J. ENVIRONMENTAL SYSTEMS, Vol. 10(3), 1980-81

ENERGY CONSERVATION BY INDUSTRIAL AND COMMERCIAL USERS: TWO SURVEYS*

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ABSTRACT

Industrial and commercial energy consumption is about 55 per cent of the U.S. total, but conservation efforts in those sectors have rarely been studied, and there are widely conflicting reports of their effectiveness. This study analyzed 133 published accounts of individual companies' energy conservation and concluded that they showed relatively good savings for most industries and excellent savings for commercial and public buildings. To check on the representativeness of these published accounts, a regional survey study was conducted by interviewing high-level officials of fifty-four Southern California chemical companies, chosen as a stratified random sample. Though many of the smaller companies had not conducted conservation efforts, companies of all sizes which had done so estimated average energy savings of 7 per cent or more per year—an encouraging level. However, due to rising production, total energy use is not declining, and strenuous additional conservation efforts are essential.

Energy conservation is generally agreed to be our nation's best short-term means of adapting to the current international energy shortage, and it may be the best long-range solution as well [1]. Empirical scientific studies of energy conservation efforts have only begun to be published in recent years. Of those that have appeared, most have focused on *individual* actions in *residential* settings involving *repetitive* behaviors which have immediate but brief consequences—such as turning thermostats up or down [2-4]. Such studies

*An earlier version of this paper was presented at the Western Psychological Association meeting in Honolulu, May 1980.

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doi: 10.2190/88U9-8VJX-UYLA-9YLN
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are rather removed from public policy issues, for government conservation programs have aimed largely at one-time, long-range decisions, such as insulating a house or buying an energy-efficient car.

By contrast, a systems approach would suggest a very different allocation of research efforts. Total U.S. energy consumption is divided into end-use sectors approximately as follows: industrial 36 per cent, commercial/service 19 per cent, residential 19 per cent, transportation 26 per cent [1, 2]. Thus the more-studied residential sector accounts for less than one-fifth of U.S. energy usage, while the industrial and commercial sectors together account for 55 per cent, yet they have rarely been studied empirically. The present research was designed to begin to rectify this imbalance by focusing on industrial and commercial energy conservation.

HOW HAS CONSERVATION BEEN GOING?

There are conflicting reports on the success of energy conservation campaigns. A pessimistic report from the International Energy Agency in 1979 showed conservation programs lagging behind projected goals in the U.S. and in many other industrialized nations. The IEA concluded that progress was "considerably less than expected." [5]

An authoritative article in *Science* in 1973 projected that both residential and commercial buildings could cut their energy usage by 40 per cent through insulation and air supply control, while industry could save 30 per cent of energy usage through these and other efficiencies [6].

Compared with such estimates, most summary reports seem discouraging. However, even within the boundaries of U.S. government reports, there is wide disagreement about the amount of recent energy conservation in industry. At the low end was a 1979 Department of Energy (DOE) estimate of a 1.2 per cent per year reduction in energy use per unit of production since 1973, and a similar report of 1.8 per cent for Canadian industry [7]. In the middle of the range, President Carter gave some figures at an energy conference in October, 1979, which indicated a 3.2 per cent per year saving per unit of production [8]. At the high end was a more glowing DOE report which claimed a 7.0 per year industrial saving per unit of production [9]. With this spread of estimates, the total industrial energy saving since the Arab oil embargo in 1973 could be anywhere between 7 per cent and 42 per cent.

It is clear that government authorities have only incomplete information about what is happening with industrial energy conservation. DOE requires regular reports on energy usage from all corporations which use at least one trillion Btus per year of energy in making a given type of product (e.g., foods, paper, or chemicals). That list includes over 800 of America's largest firms [10], and of course they use a disproportionately large share of the nation's energy, but the list omits many thousands of smaller firms, about which DOE knows little or nothing.

This paper aimed at developing more information about energy use and conservation in the industrial and commercial sectors. Two methods were used: First, collection and analysis of published accounts of energy conservation programs by businesses, obtained primarily from trade journals—a case-study approach using written materials. Second, an interview survey was conducted with a sample of Southern California businesses, providing a check on the representativeness of published findings.

STUDY OF PUBLISHED REPORTS

Method

In collecting published accounts, relevant reports were taken from books, magazines, and newspapers. However, one source was by far the most productive: *Energy User News*, a weekly newspaper of about twenty-four pages devoted exclusively to news of products, procedures, and results relevant to energy usage by companies and public agencies, both large and small. Its editions for 1979 provided the great majority of the published reports analyzed herein. Over 200 articles or reports were abstracted, of which 133 stated actual energy savings, forty-five gave estimates of expected savings, and twenty-eight provided relevant general information. The results described below are from the 133 articles which reported actual energy savings. These findings were categorized as involving industrial, commercial, or public organizations, further divided by specific industry, and analyzed in terms of the extent of savings, the period of time covered, and the types of conservation actions taken.

