EMISSION IMPACTS OF DEMAND-SIDE PROGRAMS: WHAT HAVE WE ACHIEVED SO FAR AND HOW WILL RECENT POLICY DECISION CHANGE PROGRAM CHOICES?

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Congress and many state legislatures have been discussing the possibility of regulating carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), chlorofluorocarbons (CFC's) and other emissions. Key to these discussions is the recommendation that energy efficiency, and specifically electric utility demand-side management (DSM) programs, be used as an emission control option. Methods for incorporating the social or external costs of energy production into utility planning are being developed, and estimates of potential emission impacts attributed to DSM programs have been calculated. However, little research has calculated the actual emission impacts from existing DSM programs.

The increasing need for electric energy services and fossil fuel generation create an apparent conflict with the risks and regulations associated with global climate change and clean air. Electric utility DSM programs can be used to resolve these conflicts by providing equal or better energy services and a net reduction in emissions.

This paper summarizes three separate related research projects. The first study, "Impacts of Electric Utility Demand-Side Management Programs on Power Plant Emissions," (Felix et al. 1990 - draft) collects utility and state data on existing DSM programs to approximate the level of SO_2, NO_x, and CO_2 reductions on a regional and national basis. Phase I of this study is a completed survey of DSM savings by state. This data is reported here.

The second and third studies, "Carbon Dioxide Reduction Through Electrification of the Industrial and Transportation Sectors," (Geba et al. 1989) and "Carbon Dioxide Reduction Through Electrification of the Residential and Commercial Sectors (Geba et al. 1990 - draft), compare selected high efficiency electric technologies with fossil-fueled alternatives to determine CO_2 emissions. Through these studies, we have begun to quantify the emissions impacts from utility DSM programs and efficient electric equipment.

INTRODUCTION

Electric utility demand-side management (DSM) programs have been actively pursued by electric utilities nationwide, primarily for capacity and energy savings and their ability to satisfy customer needs while reducing customer costs. Many additional benefits, such as emissions reductions, have accrued through these present efforts, but little has been done on a nationwide basis to evaluate and quantify these benefits, although several studies have quantified the *potential* impact of *possible* DSM program impacts on acid rain by selected region (Centolella et al. 1988; Geller et al. 1987; Nixon and Neme 1989) and on a national basis (Chupka et al. 1989).

Additionally, several studies have been completed which estimate the national energy and capacity impacts of utility programs that promote efficient electricity use by both surveys (Cogan and Williams 1987) and computer modeling (Keelin and Gellings 1986; Scheer 1990; Carlsmith et al. 1990; Faruqui et al. 1990 - draft). However, if energy efficiency is to be considered as an option for reducing emissions, public utility commissions and utilities must develop methods for incorporating environmental benefits and costs of DSM into strategic planning decisions. Studies are necessary to answer a number questions on performance, financial and environmental impacts, and potential accomplishments in improving efficiencies and reducing emissions.

We have recently completed two studies, (Geba et al. 1989; Geba et al. 1990 - draft) with an additional study underway, (Felix et al. 1990 - draft) that begins to develop preliminary information on how existing DSM programs have affected power plant emissions and how selected substitution of efficient electric technologies can reduce CO_2.

STEPS TOWARD ESTIMATING THE IMPACTS OF ELECTRIC UTILITY DEMAND-SIDE MANAGEMENT PROGRAMS ON POWER PLANT EMISSIONS

Electric utility promotion of energy-efficient end-use technologies is routinely recommended by federal and state policy makers, utilities, and environmentalists as the primary tool for controlling emissions. However, very little is known about the actual impacts that these programs have in comparison with traditional clean air technologies, such as scrubbers. DSM programs have been implemented for some or all of the following reasons--DSM programs: satisfy customer needs, increase revenues and/or profitability, improve market share, defer capacity additions, and promote the more efficient use of existing capacity. These objectives may or may not be consistent with controlling emissions. This determination requires a systematic evaluation of energy and capacity impacts and fuel mixes.

