Telecommuting and Emissions Reductions: Evaluating Results from the ecommute Program

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Abstract

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 express purpose of studying the feasibility of addressing air quality concerns through telecommuting. This study provides the first analysis of data from the "ecommute" program. Using two-and-one-half years of data, we look at telecommuting frequency, mode choice, and emissions reductions. We also look at reporting behavior, dropout rates, and other information to assess the program's performance. We analyze results by city—Denver, Washington, D.C., Houston, Los Angeles, and Philadelphia are the five pilot cities. And finally, we use the program's emissions reduction findings to calculate how much telecommuting would be needed to reach an annual volatile organic compounds emission reduction target in each city.

This discussion paper is one in a series of four RFF papers on telecommuting published in December 2004. In addition to analysis of the ecommute data described in this paper, Safirova and Walls (discussion paper 04-43) similarly analyze data from a 2002 survey conducted by the Southern California Association of Governments (SCAG) of telecommuters and nontelecommuters. These same authors put these findings into context by providing a review of the empirical literature on telecommuting (discussion paper 04-44). Finally, Nelson presents an assessment of institutional and regulatory barriers to using telecommuting in a mobile source emissions trading program (04-45). The studies by RFF are part of a larger report on the ecommute program completed by the Global Environment and Technology Foundation (GETF) for the U.S. Environmental Protection Agency. More information about the overall project can be found on the ecommute/GETF website: http://www.ecommute.net/program/.

Key Words: telecommuting, mode choice, air quality, emissions

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I. Introduction

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 express purpose of studying the feasibility of addressing air quality concerns through teleworking. A group of major stakeholders outlined the important goals and objectives to be achieved in the program:

- 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 through reductions in 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, Washington, D.C., Houston, Los Angeles, and Philadelphia. Chicago dropped out of the program in 2000 and was

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replaced by Denver. The "ecommute" program commenced in June 2001 and by March 2004, 49 companies with 535 employees had participated.

This paper presents the first analysis of results from the program. We summarize company and employee participation, reporting frequency, and dropout rates. We look at telework activity in the program, including the amount of teleworking that takes place among employees and by city, as well as the commute mode employees choose when not teleworking. We analyze the distances program participants travel to work and the types of vehicles they own, and finally, we estimate the emissions reductions that have taken place from the program. Emissions reduction estimates are likely to be more accurate from this program than from other telecommuting programs because participants report the make, model, and year of their vehicles as well as the distances traveled. We use the Environmental Protection Agency's MOBILE 6 model and California's EMFAC 2002 model to obtain emissions factors, in grams per mile, to calculate city-specific emissions estimates.

In the next section of the paper, we describe the data that are available from the ecommute program—and what is not available as well. Section III presents some summary information on participation and reporting in the program. Commute mode choice information, including the teleworking option, is summarized in Section IV. Section V provides more information on teleworking activity, including distributional information, statistics by days of the week, and teleworking activity by company size. In Sections IV and V, we also compare our findings from the ecommute program—on mode choice results, commute distances, and the amount of teleworking—with findings from other studies. Section VI presents the emissions information, starting with summary statistics on distances traveled and types of vehicles owned by participants in the ecommute program and concluding with total emissions reduced, emissions reduced per telecommuting day, and a calculation of how much telecommuting would be needed to reach a particular emissions target. Section VII presents some concluding remarks.

II. Data in Teletrips

Data on teleworking activity in the ecommute program, as well as information on other commuting modes, is collected using Teletrips, a Web-based software program developed by a Canadian-based firm, Teletrips Inc. The software was designed specifically to track the emissions 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 they went to work and how they traveled. 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 his vehicle and his commute. Information about the employee's vehicle includes the year, make, and model of the vehicle, the engine type, and whether 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 and arrives at work, and the time he leaves work and reaches 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 whether individuals drive more for nonwork 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 other demographic data on 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 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 dataset 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 emissions 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, in fact, provides one of the few sources of longitudinal information on teleworking behavior.

III. Basic Information from Teletrips: Number of Employees and Companies, Reporting Frequency, and Dropout Rates

We obtained the Teletrips data in March 2004, and 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 include 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. Washington, D.C., has several companies but not very many employees in each.