Energy savings were frequently stated in noncomparable units—such as dollars, KWHs, Btus, thousand cubic feet of gas, percentage return on funds invested, or length of payback period—or for other time periods (such as total savings since the pre-oil-embargo base year of 1972). Wherever sufficient information was given, these varied types of reports were converted to percentage of the past year's energy use as the measure of savings. Some sophisticated reports were stated in terms of percentage of savings per unit of production, or per square foot of building floor space, and these figures were used without modification.

What Levels of Conservation Were Expected?

Seven major energy-intensive industries consume about 75 per cent of all energy used by U.S. industries and about 25 per cent of all U.S. energy usage. In order, they are chemicals, iron and steel, petroleum, food processing, paper, aluminum, and automobiles. In 1974 a study by the National Petroleum Council predicted that they could reach the following total percentages of energy savings by 1978 [11].

Chemicals	20%
Iron and Steel	5%
Petroleum	15%
Food Processing	10%
Paper	15%
Aluminum	5%
Automobiles	10%
Remaining Industries	10%

Let us compare these predicted figures with later published accounts of actual savings by individual companies.

What Results Have Been Reported?

Table 1 presents a summary of the articles which reported energy savings, both in industry and in the commercial/service sector. The top half of the table lists the big-seven industries and then combines all others, and the first column of numbers shows the industry-wide predicted savings for 1978. The second numerical column gives industry-wide savings as reported to DOE by the largest companies in the industry and/or by the industry's manufacturers association [12]. In all cases these reports show a relatively favorable picture, with energy savings being close to or above the expected levels. Of course, these results may or may not by typical of smaller manufacturers.

The third and fourth columns in Table 1 show the mean energy savings figure and the number of reports for individual companies in a given industry, stated in terms of cumulative savings for several years (often since the base year of 1972). Though the number of cases in most industries was small, the reports were generally quite favorable, most falling between 15 per cent and 25 per cent cumulative savings and being well ahead of the 1974 predictions. Somewhat surprisingly, chemicals were an exception; despite the chemical industry's high predicted potential for energy savings, the six published reports of individual companies averaged lower than any other industry and only slightly more than half of the industry-wide goal.

Because the multi-year cumulative figures for different companies were based on varying numbers of years, columns 5 and 6 of Table 1 have restated the energy savings in comparable terms, based on the latest single-year period reported. In some cases these figures include different companies than the multi-year data, and the single-year savings are often disproportionately high for companies where the energy conservation program began only recently. It can be seen that the average single-year energy savings for various industries ranged from 3 per cent to over 8 per cent, again quite a favorable record.

The final column of Table 1 shows some extremely high savings for individual companies—figures which were not included in the previous columns because they were so atypical. However, they represent even more favorable

Table 1. Summary of Published Accounts of Energy Savings (in %) by Industry

Industry	1974 Prediction for 1978	Industry-Wide Report of Savings Since 1972	Multi-Year Cumulative Savings[a] Mean	(N)	Recent Single-Year Savings Mean	(N)	Other Notable Single-Year Savings[b]
Chemicals	20	17.2	11.5	(6)	3.1	(6)	—
Iron & Steel	5	10	16.1	(5)	3.9	(6)	43, 60
Petroleum	15	16.4	19.6	(3)	3.7	(3)	30
Food	10	16.6	21.3	(2)	8.6	(2)	70
Paper	15	13.6	22.9	(2)	4.2	(2)	43
Aluminum	5	8	18.0	(1)	7.5	(2)	30
Autos	10	18	18.5	(1)	3.1	(1)	—
Other[c]	10	—	26.4	(12)	8.5	(15)	49, 51, 59, 62, 74
Commercial/Service Sector							
Office Bldgs.	—	28.5	39.2	(6)	22.3	(14)	71
Shopping Centers	—	25.0	40.0	(2)	16.4	(4)	40
Restaurants	—	—	24.7	(3)	8.6	(4)	—
Schools	—	—	—	—	23.9	(9)	35
Colleges	—	—	38.0	(3)	10.9	(3)	65, 70
Hospitals, Museums, & Libraries[d]	—	—	30.6	(4)	8.8	(5)	62

[a]For varying numbers of years

[b]Not included in previous columns

[c]Figures in columns 3-6 are based on the following maximum number of companies: 1 can company, 4 metal products, 7 electrical and electronics, 2 textiles, 1 farming company.