Background

Over the past twenty-five years, electric utilities have helped customers become more energy efficient. Through information and education programs, financial incentives, energy audits, research and development, innovative partnerships among utilities, customers, and state agencies, electric utilities have accumulated numerous success stories. Today, all utilities combined have sponsored over 1,300 energy efficiency programs in their service territories, up from about 130 in 1977. Customers have more opportunities than ever to collaborate with their local utilities to obtain greater electric value through enhanced efficiency.

These programs involve over 13 million customers and have resulted in over $21 billion in savings since 1977 in avoided power plant construction costs. (Faruqui et al. 1986) In 1988, electric utilities spent over $1 billion dollars on efficiency programs and this amount continues to rise (Felix et al. 1990 - draft).

Methodology

In order to attempt to quantify air emissions benefits of DSM, significant quantities of data were gathered, and analyzed. The following is a simplified description of the process. The process started with the collection of utility DSM impacts from various sources: utilities, power pools, public utility commissions, and other state and federal agencies. DSM data was gathered by a combination of mail and telephone surveys from utilities and the above sources. A mail survey instrument and telephone script were developed to ascertain actual DSM efforts over a two year period ending in 1989, and to project efforts for 1990. To date, only the 1988 data has been analyzed. Several types of reference data were also requested to allow cross-verification of reported data with other utilities and sources. Follow-up calls were made to both responding and non-responding utilities and the other above sources in order to reduce biases and obtain the best possible data set. This data was aggregated state-by-state using statistical methods and some engineering judgement to estimate kilowatts reduced, kilowatt-hours saved, and costs incurred.

Most data reported are engineering estimates of real program savings as opposed to actual measured savings. There is currently little data on actual measured savings. Also, the focus of utilities and public utility commissions has been on capacity savings. As such, capacity estimates are more readily available and reported, as opposed to energy savings. We have tried to present non-cumulative data for a one year period, even though the survey was more expansive. Therefore, the capacity savings are additive and can be assumed to reduce forecasted demand. Energy savings are assumed to be annual savings in 1988, and are presumed to be on-going over the life of the equipment or program.

Next, a set of state-by-state generation profiles and fuel mixes were used to provide an estimate of the fuel displaced based on DSM savings. Other factors, such as estimated DSM program load profiles and estimated dispatch order were also integrated into the analysis. A detailed state-by-state dispatch model was not developed, as the preliminary review of the DSM data does not support this level of fuel dispatch accuracy.

The environmental emissions, CO_2, SO_2, and NO_x, will be calculated and presented in a later paper (Felix et al. 1990 - draft) by assuming heat rates and pounds of emissions per BTU input for each of the fuels displaced. The result will be a state-by-state preliminary estimate of the emissions reduced by DSM measures. The current results are presented below.

Summary of Results

The results of this major survey effort was to collect data on the capacity (kilowatts - summer and winter), and energy (kilowatt-hours) saved by end-use energy efficiency. Table 1 shows the results. The estimated summer capacity saved was over 8,100,000 kilowatts, winter capacity saved was over 5,200,000 kilowatts, and energy saved was over 8.9 billion kilowatt-hours. The utility-only investment cost was estimated as 1.283 billion dollars in 1988. This data should be viewed as a ball-park estimate of savings.

There are an enormous number of factors influencing the data. A few of these include: a lack of standardized reporting, measurement is just beginning, determination of the specific causes of action is difficult, etc. Nevertheless, this represents the first attempt to obtain field data by utility and state. The data appears to be more accurate for capacity than for energy based on the stronger focus of both utility management and public utility commissions to avoid constructing new generation. We expect this focus to broaden to provide better energy savings data in 1990 relative to fuel type displaced and load modified. Further, as DSM reduces energy generated and capacity factor, this will further reduce emissions. The importance of measuring emission reduction has significantly increased. Improvements are needed in measuring the energy impacts of DSM programs and significant efforts are underway to improve monitoring and evaluation.

