houston up to over 50% for Philadelphia, or slightly less than 1 day per week up to 2 ½ days per week. Column 2 results are obtained using the average of 35% that holds across all cities. We also assume that there are 250 workdays in a year and that each worker would otherwise have driven alone to work on all of the days that he telecommuted (Scenario 1 in Tables 12 and 13).

To achieve the 25-ton target, Philadelphia would need 3,268 people to telecommute, assuming that each one telecommutes, on average, 50.8% of the time (see Table 9) – i.e., about 2 ½ days per week. Denver's number is roughly the same – 3290 – but those people would be telecommuting only 38.6% of the time (see Table 9). If we use the overall 5-city average of 35% for Philadelphia rather than the relatively high 50.8%, we find that many more people are needed to reach the target, approximately 4,700. In Houston, if telecommuters work at home only 18% of the time, as Table 9 showed, then nearly 10,500 telecommuters are needed to reach the VOC target. If each telecommuter works at home 35% of the time, however, only about half as many people are needed. The two columns of the table simply highlight the trade-off that exists, for emissions reductions purposes, in number of people telecommuting and the frequency with which they do so.

[21] We cannot simultaneously target both NO_x and VOC so we just look at a scenario with a VOC target. Obviously, some NO_x reductions will be achieved as well.

Table 14. Number of Teleworkers Needed to Reduce 25 Tons of VOCs Per Year[1]

	Number of Teleworkers	
	Assuming % of days spent teleworking as in Table 9	Assuming 35% of days spent teleworking
Washington, DC	6,591	4,124
Denver	3,290	3,628
Houston	10,486	5,363
Los Angeles	5,012	4,640
Philadelphia	3,268	4,744

[1]Using Scenario 1 – see Table 12 – and figures in Table 9 and assuming 250 workdays in a year.

Using U.S. Bureau of Labor Statistics figures on employment during the 2001-2003 period for the five metropolitan areas in the ecommute program, the figures in the first column of Table 14 represent the following percentage of total non-farm employment: 0.24% (Washington, DC), 0.30% (Denver), 0.50% (Houston), 0.13% (Los Angeles), and 0.14% (Philadelphia).[22] So assuming that each teleworker works at home anywhere from slightly less than 1 day per week up to 2 ½ days per week and assuming the average distances commuted and types of vehicles owned correspond to the figures in Tables 9, 10, and 11 – i.e., relatively long distances and relatively clean vehicles – between 0.14% and 0.50% of the employed non-farm workforce in these metro areas must telecommute to generate a 25 ton per year reduction in VOC.

As we have seen, the current institutional context has many barriers to trading telecommuting credits. If the regulatory situation becomes more hospitable, however, what is the potential for emissions trading with telecommuting credits? In this section, we present estimates for the potential credit value per teleworker, assuming no barriers to trading. The value of the emissions reductions per teleworker is based on two components: the reduction in emissions from telecommuting and the market price for emissions reduction credits.

5.4. Emissions Reductions from Telecommuting

The emissions benefits from telecommuting are often reported in aggregate terms—that is, total pounds of pollution avoided. This is fairly misleading because the category of pollutants includes things like carbon dioxide and carbon monoxide. But not all pounds of pollution are created equal. In 2002 about 20 million tons of NO_x was emitted in the United States, versus CO_2 emissions of 5.8 *billion* tons. A number that aggregates the two pollutants is not meaningful. If pollution reductions from telecommuting are presented in aggregate terms, CO_2 reductions will account for more than 90% of “total pollutants avoided.” Moreover, the two pollutants have very different impacts on the environment.

The reductions in NO_x and VOC emissions (the two pollutants that have the most active markets) from an avoided vehicle trip are fairly small. Cars today are far cleaner than they were even 10 years ago, and this trend will continue, thanks to new vehicle and fuel standards. The upshot is that reducing a vehicle mile traveled does not deliver all that much in the way of pollution reduction.

[22] Customized table on total non-farm employment created on BLS website. See http://www.bls.gov/sae/home.htm.