[d]Figures in columns 3-6 are based on a maximum of 3 hospitals, 1 museum, and 1 library.

conservation outcomes which have been achieved by some companies, and the companies involved were by no means all small or atypical ones.

How Did They Do It?

In many industries, a common and highly-effective measure was better housekeeping regarding steam usage—plugging steam leaks, cleaning steam traps, and more efficient boiler control. A related procedure adopted by many companies was to add heat exchangers in order to use waste steam or waste heat for other lower-temperature purposes—including cogeneration of electricity, and space heating. Since about half the energy consumed by U.S. industry is used to generate steam, the savings in this area can be very great [11].

In several industries, automatic computerized controls for governing manufacturing processes exactly and efficiently are coming into common use.

In the steel industry, new electrical induction furnaces and continuous casting processes, though very expensive to install, can save half or more of the energy costs. As a result of such new equipment and other measures, some steel and aluminum companies are doing far better at conservation than the industry predictions. Similarly, some paper, food, and other manufacturing companies have saved both money and energy by converting to wood wastes or other biomass products as fuels instead of natural gas or fuel oil.

Many other types of energy-saving equipment have been adopted by individual companies, including combustion controllers, smaller boilers and compressors, added insulation, etc. However, the great majority of reports indicate that the largest and easiest energy savings were achieved through more careful housekeeping–avoiding waste, and using necessary energy more efficiently.

Conservation in Commercial and Public Buildings

Turning to the bottom half of Table 1, it is clear that reports of energy savings in the commercial and service sector have been even more favorable than those for the industrial sector. Here there were no 1974 industry-wide predictions and only two reports of overall industry energy savings since 1972 (both supplied by trade associations and both quite positive). In a similar vein, the multi-year figures for individual establishments or buildings showed that 30 per cent to 40 per cent savings were quite possible. The single-year savings for various kinds of organizations were even better, ranging from 8 per cent to 24 per cent average savings for just one year; and the largest means (for schools and office buildings) were based on the largest number of cases, making them more likely to be reliable figures. Finally, the extreme instances in the last column showed quite a number of cases where energy savings of one-third to two-thirds of total energy use had been achieved in a single year.

How were these savings accomplished? In addition to the methods used by industrial firms, commercial and public buildings were able to use many other approaches. Some of the most important methods were based on the fact that as much as half of a commercial office building's energy consumption typically goes to lighting [13]. Thus, great energy savings have often been acheived by reducing unnecessarily-high light levels and by installing more efficient lighting (e.g., fluorescent fixtures, watt-saver bulbs, or high pressure sodium lamps). Of course, reducing heating and cooling by adjusting thermostats to the federally-specified levels has also helped. A new approach that has recently become very popular is to install an automatic computer-control system to run all electrical equipment. These "load-shedders" typically cycle air conditioning, heating, and other equipment on and off. Even more important, they can turn off many kinds of unnecessary equipment before times of peak demand, thus reducing the organization's maximum demand and the heavy utility charges which are based on peak demand.

Other energy-saving steps taken in commercial buildings have included: adding insulation, cutting heat loss through windows by added glazing or plastic film, changing to shorter janitorial night schedules, installing flow controls on faucets and showers, resetting thermostats on hot and cold water, better maintenance of cooling systems, replacing inefficient boilers, adding heat exchangers, and installing new variable-air-volume air conditioning systems. Finally, many reports have emphasized that getting all personnel involved in conservation efforts has yielded many good suggestions and superior compliance with new procedures.

How Representative Are These Published Reports?

Though the articles on energy conservation summarized are quite encouraging, a major question remains: Do only the success stories get into print? More specifically, how many companies are conserving energy effectively? And how are the smaller companies doing? The government doesn't know the answers to these questions except for the very largest one-trillion-Btu energy users.

To begin answering these questions, the second phase of the present research sought a representative sample of companies to supplement the undoubtedly unrepresentative sample of companies which had been described in public reports. Furthermore, since a heterogeneous sample from a mixture of different industries would not be meaningful as a basis for forming conclusions, a single industry was chosen for initial investigation.

REGIONAL SURVEY STUDY

Method

The present survey study was confined to Southern California companies in a single industry in order to get a relatively large and stable sample of companies whose activities were somewhat comparable. The chemical industry was chosen as the focus because it was considered to have the greatest potential for energy savings of any major industry [11], and because there were many chemical companies in Southern California. All of the chemical companies listed in the *Southern California Business Directory* which were in Los Angeles or Orange Counties were classified by size in terms of number of employees.