The investor-owned utility direct mail survey resulted in obtaining data on DSM for over 50 percent of investor-owned utility kilowatt-hour sales. This is a little under 40 percent of the U.S. total kilowatt-hour sales. Public utility commissions, public power and power pool direct telephone contact brought the total survey coverage to approximately 50 percent of U.S. kilowatt-hour sales. This permitted statistical extrapolation of the DSM savings to 87 percent of the U.S. kilowatt-hour sales. Extrapolation of the sample to national estimates was based on a combination of subjective data received from interviews with public utility commissions regarding the level of effort within a state and the national pool of data. States were stratified as having a low, medium, or high level of DSM program development. Strata were also developed from the national pool and these estimates were applied using the closest proxy in terms of geography and peak characteristics. The remaining 13 percent was estimated by the existing data pool, interviews with utility commission staff, and engineering judgement.

Table 1. Summary of Demand-Side Management Savings by State in 1988

State	Capacity Savings		Energy Savings (MWH)	Dollars (millions)	Savings as a Percent of	
	Summer Peak (MW)	Winter Peak (MW)			Capacity	Sales
Alabama	210.2		261,715	8.5	1.1	0.5
Alaska		17.5	7,420	2.0	1.0	0.2
Arizona	472.6		21,102	2.3	3.0	0.1
Arkansas	99.5		48,566	10.0	1.0	0.2
California	2,776.6		731,834	360.3	6.0	0.4
Colorado	280.8		99,576	12.0	3.9	0.3
Connecticut	157.0		449,772	17.0	2.1	1.6
District of Columbia	19.3		14,262	2.0	1.0	0.2
Delaware	8.8		17,919	1.0	1.0	0.2
Florida		1,741.0	2,294,000	114.0	4.8	1.8
Georgia	442.9		283,365	42.0	2.0	0.4
Hawaii	30.6		29,491	3.0	2.0	0.4
Idaho	21.3		32,552	2.0	1.0	0.2
Illinois	375.5		209,355	36.0	1.0	0.2
Indiana	47.9		11,506	3.8	0.2	0.0
Iowa	239.3		89,906	21.7	2.8	0.3
Kansas		5.0	1,834	2.2	0.0	0.0
Kentucky		338.2	206,234	32.0	2.0	0.4
Louisiana	185.6		112,772	18.0	1.0	0.2
Maine	22.0		168,745	10.0	0.9	1.5
Maryland	106.1		90,784	10.0	1.0	0.2
Massachusetts	135.9		287,207	19.0	1.4	0.6
Michigan	35.2		19,816	13.6	0.1	0.0
Minnesota	26.6		97,872	10.0	0.3	0.2
Mississippi	72.9		54,050	7.0	1.0	0.2
Missouri	236.9		26,420	23.0	1.4	0.1

Table 1. (contd)

State	Capacity Savings		Energy Savings (MWH)	Dollars (millions)	Savings as a Percent of	
	Summer Peak (MW)	Winter Peak (MW)			Capacity	Sales
Montana		100.6	48,128	10.0	2.0	0.4
Nebraska	58.4		32,535	6.0	1.0	0.2
Nevada		31.0	22,555	1.7	0.6	0.2
New Hampshire		7.0	(8670)	2.0	0.5	NA
New Jersey	276.8		165,180	35.2	1.9	0.3
New Mexico	57.0		24,158	5.0	1.0	0.2
New York	267.8		115,361	63.1	0.8	0.1
North Carolina	266.8		237,377	38.6	1.3	0.3
North Dakota		47.7	12,673	5.0	1.0	0.2
Ohio		1,282.2	18,185	15.4	4.6	0.0
Oklahoma	387.4		7,452	7.3	2.9	0.0
Oregon		21.7	16,936		0.2	0.0
Pennsylvania		749.2	846,301	0.4	2.1	0.8
Rhode Island	30.0		20,021	42.5	11.0	0.3
South Carolina		165.7	100,601	4.9	1.0	0.2
South Dakota		1.8	1,407	16.0	0.1	0.0
Tennesee		371.0	276,075	0.3	2.0	0.4
Texas	349.3		672,411	36.0	0.6	0.3
Utah		53.2	28,540	28.0	1.0	0.2
Vermont		13.0	666	5.0	1.2	0.0
Virginia	237.7		106,293	3.0	1.7	0.2
Washington		189.9	148,478	5.7	0.8	0.2
West Virginia		43.4	19,724	49.9	0.3	0.1
Wisconsin	230.8		333,321	1.1	2.1	0.7
Wyoming		59.6	21,149	114.9	1.0	0.2
				6.0		
Country Totals	8,165.6	5,238.6	8,934,932	1,283	1.9	0.3

