Using Performance Metrics to Quantify Energy Savings and Emissions Reductions for the U.S. Department of Energy's State Energy Program

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ABSTRACT

As part of an effort to quantify the effects of the U.S. Department of Energy's State Energy Program (SEP), staff at Oak Ridge National Laboratory (ORNL) developed a set of metrics to describe key activities within 20 distinct program areas. All states, territories, and the District of Columbia were contacted in late 2001 and asked to provide data on their SEP activities, and 20 states—representing half of the entire U.S. population—responded by August 31, 2002.

Using the best of the available recent literature and drawing on their own previous research on SEP metrics, ORNL staff developed per-unit energy-savings estimates for at least one metric in each of 14 program areas. Those savings coefficients were multiplied by state-provided information on the number of activities undertaken to calculate energy savings. Estimates of cost savings and emissions reductions were then generated from the savings numbers.

Approximately 85 percent of the total energy savings occurred in five program areas: Codes and Standards, Energy Audits, Rating and Labeling, Workshops and Training, and Incentives. Nearly all of the remaining energy savings came from the next three highest-saving program areas: Retrofits, Loans and Grants, and Technical Assistance. In all 14 program areas for which outcomes could be quantified, annual energy and cost savings for the responding states were estimated to be nearly 19,000,000 million source BTUs and $117 million, respectively. Carbon emissions were reduced by nearly 328,000 metric tons, and five other measured pollutants were also reduced by significant amounts.

Extrapolations to the entire nation—based on the proportion of total SEP funding represented by the responding states—show estimated annual energy and cost savings of over 41,000,000 million source BTUs and $256 million, respectively, and carbon emissions of nearly 720,000 metric tons.

Background

The U.S. Department of Energy's State Energy Program (SEP) was established in 1996 by merging two long-standing programs, the State Energy Conservation Program (SECP) and the Institutional Conservation Program (ICP), both of which had been in existence since 1976 (U.S. Department of Energy 2001a). The SEP provides financial and technical assistance for a wide variety of energy efficiency and renewable energy activities undertaken by the states, and the resources provided by the Department of Energy typically are augmented by money and in-kind assistance from a number of sources, including other federal agencies, state government, and the private sector. The states' SEP efforts include a number of mandatory activities, such as the establishment of lighting efficiency standards for public buildings, as well as a broad range of optional activities, such as the provision of energy audits and the development of integrated energy plans.

As part of an effort to produce metrics for quantifying the effects of the SEP, staff at Oak Ridge National Laboratory (ORNL) developed a classification scheme for describing the various state activities

supported by SEP funds. This involved identifying a number of distinct program areas into which all of the various state SEP activities could be placed. Originally, 21 program areas were identified but one—Low-Income Weatherization—was dropped because no SEP funds were directly used to support those efforts. The 20 remaining program areas are as follows: (1) Information Inquiries; (2) Mass Media; (3) School Education Programs; (4) Workshops/Training; (5) Retrofits; (6) Energy Audits; (7) Procurement of Energy-Efficient Products; (8) Technical Assistance; (9) Loans and Grants; (10) Codes and Standards; (11) Rating and Labeling; (12) Home Energy Rating Systems (HERS) and Energy-Efficiency Mortgages (EEMs); (13) Incentives; (14) Interest Subsidies; (15) Alternative Fuels; (16) Planning; (17) Tax Credits; (18) Traffic Signals and Controls; (19) Research, Development, Demonstration, and Deployment (RDD&D); and (20) Carpools/Vanpools.

A set of performance indicators (called "enumeration indicators" in the ORNL study) was developed to describe key activities within each of the 20 program areas (Schweitzer et al. 2002). In the terminology of the Government Performance and Results Act (GPRA), these indicators describe program "outputs," or key actions taken (e.g., number of energy audits performed, number of buildings retrofit), rather than "outcomes," which are the ultimate program results (e.g., energy and cost savings).

All together, ORNL developed nearly 80 enumeration indicators to describe state activities performed under the SEP. For nearly all of the 20 program areas, state activities are described by between two and four indicators each. For example, the performance indicators for the Workshops/Training program area are the number of workshops and training sessions developed, number of workshops and training sessions presented, and number of persons attending those sessions, all disaggregated by energy-consuming sector. For Retrofits, the indicators are the number of buildings retrofit, number of buildings receiving various types of measures, and building square footage, all reported by building type. Each set of indicators presents a complete picture of the important activities performed within its program area.