Credit Values

The other component of the emissions credit incentive is the value of the credit. In order to be able to realize the benefits of telecommuting, the holder of the credit should be able to sell credits on the market at a price higher than the incurred costs. Apparently, telecommuting is not the only source to produce such credits. In order to get some idea how valuable telecommuting credits can be, we consider six alternative programs. As one can imagine, credit values depend greatly on the specific conditions. We present values based on six scenarios: (1) current and predicted NO_x allowance prices in regional cap-and-trade programs; (2) current and historical prices of DERs in various state programs; (3) a comparison with the costs of other on-road mobile source reductions; (4) the costs of MERCs used by firms to comply with southern California's rideshare regulation; and (5) the price of NO_x allowances in the RECLAIM program during the California electricity crisis, which represents a likely upper bound for the value of credits; and (6) the cost-effectiveness of other telecommuting programs[23].

Given figures for the yearly emissions saving from telecommuting and the prices of credits, it is possible to estimate the revenue that a firm would generate per year per telecommuter. Table 15 displays revenue estimates based on the range of NO_x credit prices presented in the above scenarios and an emissions reduction of 10 pounds of NO_x per year per telecommuter. Revenue can be as low as 1.50 cents per year per telecommuter based on the low prices for DERs. Higher prices are found when credit prices are based on other mobile source strategies. The range of revenue is mainly between $40 and $100 per year per telecommuter.

Table 15. Estimated Value of Emissions Reduction Credits per Teleworker per Year, $

	NO_x credit prices		Revenue per teleworker per year	
Scenario	Low price	High price	Low revenue	High revenue
NO_x allowance prices	1,000	7,500	5.00	35.00
DER prices	300	1,300	1.50	6.50
Mobile source reductions	7,200	33,700	36.00	168.0
Rideshare programs	8,000	19,000	40.00	95.00
RECLAIM		15,000		75.00
Other telework programs	16,250		81.26	

The potential revenue from telecommuting credits is part of the equation for evaluating whether emissions trading will promote telework on a large scale. The other piece of information is an understanding of how responsive telecommuting is to financial incentives. Unfortunately, there has been little experience with direct subsidies for telecommuting, and thus, how it responds to financial incentives is not well understood.

Discussions with business leaders participating in the ecommute Business Roundtable produced estimates of about $500 to $1,000 per teleworker per year as an amount needed to prompt firms to implement formal telework programs. The proposed Teleworking Advancement Act sponsored by Sen. John Kerry of Massachusetts would give employers a tax credit of $500 for each employee participating in an employer-sponsored telework program.[24] If $500 per employee per year is indeed the sort of number necessary to get major increases in telecommuting activity, revenue from emissions trading is likely to fall short, even using high-end estimates for the future value of credits. However, as stated above, the responsiveness of telecommuting behavior to financial inducements is not well understood,

[23] See Nelson (2004) for more details on the 6 hypothetical scenarios.
[24] Teleworking Advancement Act, S. 1856, 107th Congress, December 18, 2001.

and a lower dollar figure could conceivably be sufficient to promote large-scale increases in telecommuting.

6. Conclusions

In this paper we analyzed the results of the ecommute program. The program conducted pilot projects in five US metropolitan areas to study the feasibility of trading mobile source emissions credits created from telecommuting.

Mobile source emissions come from a large number of vehicles, each emitting a relatively small amount, and as a result the costs of monitoring and verifying the emissions will greatly cut into the efficiency benefits of an emissions trading regime. It is worth noting that in discussions about including the transport sector in carbon cap-and-trade regimes, the focus has been *upstream,* for either fuel producers or vehicle producers, rather than *downstream,* for drivers (Australian Bureau of Transport and Communications Economics 1998). The reason, of course, is the significant administrative burden associated with monitoring individual driving activity.

EPA requires that any emissions trades demonstrate environmental integrity by showing that the reductions are surplus, permanent, quantifiable, and enforceable. In practice, the surplus requirement brings emissions trading of telecommuting credits into conflict with other claims on telecommuting, notably from local planning organizations seeking reductions in the transportation conformity process and regional transportation plans, and from state environmental agencies seeking compliance in their air quality plans.