Source: *Felix, Curtis S., et al., Environmental Benefits of National Demand-Side Management Program Implementation, Energy Research Group, Inc., prepared for Edison Electric Institute, Washington, D.C., 1990 (draft).*

CARBON DIOXIDE REDUCTION THROUGH ELECTRIFICATION

The electric utility industry is perceived to be the largest potential generator of global warming gases in the United States.[1] This perception has lead to the assumption that increasing electricity consumption cannot reduce CO_2. However, recent research indicates that in selected applications this assumption is incorrect. (Geba et al. 1989; Geba et al. 1990) In fact, the use of highly efficient electric technologies in several traditionally fossil-fueled applications has the potential to significantly reduce CO_2 emissions.

Background

CO_2 is produced when fossil fuels are burned for electricity generation, and for transportation, residential and commercial, and manufacturing purposes and is estimated to represent approximately 50 percent of the gases contributing to potential global warming trends. Other major gases identified as contributing to global warming include chlorofluorocarbons, methane, and nitrous oxide. According to the United States Department of Energy (DOE), the electric utility industry emits approximately 35 percent of the total man-made CO_2 generated in the country. The transportation sector produces 32 percent, and the industrial sector 20 percent. The remaining 12 percent is emitted from other sources such as residential and commercial use of fossil fuels.[1]

The higher efficiencies generally associated with electric end-uses could reduce CO_2 in several of these sectors by decreasing overall energy use when compared with fossil-fueled processes. Since less energy is required to perform the same task, direct fossil fuel consumption can be reduced or eliminated, decreasing the amount of combustion products, including CO_2. Reductions in combustion products are dependent upon two factors: first, the relative technology efficiencies, including end-use and generating efficiencies[2]; and second, the mix of fossil and lower polluting non-fossil fuels used to generate electricity.

The two studies show that increased use of electrification in certain applications can reduce the amount of CO_2 generated nationally by fossil fuels. A number of commercially available and competitive electrotechnologies could be substituted for fossil-fueled processes, resulting in substantial reductions of CO_2 emissions. Reductions of other gases such as methane and additional pollutants are possible as well, but were not analyzed.

Methodology

To compare CO_2 production in comparable fossil fuel and electric end-uses, the total amount of CO_2 produced by the utility sector in 1988 was calculated and an average "pounds of CO_2 per kilowatt-hour generated" was estimated.[3] In 1988, based on the national average fuel mix, 1.34 pounds of CO_2 were produced for every kilowatt-hour generated. Only direct CO_2 emissions from combustion were considered in the analysis. Indirect CO_2 emissions during fuel extraction and refining processes for coal, natural gas, and petroleum were not included.[4]

To illustrate the importance of utility fuel mix variations on the amount of CO_2 generated per kilowatt-hour, CO_2 emissions from two different regions were also calculated. The Pacific Northwest region (including California, Oregon, and Washington) was selected as the "low CO_2 per kilowatt-hour" case region, having an electric fuel mix predominately consisting of hydroelectric and nuclear power. In this region, on average, only

1 *"Technical Feasibility and Implications of Reducing U.S. CO_2 Emissions in the Period from 1995 to 2010," a briefing to Al Streeb, Deputy Assistant Secretary for Energy Conservation (March 4, 1988).*

2 *As an approximation, due to the lack of data for comparison, the electrical transmission and distribution losses were assumed to have emissions impacts similar to fuel distribution losses.*

3 *This number was calculated by quantifying the amount of fuel consumed for electric generation in BTUs, along with the total amount of kWhs generated on a national basis. Using values derived for estimated CO_2 production from the combustion of each fuel type, the total amount of CO_2 produced was calculated and an "average pound of CO_2 per kWh was calculated.*

4 *The exclusion of primary energy used in mining, extraction, etc. should not substantially influence the overall outcome, since it applies to energy used in utilities as well as in other sectors.*

0.40 pounds of CO_2 are emitted for every kilowatt-hour generated. The Southeast Central region (including Alabama, Kentucky, Mississippi, and Tennessee) was selected as the "high CO_2 per kilowatt-hour" case region, having an electric fuel mix predominately consisting of coal. In this region, on average, 1.56 pounds of CO_2 are emitted for every kilowatt-hour generated.