The enumeration indicators were developed to provide a uniform and systematic way for describing and measuring the broad range of SEP-supported activities undertaken by the various states and territories. This activity-based approach focuses on important program outputs and provides a detailed and comprehensive picture of what the SEP has accomplished in any given time period. It goes beyond a general description of the broad functional areas and energy-consuming sectors addressed to describe, in substantial detail, the specific actions that are taken by the states.

Data Collection

ORNL staff prepared a set of electronic spreadsheets containing all the enumeration indicators developed for each of the program areas and presenting blank spaces in which representatives of the states could indicate the number of SEP-supported activities of each type in which they had engaged in their most recent completed program year. In early October of 2001, National Association of State Energy Officials (NASEO) staff contacted the appropriate people in the states, territories, and District of Columbia, and asked them to fill in the spreadsheets, which were posted on the NASEO website (NASEO 2001), and return the completed materials to NASEO.

Between late November 2001 and the end of August 2002, twenty states provided the requested enumeration indicator data for their most recent completed program year. As shown in Figure 1, these states are spread across the entire United States, both from east to west and from north to south. They include the three most populous states in the nation (California, Texas, and New York) as well as the least populous state (Wyoming). Together, they represent 45.6% of all funds allocated by SEP in Fiscal Year 2000 (from formula grants *and* special project awards) and 49.6% of the entire U.S. population. As a group, the respondents do a good job of representing the diversity of SEP activities and performance found nationwide.

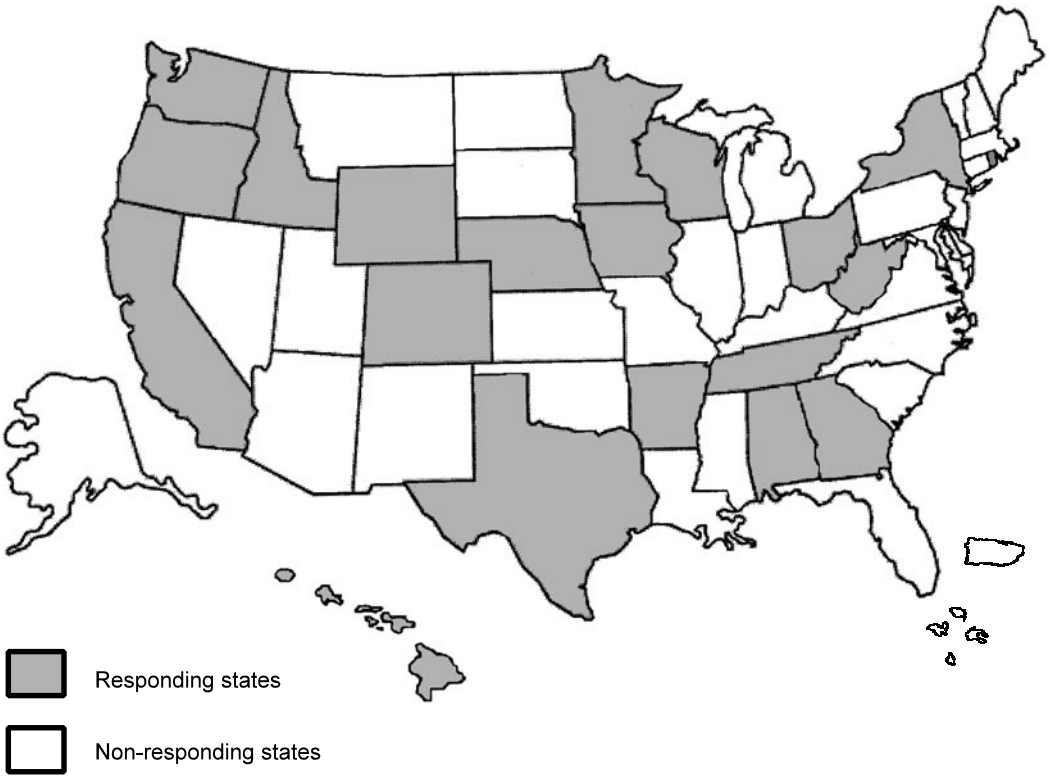

Figure 1. States providing enumeration indicators data.