Table 1. Number of Companies and 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, D.C.	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

The companies enrolled in the ecommute program vary in size and type. Table 2 categorizes companies by size—that is, number of employees—and shows the number of companies enrolled in the program by size category, as well as the number of total employees in the program by company size category. The smallest size category (fewer than 25 employees) has the highest number of participating companies, nine. The remaining categories have approximately the same number of companies enrolled, except that no participating companies are in the category of 1,000 to 2,000 employees. The average number of employees signed up per company varies across the company size categories. The average across all 49 registered companies is just under 11 employees.

That average masks some wide differences across companies. Table 3 shows the number of companies with fewer than five, five to 10, 11 to 20, 21 to 50, and more than 50 employees enrolled in the ecommute program. Twenty-seven companies—fully 55% of the total number of companies registered in the program—have fewer than five employees signed up. In Los Angeles, 11 of the 13 companies have fewer than five employees participating. But two companies have a substantial number of employees enrolled: in Denver, CH2M Hill has 88 employees in the system; in Houston, BP has 103 employees.

Table 2. Number of Companies and Employees per Company Enrolled in the ecommute Program, by Company Size, as of March 1, 2004

Company size (number of employees)	*Number of companies*	*Average number of employees enrolled per company*
< 25	9	3.4
25–50	2	6.5
50–100	5	17.6
100–200	4	4.3
200–500	7	8.0
500–1,000	5	21.4
1,000–2,000	0	—
2,000–4,000	3	10.0
4,000–8,000	3	30.7
8,000–16,000	5	4.4
16,000–32,000	3	11.7
>32,000	3	14.7
ALL	49	10.9

Table 3. Distributional Information on Number of Employees Enrolled in the ecommute Program per Company, by City, as of March 1, 2004

	Number of companies with…				
	<5 registered employees	*5–10 registered employees*	*11–20 registered employees*	*20–50 registered employees*	*>50 registered employees*
Washington, D.C.	6	4	1	0	0
Denver	5	2	1	4	1
Houston	5	1	0	0	1
Los Angeles	11	2	0	0	0
Philadelphia	0	2	0	3	0
TOTAL	27	11	2	7	2

Not all employees have been in the ecommute program since it began, and not all who started have remained in the program or continued to fill out a weekly commute log. Moreover, even those who have been in the system for a significant period 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, dropout rates, and reporting frequency.

Table 4 shows the number of employees enrolled less than three months, three to six months, six to 12 months, and a year or more. These figures are based on the number of days between the date the employee first reported to the system and the date she last reported (as of March 1, 2004). Thus, an employee may have gaps in her commute log, but we do not consider that dropping out of the program. More than 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, and 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 three months. Sixty percent of employees in the D.C. area have been in six months or less.

Table 4. 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, D.C.	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 5, 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. Nonreporting 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.[1]

Table 5. 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 percentage of days in the program
Washington, D.C.	72.7
Denver	76.5
Houston	51.7
Los Angeles	82.5
Philadelphia	74.0
TOTAL	71.0

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

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 supposed to fill the log out, stating that they did not work on those particular days. Likewise, if they worked but did not telecommute, they are still supposed to log their commute activities. In fact, more than 100 people in the system report that they have never telecommuted but 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.

Another issue with the data is program dropouts: a large percentage of employees stop reporting. 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. to 73% in Philadelphia. It is not surprising that L.A.'s dropout rate is lowest, since most of the employees enrolled there have signed up only recently.

Tables 5 and 6 provide some useful information about tracking commute behavior over time. Even though Teletrips is reportedly easy to use 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, plus a very high percentage who appear to drop out completely. As we said in Section II above, this dataset provides the unique opportunity to observe telecommuting behavior over time. However, the 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 6. Employee Dropout 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, D.C.	71.2
Denver	62.3
Houston	70.4
Los Angeles	41.9
Philadelphia	72.8
TOTAL	65.4

IV. 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 7 shows, for each pilot city, the percentage of total days that an employee teleworked (either at home or at a telework center), as well as days he drove alone to work in a motor vehicle (including motorcycles), drove or rode in a car or van pool, used public transit, or used other forms of transportation (including bicycling and walking, as well as a self-reported "other" category). The figures in Table 7 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; that is, we do not take into account which employee is reporting. Because employees enter and leave the program—or at least stop reporting—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 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 7 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 7 highlight the self-selection issue with the 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 two days per week, on average. We have no information on the general, nontelecommuting workforce. Another potential problem is that, as we mentioned above, people may be reporting more faithfully on the weeks when they do some telecommuting and not reporting on 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 7. 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 in which employees…				
	drove alone[1]	*drove or rode in a car or van pool*	*used public transit*	*walked or other*[2]	*teleworked*[3]
Washington, D.C.	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 using inline skates.
[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: more than 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%, and also the highest percentage of employees who drove alone and the highest reported carpool and vanpool use.