Because electric utility fuel mix compositions vary significantly by region, different levels of CO_2 generated per kilowatt-hour are possible and need to be analyzed if individual region or utility specific impacts are to be evaluated.

In order to quantify CO_2 emissions associated with comparable electrotechnologies and fossil-fired systems, CO_2 production for each fuel type on a stoichiometric basis were estimated. The results are provided in Table 2.

These estimates were used to compare the CO_2 reducing potential of electrotechnologies in the residential and commercial, as well as the industrial and transportation sectors. Although electricity is more CO_2 intensive than other fuels, power plant conversion losses have been taken into account, and many electric end-uses are significantly more energy efficient than comparable fossil-fueled processes, lowering total BTU requirements considerably.

Summary of Results

Significant CO_2 reductions can occur by substituting electricity for fossil fuels in many applications. CO_2 emissions from the electrotechnologies were calculated for all three regional fuel mixes (base case, low case, and high case). A summary of findings are provided below, focusing primarily on those related to the residential and commercial sectors.

Residential Sector. The technologies that were evaluated included the electric heat pump, electric heat pump water heater, and the microwave oven. CO_2 reductions were found to exist in applications involving the use of efficient electric heat pumps in place of average heat pumps, in addition to electric baseboard heating, average efficient natural gas-fired furnaces, and average and efficient oil-fired furnaces, all in combination with central electric air conditioning systems (identical electric central air-conditioning systems were matched with each heating system). CO_2 reductions were not found to exist in comparison to high efficiency (95 percent) natural gas furnaces in the base and high case regional fuel mix scenarios, which depict areas of the country where significant amounts of coal are used to generate electricity. In areas where non-CO_2 emitting fuels predominate, heat pumps offer CO_2 savings compared to efficient gas-fired furnaces.

Table 2. Carbon Dioxide Generated per End-Use BTU for Various Fuel Types

Electricity:	
Low Case	1.2×10^{-4} lbs CO_2/Btu
Base Case	3.9×10^{-4} lbs CO_2/Btu
High Case	4.6×10^{-4} lbs CO_2/Btu
Coal:	1.9×10^{-4} lbs CO_2/Btu
Oil:	1.7×10^{-4} lbs CO_2/Btu
Natural Gas:	1.2×10^{-4} lbs CO_2/Btu

Source: Geba, Vera B., et al., Carbon Dioxide Reduction Through Electrification of the Residential and Commercial Sectors, Energy Research Group, Inc., prepared for Edison Electric Institute, Washington, D.C., 1990 (draft).

Residential heat pump water heaters (HPWH) were found to offer large CO_2 savings compared to all other system alternatives. HPWHs generate less CO_2 than efficient electric resistance, natural gas and oil-fired hot water heating systems. It was found that, based on the national average fuel mix, about 220 billion pounds of CO_2 could be saved per year if all of the existing electric resistance water heaters and 50 percent of all gas and oil-fired heaters were converted to efficient HPWH. Lastly, it was found that the microwave oven generates between two and fourteen times less CO_2 compared to standard electric and gas ranges in several cooking applications.

Table 3 summarizes the key findings of the residential analysis. Additional research is needed to further quantify the total CO_2 reduction potential from these technologies. It is also likely that other CO_2 reducing applications of electrification exist (i.e., dual-fuel systems). This analysis was limited to an evaluation of the most likely CO_2 reducing candidates.

Commercial Sector. The commercial analysis focused on several end-uses including: space cooling, hot water heating, commercial cooking applications, and the use of peripheral office equipment such as the facsimile or fax machine.