Calculating Savings and Emissions Reductions

Energy and Cost Savings

Although the enumeration indicators developed by ORNL originally were intended to count program "outputs," they also can be used as a basis for estimating "outcomes" (Schweitzer et al. 2003). State-provided information on the number of activities undertaken can be multiplied by estimates of the amount of energy saved per activity, and the product will approximate energy savings. For example, if a state provides counts of the number of people attending workshops and training sessions and a coefficient is developed for average energy savings achieved per workshop participant, multiplying the first number by the second one will yield estimated energy savings within the Workshops/Training program area for that state. The energy-savings numbers calculated in this manner for each state can be summed to get estimated total savings for all responding states. Those estimates of energy savings, in turn, can be multiplied by the average cost of energy for all energy-consuming sectors nationwide to give estimated cost savings[1].

[1] Based on 2000 energy prices, the average cost of one million source BTUs of natural gas in all energy-consuming sectors was approximately $6.28 and the average cost of one million source BTUs of electricity was $6.14. Accordingly, $6.20 per million source BTUs was used as an approximation of the cost of fuel of all types in all sectors.

During the Fall of 2001, while state energy officials began to fill in the spreadsheets with information about their SEP activities, ORNL staff developed estimates of per-unit energy savings for key activities in the various program areas[2]. The information for that endeavor came from recent evaluations focusing on the effects of various state energy efficiency and renewable energy programs. A number of reports and articles published in journals and conference proceedings were reviewed (e.g., Abraham & MacDonald 1995; Coates 1995; Greely, Harris & Hatcher 1990; Haberl et al. 2000; Lew & Wang 1998; Nadel & Goldstein 1996; Webber, Brown & Koomey 2000), and findings were extracted from those that were relevant to this study and employed rigorous and well-accepted research methods. Drawing from the best of the available data and their own previous research on SEP metrics, ORNL staff developed per-unit energy-savings estimates for at least one performance indicator in each of 14 program areas[3]. The program areas covered and the specific performance indicators for which savings coefficients were developed are shown in Table 1.

In most program areas, energy savings coefficients were developed for only a single performance indicator but, in a few cases, we developed coefficients for more than one indicator. In one instance, the different per-unit savings estimates applied to mutually exclusive activities, so the savings calculated by using both of them were summed to get total savings for the entire program area. However, in the other two cases where multiple coefficients were developed, only one of those multipliers was used for each state, to avoid double-counting savings related to the reported activities. In the Energy Audits area, for example, state-provided projections of energy savings (adjusted downward to account for installation and realization rates) were used if available. Otherwise, the floor space audited served as the basis for our savings calculation. If data were provided for neither of those indicators, we calculated savings from the number of buildings retrofit.

For each performance indicator, we typically developed different savings coefficients for the various end-use sectors[4]. The Retrofits program area provides a good example of how savings coefficients were developed. In that case, we produced energy-savings estimates for the residential, commercial, education, hospital, and industrial sectors. For the commercial sector, we developed a coefficient for energy savings per building retrofit based on information provided by the *1999 Commercial Building Energy Consumption Survey* (U.S. Department of Energy 2002) on the average annual energy use of commercial buildings (2574.0 million source BTUs). From two extensive studies of retrofit projects in commercial buildings (Greely, Harris & Hatcher.1990; Coates 1995), we took the average retrofit-generated savings figure of 18.8 percent.

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[2] Energy savings were expressed in terms of millions of British Thermal Units (BTUs), regardless of the fuel involved, to allow the combination of savings by different fuel types. Where the fuel in question was electricity, kilowatt hours were converted to *source BTUs* (i.e., the amount of energy required at the power plant to produce a specified amount of usable energy), using the formula: one kWh = 0.010883 million source BTUs. If electricity savings were expressed in site BTUs, they were converted to source BTUs by multiplying by 3.189. Source BTUs were used as the common unit of measurement to reflect the *total* amount of energy saved.

[3] Several of the energy-savings coefficients were later refined based on reviewers' comments on a draft report documenting the findings of the ORNL study. In six of the 20 program areas, energy-savings coefficients were not developed at all, either because insufficient data were available, the indicators did not lend themselves to the estimation of savings, or—in the case of Alternative Fuels—the program area's efforts were not primarily designed to save energy.

[4] In some program areas, coefficients could not be developed for one or more energy-consuming sectors, resulting in incomplete estimates of savings for those areas.