It is also interesting to look at the commute mode for nontelework days: on days that the employee worked but did *not* telecommute, how did he get to work? Table 8 shows the findings. If all employees who telecommute would otherwise have driven alone to work—a typical assumption made in many studies seeking to estimate the congestion and emissions benefits from telecommuting—we would expect that the percentages in the first column of Table 8 would be roughly equal to the sum of the first and last columns of Table 7. In other words, the percentages attributable to teleworking in Table 7 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 VII 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 nontelecommuting workdays, and car and van pools, approximately 10%.

Table 8. Mode Choice of Employees in the ecommute Program on All Nontelecommuting Workdays, by City, as of March 1, 2004

	Percentage of nontelecommuting workdays in which employees reported that they…			
	drove alone[1]	*drove or rode in a car or van pool*	*used public transit*	*walked or other*[2]
Washington, D.C.	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 using inline skates.

We can compare the figures in Tables 7 and 8 with mode choice numbers from other sources. Table 9 shows estimates for the year 2000 from the Federal Highway Administration's Journey to Work survey for the five ecommute cities.[2] This is a broad survey across employees, some with access to telecommuting options but many more without it. Compared with employees in the ecommute program, then, we would expect far fewer respondents to report working at home. The last column of Table 9 confirms this expectation. Thus, it is probably best to compare the percentages in Table 9 with those in Table 8, the mode share figures on nontelecommuting 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 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 because 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. Fewer than 5% of people in L.A. use transit and nearly 73% drive alone to work, according to

[2] The areas covered in the FHWA study are Consolidated Metropolitan Statistical Areas (CMSAs), which cover a broader geographical area than the ecommute program.

the Journey to Work, but in the ecommute program those percentages, on nontelecommuting days, are 27% and 60%, respectively.

Table 9. Commute Mode Choice, from 2000 Journey to Work Survey, by Consolidated Metropolitan Statistical Area

	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 or van pool*	*Used public transit*	*Walked or other*[2]	*Worked at home*[3]
Washington, D.C.	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
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 10 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 reported with varying frequency, we make them comparable by looking at the proportion of their days in the system that they undertake each activity. In Table 10, 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 7: on average, employees telecommute 35% of the days that they work and report to Teletrips. The percentages for the individual cities are also comparable to those in Table 7, with the exception of Washington. According to Table 7, 36% of the total days reported in D.C. are telecommuting days, but according to Table 9, the average employee telecommutes only 22% of her workdays. This must mean that there are a few frequent teleworkers in the D.C. area who have been with the program for a while, or at least reported to Teletrips relatively more than have others in that region, and they bring up the average in Table 7 relative to Table 10. Similarly, the drove-alone percentage for D.C. is lower in Table 7 than in Table 10. In both tables, the percentage of workdays telecommuted in Philadelphia is quite high, 50.8% in Table 10. This high number appears to stem primarily from 17 employees at Amtrak who report that they telework nearly every day.

Table 10. 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, D.C.	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]The drove-alone option includes motorcycles.
[2]Telework includes working at home and working at a telework center.

V. Telecommuting Behavior of Employees in the Ecommute Program

In this section, we continue to use the method of summarizing the Teletrips data that we used in Table 10 above—that is, we look at the summary statistics for the proportion of time spent telecommuting across employees. Table 11 shows the means (from the last column of Table 10), along with the median, standard deviation, minimum, and maximum for each city. The median percentage, across all five cities, 21.9%, is less than the mean, indicating that the mean is high because of a small number of frequent telecommuters. This effect holds in each city individually, with Denver having the widest gap between the mean and median. A range of telecommuting intensity takes place: some employees never telecommute, and three of the five cities have some employees who telecommute every day. Denver has 11 employees who report that they telecommute every day, L.A. has 2, and Philadelphia has 7.