It was found that electric chillers, and possibly cool storage technologies, generate significantly less CO_2 under all three regional fuel mix scenarios compared to gas cooling technologies. An exception is the use of small electric chiller systems in areas of the country where significant amounts of coal are used to generate electricity. In those cases, gas cooling generates less CO_2.

Similar to residential heat pump water heaters (HPWH), commercial HPWHs offer substantial CO_2 reducing potential. An analysis of three case studies involving use of HPWHs in restaurant, hotel and school applications, revealed that annual CO_2 savings could range from about 100,000 pounds to over 4 million pounds per facility. Because savings are very facility specific, and market penetration data on the use of commercial HPWHs was not evaluated, a national estimate of CO_2 reduction potential using HPWHs was not calculated.

Electric commercial cooking technologies were also evaluated for their CO_2 reducing potential. It was found that efficient electric fryers generate less CO_2 than average gas-fired models under all three regional fuel mix scenarios, but compared to the efficient gas fryer, the electric fryer generates less CO_2 only under the low case regional fuel mix scenario. Electric griddles were not found to produce CO_2 savings except in the low case fuel mix region, where significant amounts of non-CO_2 producing fuels are used to generate electricity.

Lastly, on a per document basis, the fax machine has the potential to save between two and seven times the amount of CO_2 that is typically produced from transporting documents via overnight delivery services. On a national basis, increased use of the fax machine could save about 14 million pounds of CO_2 annually. This would occur if 30 percent of the letters currently transported by express mail were delivered via fax machines.

Table 4 summarizes the key findings of the commercial analysis. For most of the technologies, national CO_2 reduction impacts of electrotechnology substitution were not estimated as part of this study. Additional research is needed to further quantify national impacts of these technologies and identify other CO_2 reducing applications.

Industrial Sector. By substituting the following electrotechnologies for comparable industrial fossil-fueled processes, a minimum reduction of 17 percent in annual CO_2 generation from the industrial sector may be realized: electric arc furnace; induction heating; electric glass melting, annealing, and conditioning; infrared heating; and freeze concentration.

Electrotechnologies are already gaining wide-spread acceptance within the industrial sector because of their high efficiencies, precise energy control capabilities, and high processing and production rates. The fact that they are CO_2 reducing as well should provide an added incentive for their development and use.

Transportation Sector. Electric modes of transportation also have CO_2 reducing potential. An

Table 3. Summary of Carbon Dioxide Reduction from Efficient Residential Electrotechnologies Versus Comparable Systems

Electrotechnology/ Substitute	Estimated Annual CO_2 Savings (lbs.) Per Unit			Percent Base-Case Reduction
	Low-Case	Base-Case	High-Case	
Electric Heat Pumps (most efficient)				
• Average Electric Heat Pump	2,835	9,497	11,057	30%
• Electric Resistance	3,781	12,666	14,747	36%
• Natural Gas (Electric A/C)				
- Average (62%)	9,084	2,776	1,300	11%
- High Efficient (95%)	4,103	(4,305)	(6,272)	---
• Oil (Electric A/C)				
- Average (60%)	16,322	10,028	8,556	31%
- High Efficient (80%)	10,696	2,343	389	10%
Heat Pump Water Heaters (HPWHs) (most efficient)				
• Average Electric Heat Pump	232	778	905	29%
• Electric Resistance	1,492	4,997	5,818	72%
• Natural Gas				
- Average (50%)	3,578	2,215	1,896	53%
- High Efficient (83%)	1,925	562	243	22%
• Oil				
- Average (50%)	5,947	3,947	3,628	67%
- High Efficient (63%)	4,095	2,732	2,413	58%
Microwave Oven				
• 4 Baked Potatoes				
- Electric Range	0.29	0.97	1.14	64%
- Gas Range	2.23	1.82	1.73	76%
• Cake				
- Electric Range	0.17	0.58	0.67	62%
- Gas Range	1.62	1.44	1.38	80%
• Roast				
- Electric Range	0.37	1.26	1.47	56%
- Gas Range	3.70	3.01	2.85	75%

Source: Geba, Vera B., et al., Carbon Dioxide Reduction Through Electrification of the Residential and Commercial Sectors, Energy Research Group, Inc., prepared for Edison Electric Institute, Washington, D.C., 1990 (draft).