All of the large companies (100 or more employees) were included in the sample. Since there were more of the smaller companies, a random sample of half of the medium-sized companies (20–99 employees) and half of the small companies (1–19 employees) was chosen. Some of the companies were divisions of larger firms, but their size measurement was based on the number of employees in their local plants.

Interviews were conducted by telephone using a five-page structured interview schedule, which usually took about ten minutes to complete. The two interviewers attempted to reach the highest company official at the local site—most often the President or the General Manager. However, if informed that someone else knew more about the energy picture, we interviewed whoever could give us the desired information. There were no outright refusals among the companies contacted, though three requested us to send our questions in writing and then did not reply.

Of the eighty-one chemical companies selected, twenty-two were found to be nonsample cases (no longer in business, a distributer rather than a manufacturer, or not really a chemical company) and were eliminated from the sample without replacement; fourteen of these were small, three medium sized, and five large. Of the remaining fifty-nine, all but five (3 small and 2 medium sized) were able to be contacted and gave some response, yielding a response rate of 92 per cent. However, some of the answers given were perfunctory or poorly informed or rough estimates. Of the companies which responded, thirteen were small, twenty-three medium-sized, and eighteen large. Because of the coverage of the sampling, the responses should be highly representative of all Southern California chemical companies.

Results

Table 2 shows the distribution of responses to the main interview questions, broken down by size of company. Through persistent phoning we succeeded in reaching the president or local manager in a high proportion of cases. About one-third of the large companies (and hardly any others) had an energy manager or environmental or maintenance engineer, and their reports were usually the most detailed and knowledgeable.

The great majority of companies had felt the need to cut energy usage, though a few of the small and medium ones hadn't. The larger the company, the more likely they were to have an energy conservation program, and often a formal one, whereas a majority of small companies had none. Similarly, most small and medium companies said they had no data available on energy savings, whereas a majority of large companies did. In the absence of hard data, respondents were asked to make an estimate of the amount of their recent energy savings, and still about 40 per cent of small and medium companies were unable to do so, compared with about 10 per cent of large companies. If neither data nor estimates were available, we asked if the company had taken any steps toward conserving energy; perhaps surprisingly, about 30 per cent of the small companies said no to this, while almost all the others claimed at least minimal actions. Question 9 showed that the kinds of energy used by large companies were more diverse than other companies.

The most important findings of the survey are shown in question 10, concerning the size of energy savings in a recent year. Here only about 60 per

Table 2. Responses to Interviews with Small, Medium and Large Chemical Companies (in %)

Item	*Small (N=13)*	*Medium (N=23)*	*Large (N=18)*
Respondent			
President, owner, or partner	62%	39%	0%
Manager or operations director	38	35	39
Engineer or energy manager	0	8	33
Other (VP, comptroller, asst. to pres.)	0	17	28
1. Company has felt it desirable to cut down on energy use.	77	87	100
2-3. Does company have an energy conservation program?			
Yes, formal	0	17	44
Yes, informal	31	43	50
Said no, but informal program described	15	13	0
No	54	26	6
4-6. Has data on energy savings for a recent year.	15	26	61
7. (IF NO DATA) Can estimate energy savings.	46	30	28
7A. (IF NO ESTIMATE) Did company take any steps to try to save energy?—Answered No.	31	9	0
9. Main kinds of energy used. (Check all that apply)			
Electricity	100	100	89
Natural gas	50	82	94
Gasoline	8	36	17
Fuel oil	0	9	33
Bottled gas	0	5	6
Coal	0	0	0
Other (diesel, methane, purchased steam)	0	5	28
10. What were energy savings for a recent year?			
Gave indefinite negative responses (i.e., greater energy usage)	8	13	0
Gave numerical responses	54	61	83
Mean of numerical responses	7.4%	7.2%	11.0%
12. Energy saving programs which were tried.			
Housekeeping measures only	31	43	11
New equipment only	0	4	6
Both	31	39	67
No response	38	13	17
Other (in addition to above measures)	0	17	6

Table 2. (Cont'd.)