We can compare these mean percentages with results from other studies. A telecommuting survey done by the Southern California Association of Governments (SCAG) in 2002 found that people who reported that they telecommuted did so, on average, about 48% of the time, or between two and three days per week (NuStats 2003). Popuri and Bhat (2003) report from a survey of telecommuters in the New York City metropolitan area that the mean number of telecommuting days among telecommuters is two per week. Thus, high means have been found

in other studies of telecommuters.[3] Pratt (2002) reports that responses to telecommuting questions added to the federal government's Current Population Survey indicate that male telecommuters work about 22% of the time at home and females 25% of the time.

Table 11. Distribution of Telecommuting Days in the ecommute Program as a Percentage of Total Workdays, by City, as of March 1, 2004

	Mean	*Median*	*Std. dev.*	*Minimum*	*Maximum*
Washington, D.C.	21.9	16.7	22.9	0	88.9
Denver	38.6	21.9	36.7	0	100.0
Houston	17.9	15.1	14.9	0	66.2
Los Angeles	32.4	23.2	30.3	0	100.0
Philadelphia	50.8	42.7	34.9	0	100.0
ALL CITIES	35.0	21.9	33.6	0	100.0

It is also interesting to look at telecommuting activity in the ecommute program by size of company. Using the size categories from Table 2, we show telecommuting days as a percentage of total workdays in Table 12. The average of 35% across all companies is shown in the last row of the table. The percentages by company size vary around this average, with no clear correlation with company size. Employees at companies with fewer than 50 employees telecommute less than average, and those at companies having 50 to 500 employees telecommute more than average. Above a size of 500 employees, the percentages seem to drop, but then in the 16,000 to 32,000 category, the percentage rises sharply to 75%. This high average is due to the Amtrak employees in Philadelphia who, as we mentioned in Section IV above, telecommute nearly every day that they work.

[3] The percentage of workers surveyed in the SCAG study who reported that they telecommuted at least one day in the past two months was approximately 10%; thus, 90% of workers never telecommute. In the New York study, 15.7% of the sample reportedly telecommuted.

Table 12. Telecommuting Activity in the ecommute Program by Company Size, as of March 1, 2004

Company size (number of employees)	*Telecommuting days as a percentage of total workdays*
<25	26.1
25–50	22.9
50–100	46.8
100–200	35.9
200–500	55.0
500–1,000	28.7
1,000–2,000	—
2,000–4,000	16.0
4,000–8,000	16.0
8,000–16,000	14.5
16,000–32,000	75.2
>32,000	36.6
ALL COMPANIES	35.0

Since participants in the ecommute program fill out daily commute logs, we can look at the days of the week that employees telework. Table 13 shows the percentage of total telecommuting days that fall on each weekday, by city. There is clearly a "Friday effect" showing up in the data: nearly 28% of all telecommuting days occur on Fridays. Program participants in Denver, Houston, and Philadelphia all telework more often on Fridays than any other day. In Washington, participants telework most often on Wednesday, followed by Friday. In Los Angeles, Monday is the most common telecommuting day, with Friday again a relatively close second.

Commute traffic tends to be lighter on Fridays in most metropolitan areas, meaning that the congestion benefits from telecommuting could be less if most of that telecommuting takes place on Fridays. Similarly, since emissions are linked to congestion, this Friday effect could slightly reduce the emissions benefits from telecommuting.

Table 13. Telecommuting Activity in the ecommute Program by Days of the Week, by City, as of March 1, 2004

	Percentage of total telecommuting days that fall on…				
	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
Washington, D.C.	17.4	18.2	23.5	16.2	22.4
Denver	14.5	17.9	17.3	18.2	27.4
Houston	13.4	12.5	14.3	21.1	33.5
Los Angeles	23.1	19.4	17.7	11.7	20.0
Philadelphia	15.9	19.7	17.7	17.4	27.1
ALL	15.1%	17.2%	17.2%	18.2%	27.9%

In the next section, we show distances commuted by ecommute program participants and the types of vehicles owned and calculate the emissions reductions from the program.

VI. Estimates of Emissions Reductions from the Ecommute Program

As we explained in Section II above, participants in the ecommute program report the age, make, and model of the vehicles 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 the Environmental Protection Agency's MOBILE6 model for four of the five cities and from runs of California's EMFAC 2002 model for Los Angeles. Both models have very detailed emissions factors specific to both vehicle type (passenger car, motorcycle, large and small trucks, and so on) 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 emissions 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 14 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, but the longest

one-way commute is 146 miles.[4] 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 nonwork trips during the day, were given for each of the five cities. These averages are as follows: 19 miles for D.C., 15 for Denver, 27.5 for Houston, 16.5 for Los Angeles, and 12.5 for Philadelphia. With the exception of Houston, these averages are all below the averages in the first column of Table 14.