Table 1. Performance indicators for which per-unit savings coefficients were developed

Program area		Performance indicator
• Workshops/Training	1.	Number of people attending workshops, by sector
• Retrofits	1.	Number of buildings retrofit, by sector
	2.	Floor space of buildings retrofit, by sector
• Energy Audits	1.	Number of audits performed, by sector
	2.	Floor space audited, by sector
	3.	Projected energy savings, by sector
• Procurement of Energy-Efficient Products	1.	Number of units purchased, by type
• Technical Assistance	1.	Number of recommendations made for energy-efficiency measures or strategies, by sector
• Loans and Grants	1.	Monetary value of loans given, by sector
	2.	Monetary value of grants given, by sector
• Codes and Standards	1.	Number of energy-consuming systems or technologies for which codes and standards are adopted at state or local level, by sector
• Rating and Labeling	1.	Number of energy-consuming devices for which rating and labeling systems are endorsed by the state
• HERS and EEMs	1.	Number of Energy Efficiency Mortgages issued in conjunction with a Home Energy Rating System
• Incentives	1.	Monetary value of rebates provided, by sector
• Interest Subsidies	1.	Monetary value of interest subsidies provided, by sector
• Tax Credits	1.	Monetary value of tax credits given, by sector
• Traffic Signals and Controls	1.	Number of energy-efficient traffic signals and controls installed
• Carpools/Vanpools	1.	Number of new carpools/vanpools formed

The product of the energy use and savings figures yields a coefficient of 483.9 million source BTUs of energy savings per commercial retrofit project. To calculate average savings per square foot of commercial retrofit (the other savings coefficient developed for this program area), we divided the whole-building energy savings (483.9 million source BTUs) by the average building size shown in the above-mentioned CBECS survey (14,500 square feet) to obtain a coefficient value of 0.033 million source BTUs per square foot. Similar methods were used to develop savings coefficients for the other energy-consuming sectors affected by Retrofits programs.

An effort was made to keep the energy-savings coefficients conservative by adjusting them downward to account for factors such as installation, savings-realization, and compliance rates, where appropriate. For example, where the states provided their own estimates of audit-generated energy savings, those numbers were adjusted downward to reflect the expectation that only half of the recommended measures would be installed and that only a portion of the projected savings (60 percent in the residential sector and 90 percent elsewhere) actually would be realized by the measures taken. Based on those

expectations, state-projected savings were multiplied by adjustment factors of 0.3 in the residential sector and 0.45 in all other sectors.

In the 14 program areas where energy savings could be quantified, the individual savings estimates generally were taken from a limited number of studies and are applied broadly to the entire SEP. Accordingly, they must be recognized as approximations of actual savings. Despite this, the ORNL study represents the most comprehensive and rigorous evaluation of the SEP performed to date, and the savings numbers presented here are valid estimates of program accomplishments.

Emissions Reductions

Emissions reductions were calculated directly from the energy-savings estimates discussed above. Essentially, the amount of savings achieved by each state within each program area was multiplied by coefficients representing average emissions per million source BTUs for that program area for six different emissions types: Carbon; Nitrogen Oxide (NO_x); Sulphur Dioxide (SO_2); Volatile Organic Compounds (VOCs); Carbon Monoxide (CO); and Fine Particulate Matter (PM10). Where emissions coefficients varied for different energy-consuming sectors within a given program area, the individual coefficients were multiplied by the energy savings achieved within the appropriate sectors and those products were summed to get total emissions reductions for the entire program area for each responding state. The emissions reductions of each type achieved by the various states in each program area were summed to get estimated total emissions reductions for all respondents.

To perform the calculations described above, coefficients had to be developed to represent average emissions per million source BTUs for each emissions type within each program area or relevant energy-consuming sector. The first step in accomplishing that was to obtain data on the average amount of various emissions associated with the consumption of five different fuel types: electricity; natural gas; fuel oil; coal; and gasoline (U.S. Department of Energy 2001b). Then, from the same sources used to develop per-unit energy-savings estimates, we obtained estimates of the fuel mix for each program area and, where relevant, for specific energy-consuming sectors within the broader area. For each program area or relevant energy-consuming sector, the portion of total energy usage accounted for by each fuel was multiplied by the amount of emissions per million BTUs for that fuel and the products were summed for all fuels involved to yield a weighted emissions coefficient. This was done separately for each of the six emissions types.

Savings and Emissions Reductions by Responding States

Outcomes by Program Area

The estimated energy and cost savings achieved by each of the 14 program areas for which savings could be calculated are presented in Table 2. Codes and Standards activities accounted for approximately one-third of the total energy savings. The magnitude of these savings is partly due to the fact that there was intensive code activity in the high population states of California, Texas, and New York, where a very large number of buildings would be affected by the energy-efficient codes and standards enacted. In general, Codes and Standards activities can be expected to save energy cost-effectively, especially in areas with substantial building activity, because the adoption of codes and standards is relatively inexpensive while the results, which typically apply to entire states, are wide-reaching.