The quantification protocols for activity-based vehicle emissions reductions are not well developed and necessarily rely on a hypothetical baseline. Thus, the emissions reductions from telecommuting, even in a carefully designed program like ecommute, will remain speculative when compared with emissions reductions from continually monitored sources like power plants. Furthermore, the administrative burdens associated with making sure that firms aren't cheating and claiming excess telecommuting are fairly high and might make the reductions difficult to enforce.

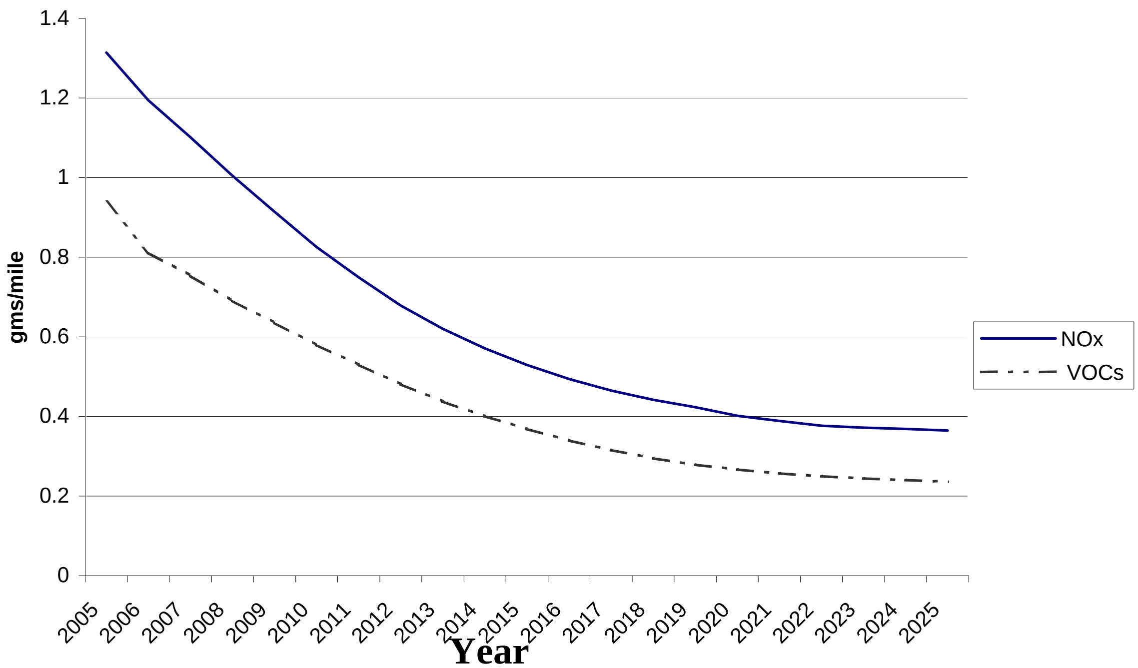
The above issues could conceivably be overcome. For example, a cost-effective technology could emerge that would ease the monitoring of individual driving activity. Similarly, the Clean Air Act could be amended or interpreted differently to ease the integrity requirements as they apply to mobile sources and provide more latitude for trading of pollution credits generated from reduced driving (although whether such changes are worth the reduced certainty of the reductions will be a subject for debate).

But the most intractable issue is probably economic—the low value of the credit revenue. The emissions reductions from a single avoided trip are not large. Given the range of estimates for the future value of pollution credits, it is hard to see the potential revenue to firms being large enough to induce large-scale changes in driving activity. It is possible that the low level of participation by employers in the ecommute pilot programs is an indicatiin that companies knew the credits had very low value. From the point of view of local planning organizations and state agencies looking to direct scarce public funds to emissions reduction activities, in the short and medium term there are far more cost-effective uses for the funds (if the measure is purely emissions reductions). This situation is likely to persist for the foreseeable future.