Table 14. 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, D.C.	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

The telecommuting survey done by the Southern California Association of Governments (SCAG) shows that the average commuting distance of a teleworker in Los Angeles and the surrounding region is 21 miles. The SCAG number is useful as a comparison since it is an average only of people who telecommute and not of 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, compared with 27.5 miles in the NEPI report. The medians reported in Table 14 are actually closer to the averages reported by NEPI for Denver and Washington. 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 14.

Tables 15 and 16 show the distribution of vehicle types and ages among the 535 employees in the ecommute program. Table 15 shows that most employees, 67.5%, own light-

[4] 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 distances between zip codes on the Internet.

duty gasoline vehicles. The next highest percentage is midsize trucks, at nearly 18%, followed by full-size trucks (>8,500 pounds), at 7.5%. Table 16 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.[5] According to the Federal Highway Administration (U.S. FHWA 2003), the average car on the road in 2000 was nine years old, nearly four years older than the vehicles owned by participants in the ecommute program. This could be significant. If telecommuters own newer-than-average (and thus cleaner-than-average) vehicles, the emissions benefits of telecommuting may not be that great.

Table 15. Distribution of Types of Vehicles Owned by Employees in the ecommute Program, as of March 1, 2004

Vehicle type	*Percentage of employees enrolled*
Light-duty gasoline vehicles (passenger cars)	67.5
Medium-duty gasoline trucks (6,000–8,500 lbs. gross vehicle weight)	17.8
Heavy-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 (passenger cars)	0.6
Light-duty diesel trucks (<8,500 lbs. gross vehicle weight)	0.6

[5] 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.

Table 16. Distribution of Ages of Vehicles Owned by Employees in the Ecommute Program, as of March 1, 2004

Vehicle model year	*Percentage of enrolled employees*
1984–1989	5.6
1990–1994	15.3
1995–1999	37.8
2000, 2001	27.1
2002, 2003	14.0

To generate specific emissions factors for nitrogen oxides (NO_x) and volatile organic compounds (VOCs) for each city, we use the assumptions employed by local planners. 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 was a summer day in 2005, except that for Denver a winter run was used: 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 he not telecommuted, and (2) whether we assume that there is any change in nonwork 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 the second issue: we simply assume there is no change in nonwork travel as a result of telecommuting. With respect to the first, we show emissions results under two assumptions. In Scenario 1, we assume that everyone who telecommuted would otherwise have driven alone to and from work in the vehicle he reports that he owns. The emissions reduction from telecommuting is then the emissions factor, in grams per mile, multiplied by the reported round-trip commute mileage from home to office.[6] In Scenario 2, we use the information on employees' mode choices to 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

[6] When the employee uses a telework center and reports the distance to the center, we account for that in our mileage calculations. If the distance was unreported, which it was for approximately 50 employees, we multiplied the reported home-to-office distance by the average ratio of the home-to-telecenter distance to home-to-office distance, across employees, to obtain an estimate of the home-to-telecenter distance.

second scenario thus assumes that some of the workers telecommuting would otherwise have used public transit, walked or biked, or ridden in a carpool or vanpool.[7]

Table 17 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 third and fourth 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 its program has fewer employees, and most have been enrolled only a few months. Emissions reductions across all cities since inception of the program through February 2004 total approximately 2 tons each of VOCs and NO_x.

Table 18 provides more information by showing emissions reductions *per telecommuting day*—in other words, the numbers in Table 17 are divided by the total number of days of telecommuting for each city.

Table 17. Total Emissions Reductions from the Ecommute Program, June 1, 2001–February 29, 2004 (in pounds)

	Scenario 1		*Scenario 2*	
	VOCs	*NO_x*	*VOCs*	*NO_x*
Washington, D.C.	260	237	218	203
Denver	2,992	2,319	2,539	1,981
Houston	316	289	228	226
Los Angeles	49	24	39	19
Philadelphia	907	1,055	794	892
ALL CITIES	4,524	3,925	3,818	3,321

[1]Under Scenario 1, it is assumed that employees would have driven alone to work 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.