Table 4. Summary of Carbon Dioxide Reduction from Efficient Commercial Electrotechnologies Versus Comparable Systems

Electrotechnology/ Substitute	Estimated Annual CO_2 Savings (lbs.)			Percent Base Case Reduction
	Low-Case	Base-Case	High-Case	
Electric Chillers vs. Gas Fired Chillers/Heaters				
• Northeast Region				
- 30 Ton Unit	33,560	5,548	(1,008)	11%
- 250 Ton Unit	292,000	151,940	119,160	37%
- 500 Ton Unit	585,640	307,118	241,932	38%
• Southeast Region				
- 30 Ton Unit	90,576	14,944	(2,758)	11%
- 250 Ton Unit	788,400	410,238	321,732	37%
- 500 Ton Unit	1,581,276	829,267	653,264	38%
Document Transfer: Fax Machines				
Conventional Overnight Document Delivery Service	0.4	0.25	0.20	54%
Chilled Storage	Since chilled storage units use about the same amount of energy as conventional electric chillers, the CO_2 savings may be similar to above. However, actual savings would be dependent upon off-peak utility fuel mix.			

8.2 percent reduction in the total amount of CO_2 currently produced in the transportation sector could be realized from direct substitution of gas or diesel cars or buses with equivalent electric cars, and cross substitution of more efficient electric modes of transit for less efficient fossil-fueled modes.

Additional research is needed to further quantify the CO_2 reductions of these and other potential CO_2 reducing technologies on a nationwide basis. The preliminary findings, however, provide a basis for future R&D and legislative efforts to reduce CO_2 through the use of highly efficient electric transport.

CONCLUSIONS

DSM has a proven potential to reduce both capacity and energy requirements. DSM has shown a 1988 capacity reduction of over 13,300 megawatts and energy reduction of almost 9 billion kilowatt-hours. This will translate to reduced CO_2, SO_2, and NO_x emissions.

These reductions will increase and accelerate, as DSM experience and expenditures are increasing and accelerating. In addition, we expect that energy savings have been under-reported, and we have

Table 4. (contd)

Electrotechnology/ Substitute	Estimated Annual CO_2 Savings (lbs.)			Percent Base Case Reduction
	Low-Case	Base-Case	High-Case	
Cooking: Electric Fryers (most efficient)	493	1,653	1,925	10%
• Average Electric Fryer				
• Natural Gas	4,541	(3,394)	(5,251)	--
- High Efficient	8,792	1,834	204	10%
- Average				
Cooking: Electric Griddles • Natural Gas Model	9	(5)	(8)	--
Heat Pump Water Heaters				
• Restaurant (converted from electric resistance)	--	106,128	--	35% (estimate)
• Hotel (converted from gas water heating)	--	4,141,642	--	79% (estimate)
• School (converted from oil-fired boiler)	--	170,175	--	

Source: Geba, Vera B., et al., Carbon Dioxide Reduction Through Electrification of the Residential and Commercial Sectors, Energy Research Group, Inc., prepared for Edison Electric Institute, Washington, D.C., 1990 (draft).

therefore underestimated energy savings. Because the focus has been load factor improvement (i.e., capacity savings) attention to energy savings has been lower, and we expect higher savings will be reported with better measurement. Since energy savings translate to emissions savings, the final results will underestimate emissions savings. In addition, as regulatory incentives change to promote greater emissions savings, programs that reward energy savings may become the future focus.

Care needs to be taken in legislation and regulation that results in specifying equipment that has implications for global warming. Efficiency improvements can greatly reduce CO_2 emissions from both electric-powered equipment and advanced gas-fired equipment. Legislation and regulation, as well as specification of equipment, will need an improved data base on emissions. As this research demonstrates, highly efficient electric equipment reduces CO_2 emissions over comparable gas or oil-fired alternatives. Therefore, new equipment specifiers need to be and will be more cognizant of efficiency impacts.

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