	Item	*Small (N=13)*	*Medium (N=23)*	*Large (N=18)*
13.	(IF BOTH) Mean % of savings from:			
	Housekeeping measures	62	38	45
	Space-conditioning equipment	0	1	0
	Production equipment	38	39	52
	Other programs (process changes)	0	22	2
17.	Year energy-saving program started.			
	1979	8	17	11
	1978	8	17	17
	1977	31	17	17
	1976	0	4	11
	1975 or before	8	17	28
	No response	46	26	17

cent of the small companies were able to provide data or an estimate, progressing upward to around 75 per cent of the medium companies and over 80 per cent of the large companies. Though the energy savings figures for individual companies ranged from 0 per cent to 25 per cent, the means were rather similar and appeared fairly stable. They were around 7 per cent annual savings for the small and medium companies, and about 11 per cent for the large companies. Of course it seems likely that the minority of nonreporting companies achieved smaller savings than this (perhaps even none), particularly since several of them stated that they hadn't taken any steps toward energy conservation. In addition, as shown under question 10, there were four companies which reported unspecified amounts of *increase* in energy usage rather than energy savings. These increases were generally due to increased production, but the reported information was not sufficient to compute energy usage per unit of production.

In question 12, companies which had attempted or achieved energy savings reported what types of programs they had used. Housekeeping measures alone were more common among the small and medium companies, while the large companies more frequently had invested in new equipment in addition to stressing housekeeping. Typical housekeeping measures mentioned were turning thermostats down, turning lights and motors off, delamping, stopping steam leaks, cleaning steam traps, and cutting losses due to waste material. The proportion of savings stemming from housekeeping measures was somewhat higher for the small companies than for the others, while the large companies got a bit more of their savings from new production equipment. The new equipment mentioned most often was more energy-efficient motors, lights, and smaller cars for salesmen and company fleets; a few companies mentioned new boilers, heat exchangers, better steam traps, insulation, or automatic control

systems. In addition to new equipment, a few of the medium and large companies mentioned savings from process changes in the way they manufactured their products (or also in selling them more over the phone instead of by traveling salesmen).

The last question in Table 2 showed that most of the small companies began their energy-conservation programs in 1977 or later. In contrast, quite a few of the large companies began in 1975 or earlier. This is interesting in that the large companies tended to start earlier and so are past their first easy and large energy-saving steps, yet they are still reporting larger annual savings than the small or medium-sized companies.

Discussion

The data of this survey are susceptible to several potential sources of error. First, it seems likely that some social desirability bias would be present when company officials were asked if they had been trying to conserve energy. Yet, despite the Mom-and-apple-pie nature of the question, a substantial number of the respondents said no. Those answers were probably honest, and this suggests that other reports may be essentially honest as well. A second problem might be the admittedly rough nature of many of the estimates of savings. In contrast, there were some very precise and complete data reports, and these precise figures frequently (but not always) indicated somewhat smaller energy savings than the rougher estimates. A third question might be the diversity of the companies involved (despite their all being chemical companies) and of their opportunities for energy savings. Yet, in spite of their diversity in size and in products, their reports of savings clustered fairly closely, and the means appeared to be quite stable. Thus, none of these objections seems to invalidate the present data to a major degree, and the findings of this study seem fairly encouraging about the energy conservation efforts of medium-sized and small companies, about which DOE has had relatively little information.

Also the present survey findings on conservation seem consistent with or higher than the published case reports analyzed in Table 1. Thus they suggest that the published reports are not just atypical success stories which are unrepresentative of other companies' energy-saving efforts.

However, these data clearly show that many smaller companies are still doing little or nothing to conserve energy, and that many other companies have only started conservation programs recently. Nevertheless, those which began their efforts earlier still seem to be succeeding in achieving worthwhile savings each year. This is encouraging because the first savings are the easiest ones, and yet these companies are still making headway. The respondents very often cited increasing energy costs as an important motivator of their conservation efforts, and this factor should increasingly pressure the so-far nonconserving companies to begin energy-saving programs of their own.

Both the comments of survey respondents and the information in published reports indicate that important factors aiding the success of conservation programs are: strong support from top-level management, appointment of an energy manager with real authority, initial use of energy audits to pinpoint most cost-effective changes, availability of regular and detailed energy accounting reports, specification of clearcut goals for participant behavior (e.g., keeping entrance doors closed), and encouragement of feelings of involvement among all employees.

A final aspect of the need for energy conservation is present in these data but in an obscured form. Though both published accounts and our survey interview responses report quite commendable percentages of energy savings per unit of output since 1972, it is also true that production has been increasing during those years in most industries. The result is that many industries may actually have increased their total energy consumption instead of reducing it during that time [12, p. 2]. For example, the chemical industry total energy use in 1979 was 2.1 per cent *greater* than in 1972 [14]. This astounding fact dramatically underlines the need for continuing and increasing energy conservation efforts as the U.S. faces diminishing supplies of both domestic and foreign fossil fuels.

ACKNOWLEDGEMENT

Thanks are expressed to Elyse Kerce for interviewing assistance and Rob Simon and Yasmin Attar for bibliographic help.

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