[7] 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.

Table 18. Emissions Reductions from the Ecommute Program per Telecommuting Day, June 1, 2001–February 29, 2004 (in pounds)

	Scenario 1		*Scenario 2*	
	VOCs	*NO_x*	*VOCs*	*NO_x*
Washington, D.C.	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 are as defined in Table 17.

Some interesting results show up in a comparison of Tables 17 and 18. The emissions reductions in Table 17 are strongly determined by the overall number of participants in the program. Thus, in Scenario 1, the emissions reductions in Philadelphia (92 employees) are more than 18 times the reductions in Los Angeles (31 employees). On a per telecommuting day basis, however, Table 18 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 driven, 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 17) because of the large number of people enrolled, also has the largest reductions on a per telecommuting day basis as well (Table 18), apparently because of emissions factors. The overall average emissions factors for VOCs and NO_x across all five cities are 1.308 g/mi and 1.109 g/mi, respectively, but in Denver, the averages are 1.530 g/mi and 1.242 g/mi, respectively.

In general, a combination of factors comes into play in Tables 17 and 18: 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 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 VOCs and NO_x is reduced per day of teleworking.

We can use these figures in Table 18 to calculate the number of teleworkers needed to achieve a hypothetical annual emissions reduction target from telecommuting. Table 19 shows the results of this calculation, assuming a target of 25 tons of VOCs.[8] Results in the first column are obtained assuming that each worker telecommutes the percentage of days given in Table 11. These percentages range from 17.9% for Houston to more than 50% for Philadelphia, or slightly less than one day per week up to two and one-half 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 the days that she telecommuted (Scenario 1 in Tables 17 and 18).

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 11), or about two and one-half days per week. Denver's number is roughly the same—3,290—but those people would be telecommuting only 38.6% of the time (see Table 11). If we use the overall five-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 11 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.

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

Table 19. Number of Teleworkers Needed to Reduce 25 Tons of VOCs per Year[1]

	Number of teleworkers	
	Assuming % of days spent teleworking from Table 11	*Assuming 35% of days spent teleworking*
Washington, D.C.	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 17) and figures from Table 11 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 19 represent the following percentages of total nonfarm employment: 0.24% in Washington, 0.30% in Denver, 0.50% in Houston, 0.13% in Los Angeles, and 0.14% in Philadelphia.[9] So assuming that each teleworker works at home anywhere from slightly less than one day per week up to two and one-half days per week and assuming the average distances commuted and types of vehicles owned correspond to the figures in Tables 14, 15, and 16—that is, relatively long distances and relatively clean vehicles—between 0.14% and 0.50% of the employed nonfarm workforce in these metro areas must telecommute to generate a 25-ton-per-year reduction in VOCs.

VI. Conclusions

The ecommute program provides an interesting dataset on teleworking because vehicles, commute patterns, and mode choices are directly linked to the individual employee; it is not necessary to rely on default average emissions factors and distances. Moreover, because

[9] Customized table on total nonfarm employment created on BLS Website. See http://www.bls.gov/sae/home.htm.

telecommuting behavior in the program has been monitored over time, this is one of the few datasets that tracks employees weekly rather than asking them a question in a survey once a year. This paper provides the first analysis of results from the program.

We discovered that although employees are tracked over time, many drop out or have reporting gaps, and thus the data are not as complete as one would like. In addition, although participants in some of the cities have been enrolled for more than a year, other cities have only recently become active in signing up companies and their workers. So Denver, for example, has hundreds of employees who have been reporting for a significant length of time, but most participants in Los Angeles have been reporting for only a few months, at the longest.

Nonetheless, we are able to summarize several aspects of the program, including how much participants have telecommuted, what transportation modes they use to get to work, what days of the week they have telecommuted, how far they travel to and from work, what types of vehicles they own, and finally, what reductions in total VOC and NO_x emissions can be attributed to the program. Although total emissions reductions are relatively modest—Denver, which has by far the most telecommuters of the five cities, prevented only one to 1.5 tons of VOCs and NO_x between June 2001 and March 2004—the potential of the program may be much greater. We calculate that 25 tons per year of VOCs (and nearly as much NO_x) could be reduced in each city without enormous increases in the number of workers who telecommute. Less than 1% of the workforce working at home one to two days per week would roughly accomplish this goal.

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