The emissions characteristics of the vehicle fleet (particularly light-duty vehicles) are expected to improve dramatically over the next 20 years, making per trip emissions reductions from transportation demand management strategies still smaller. Figure 1 shows projected composite emissions factors for light-duty gasoline vehicles over the next 20 years. Paradoxically, improvements in vehicle technology will reduce the emissions benefits from each teleworked day. This already showed up in the ecommute pilot programs where the data revealed that participants owned relatively new and clean vehicles.

All of this is not to say that the government does not have any reason to promote telecommuting. A large-scale increase in telecommuting could produce welcome emissions benefits for many highly polluted areas. Approaches that minimize transaction costs—wholesale approaches like public outreach programs and eliminating regulatory obstacles to teleworking—may be warranted, especially considering the other potential social benefits from telecommuting, most notably, congestion benefits.

Fig. 1. Composite Emission Factors for LDGVs 2005-2025



Source: Authors' calculations using MOBILE6

The issue of climate change offers perhaps the most hospitable context for emissions trading. The environmental impacts of CO_2 and most other greenhouse gas emissions are independent of where they occur. A ton of CO_2 emitted in Los Angeles has essentially the same environmental effect as a ton emitted in Wyoming or India. The geographic scope of the market is much larger than for pollutants like NO_x and hydrocarbons, which affect local and regional air quality. Thus, whereas the market for NO_x, VOC, carbon monoxide, and particulate matter reductions from telecommuting will necessarily depend on local environmental and regulatory conditions in a nonattainment area, a firm wishing to sell carbon credits from telecommuting has a much larger potential market of buyers.

Carbon emissions are not currently regulated in the United States, but as noted above, the European Union is preparing to implement a carbon trading regime in early 2005. The transport sector is currently excluded from this regime but may have to be included at some point if E.U. nations have difficulty meeting their targets under the Kyoto Protocol. Because the United States is not a signatory to the protocol, it is not possible to trade U.S.-generated credits in the European Union or Kyoto systems. Within the United States and Canada there are scattered voluntary trading programs, and several northeastern U.S. states are moving to a limited cap-and-trade system for CO_2 emissions; the level of the cap is not yet known, making it impossible to forecast allowance prices.

The lack of a national and comprehensive policy on greenhouse gas emissions seriously limits the demand for reductions. Within U.S. voluntary trading programs, prices for CO_2 credits and allowances have ranged between $0.50 and $2.50 per ton, and comparable prices have been seen in Canada's trading programs, GERT and PERT (Zaborowski and Reamer 2004). To give some perspective, a price of $25 per ton of carbon translates into about an additional 6 cents per gallon of gasoline.

The strongest argument for promoting telework may be the benefits for traffic congestion. In a recent review of studies on the social costs of driving, a Federal Highway Administration (2000b) report presents a figure of 7.7 cents per mile (2000 dollars) in external congestion costs from auto travel in urban areas. The same report places external air pollution costs in urban areas at 1.33 cents. In other words, a 10-mile automobile trip in an average urban area will generate 77 cents in external congestion costs and only 13 cents in external pollution costs. Along specific corridors, external congestion costs can be much higher. A recent study estimates that marginal congestion costs on the most crowded roads in the Washington, D.C., area are well over $1 a mile (Safirova and Gillingham 2004).

Looking ahead, while cars are projected to get cleaner, all estimates show traffic congestion worsening. Vehicle miles traveled will continue to rise thanks to demographic factors, such as population growth, rising incomes, and a larger share of licensed drivers in the population. Many metropolitan areas are dealing with tight budgets and an inability to fund new road and transit infrastructure to keep pace with travel demand. Recent construction cost data suggest that average costs for providing additional peak-period capacity on urban freeways can run as much as $10 million per lane mile (Federal Highway Administration 2000b). State transportation agencies have a strong interest in delaying or averting costly road construction, and strategies like telecommuting may lessen the pressure for the investments by reducing vehicle trips. Therefore, transportation agencies and metropolitan planning agencies are likely to continue to pursue telecommuting, as one strategy among many, to reduce both traffic congestion and air pollution.

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