Table 2. Estimated annual energy and cost savings, by program area

Program area	Estimated annual energy savings (million source BTUs)	Estimated annual cost savings ($)	Estimated energy savings as percent of total savings in all program areas (%)
Codes and Standards	6,396,625	39,659,074	33.91
Energy Audits	3,354,427	20,797,448	17.79
Rating and Labeling	2,466,907	15,294,823	13.08
Workshops/Training	2,069,284	12,829,559	10.97
Incentives	1,815,481	11,255,984	9.63
Retrofits	970,465	6,016,901	5.15
Loans and Grants	860,693	5,336,295	4.56
Technical Assistance	580,422	3,598,618	3.08
Traffic Signals	196,053	1,215,529	1.04
Tax Credits	78,507	486,744	0.42
Procurement	49,867	309,173	0.26
Carpools/Vanpools	19,143	118,686	0.10
Interest Subsidies	1,291	8,007	0.01
HERS and EEMs	301	1,865	0.002
Total	18,859,466	116,928,706	100.00

The estimated amount of energy saved by Energy Audits also was large (nearly 18% of total energy savings). According to the responding states, most of those savings occurred in the institutional sector (i.e., government buildings, schools, and hospitals). The Energy Audits savings number is based largely on state projections of how much energy would be saved as a result of the audits that were performed. It makes sense that audits would achieve relatively high savings per dollar spent because, in most cases, the program pays only for the audit itself and not for the actual energy efficiency improvements made as a result of the audit recommendations.

Substantial savings also were achieved in the areas of Rating and Labeling, Workshops and Training, and Incentives. In each of those program areas, the amount of energy saved relative to the magnitude of funding is high because the program does not pay the full cost of the energy-saving actions that ultimately are taken. These three program areas, in conjunction with Codes and Standards and Energy Audits, account for approximately 85 percent of the savings achieved in all areas combined. When the next three highest-saving program areas—Retrofits, Loans and Grants, and Technical Assistance—are added, cumulative savings amount to 98 percent of the total.

The lowest amount of energy savings occurred in the areas of Traffic Signals, Tax Credits, Procurement, Carpools/Vanpools, Interest Subsidies, and HERS/EEMs. In all cases, activities in these program areas were undertaken by less (often much less) than one-third of the responding states, and the amount of SEP funding allocated to them was relatively small.

Emissions reductions are based directly on the energy savings described above. Accordingly, the rank order of the program areas, and the relative magnitude of the outcomes achieved in each one, are the same for emissions reductions (Table 3) as for energy savings (Table 2).

Total Outcomes for All Program Areas Combined

As shown at the bottom of Table 2, annual energy savings totaled nearly 19,000,000 million source BTUs for all 14 program areas for which outcomes could be quantified. For those same program areas, estimated annual cost savings amounted to almost $117 million. It is important to note that actual energy and cost savings are likely to be higher than those reported here, because savings were not calculated for six of the 20 program areas[5]. Also, the annual savings described here are likely to continue over time, because the effects of the SEP-supported energy-saving measures tend to last for many years.

As shown at the bottom of Table 3, it is estimated that carbon emissions were reduced by nearly 328,000 metric tons annually in those 14 program areas where energy savings could be quantified. The magnitude of emissions reductions was also significant for the other substances studied. SO_2 emissions were reduced by nearly 3,500 metric tons per year; NO_x emissions were reduced by over 2,600 metric tons; and annual CO reductions totaled nearly 450 metric tons.

It is important to note that the estimates of cost savings presented in this document do not include the monetized value of emissions reductions nor of any other non-energy benefits (e.g., social, economic, national security) associated with program activities. If the full monetary value of those benefits were quantified, total savings attributed to the SEP would probably be considerably greater than indicated here.

Extrapolation of Findings to State Energy Program Nationwide

The savings and emissions reductions estimates for the responding states can be extrapolated to the nation as a whole based on the proportion of *total* SEP funding represented by the responding states[6]. Since the 20 responding states combined receive 45.6% of total SEP funding, multiplying energy and cost savings for this group by an adjustment factor of 2.19298 (the inverse of 0.456) gives an approximation of what the numbers would be if *all* states had provided information on their SEP activities. Using this adjustment factor to extrapolate the findings to the entire United States yields imperfect results because it rests on the assumption that the non-responding states would achieve the same amount of energy savings per dollar of SEP funding as did the responding states. Despite the fact that the non-responding states are likely to differ somewhat from the responding states in the overall cost-effectiveness of their programs, the above-described method provides a defensible approximation of nationwide outcomes in all program areas combined. However, because the mix of SEP activities tends to vary substantially from state to state, we did not feel comfortable extrapolating results to the entire nation for each individual program area.

[5] The six program areas for which savings were not quantified received a little more than one-third of the total funding (SEP plus non-SEP) that went to the responding states.

[6] Data on each state's Fiscal Year 2000 SEP funding was taken from the WINSaga data base.

Table 3. Annual emissions reductions, by program area

Program area	Carbon*	Nitrogen Oxide (NO_x)*	Sulphur Dioxide (SO_2)*	Volatile Organic Compounds (VOCs)*	Carbon Monoxide (CO)*	Fine Particulate Matter (PM10)*
Codes and Standards	109,720.2	862.2	1130.2	19.9	151.9	20.5
Energy Audits	57,682.2	460.4	569.9	10.2	79.9	11.0
Rating and Labeling	43,985.0	360.2	483.5	7.4	56.7	9.9
Workshop/Training	36,543.2	289.9	449.9	6.6	46.8	8.0
Incentives	32,370.0	265.1	355.8	5.4	41.8	7.3
Retrofits	16,663.2	131.6	172.0	3.0	22.9	3.2
Loans and Grants	14,904.1	119.8	149.0	2.6	20.4	2.9
Technical Assistance	9,993.8	78.5	108.4	1.8	13.6	1.9
Traffic Signals	3,495.6	28.6	38.4	0.6	4.5	0.8
Tax Credits	1,372.6	11.1	14.0	0.2	1.8	0.3
Procurement	854.2	6.7	9.5	0.2	1.2	0.2
Carpools/Vanpools	367.0	2.7	10.1	0.08	0.2	0.1
Interest Subsidies	22.6	0.2	0.2	0.004	0.03	0.005
HERS and EEMS	5.1	0.04	0.05	0.0009	0.007	0.001
Total	327,978.8	2,617.0	3,491.0	58.0	441.7	66.1

*All emissions are given in metric tons.

Table 4 shows that, based on the savings estimates generated for the responding states and the adjustment procedure described above, estimated annual energy and cost savings for the nation as a whole would be 41,358,478 million source BTUs and $256,422,600, respectively.

Table 4. Total annual savings and emissions reductions for responding states and entire nation

	Total for responding states	Extrapolated total for nation*
Estimated annual energy savings (million source BTUs)	18,859,466	41,358,478
Estimated annual cost savings ($)	116,928,706	256,422,600
Estimated annual carbon reduction (metric tons)	327,978.8	719,251.8
Estimated annual NO_x reduction (metric tons)	2,617.0	5,739.0
Estimated annual SO_2 reduction (metric tons)	3,491.0	7,655.7
Estimated annual VOCs reduction (metric tons)	58.0	127.2
Estimated annual CO reduction (metric tons)	441.7	968.7
Estimated annual PM10 reduction (metric tons)	66.1	144.8

*Extrapolated to entire U.S. using adjustment factor of 2.19298 (the inverse of 0.456, which is the proportion of total SEP funding received by responding states).

Table 4 also shows extrapolated emissions reductions for the entire nation based on information provided by the 20 responding states. Using the extrapolation method described above, carbon emissions would be reduced by nearly 720,000 metric tons; SO_2 emissions would shrink by more than 7,600 metric tons; NO_x emissions would fall by over 5,700 metric tons; and CO emissions would be reduced by nearly 1,000 metric tons. VOCs and PM10 reductions would be less, by weight, but still substantial.

Conclusions

As pointed out previously, the individual savings estimates that formed the basis of our calculations generally were taken from a limited number of studies and, accordingly, must be treated as approximations when applied to SEP as a whole. In order to improve current savings estimates, and generate new ones where none currently exist, additional evaluations of various SEP activities that quantify the resulting savings are needed. Still, the estimates of energy and cost savings and emissions reductions presented here provide useful and valid information on what the State Energy Program has accomplished in its most recent year of operation.

It is important to remember that the estimates given here are based on detailed descriptions of SEP activities provided by the largest states in the nation and a number of smaller ones, representing every major geographic region of the United States. The large savings and emissions reductions numbers, while not precise, indicate that the SEP is operating effectively and is having a substantial positive impact on the nation's energy situation and its natural environment.

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