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DOE/CS/40224-T1 T.O. # 8

**The CEREN Concept:
A Case Study of the French
Industrial Energy Data System**

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prepared for
U.S. Department of Energy
Office of Industrial Applications and Commercialization
Washington, D.C. 20545

CS 40224

TIC

DOE/CS/40224--T1

DE82 008548

RPA Reference No.: RA-78-0908(1)

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October 12, 1978

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Introduction

High energy prices and the threat of potential fuel supply shortages can seriously disrupt the industrial sector through work stoppages and changes in product cost structures. In recognition of the potentially severe effects of these energy trends on production, and, in the longer term, on social and economic stability, both the public and private sectors are concerned with devising plans for reducing energy consumption by industry. Under the terms of the National Energy Act, the U.S. government is performing research, development, and demonstration (RD&D) programs, offering incentives, and instituting regulatory actions to improve energy conservation and fuel efficiency in industry. At the same time, individual industrial firms are developing energy management procedures and fuel substitution policies to reduce the effects of energy price increases and energy shortages on their operations. Private firm actions include energy improvements in process technologies and substitution of less energy-intensive input products.

In the last 4 years, these public- and private-sector efforts have achieved major gains in energy savings and fuel substitution. However, two factors will make it harder to achieve further needed improvements. First, further energy savings will be more difficult to accomplish as the more obvious conservation opportunities have been identified and exploited. Second, we are beginning to realize that conservation actions taken in one firm or industry have consequences for other firms, industries, and the nation as a whole. For example, energy-use patterns within one industry can change not only because of equipment replacement or process efficiency improvements, but also because of dependence on products from other industries or market competition effects. In addition, changes in energy-use patterns in an industry can have socioeconomic consequences such as a drop in employment or increased dependency on foreign imports.

These complex interdependencies within the industrial sector and its socioeconomic environment require clearly defined conservation strategies to guide both public and private decision makers.

For the public sector, a conservation strategy must take into account three critical factors:

1. The potential for change in energy-use patterns within each industry
2. The impact of changes in energy-use patterns in one industry on other dependent industries
3. The financial and social costs of changing energy-use patterns.

Developing such an energy conservation strategy for the industrial sectors clearly requires understanding a wide range of information on energy flows and uses within the industrial sector. The extent and quality of data available on energy uses will determine whether or not that understanding can be gained. Thus, a comprehensive industrial energy-use data system is critical for establishing an industrial energy conservation strategy.

By providing data on current energy-use patterns in specific industry segments and by comparing these data with past trends, such a system enables government and industry planners to obtain the information needed to analyze energy use in industry. The data system can be designed to provide information on energy-use patterns within an industry and among industries as well as data on the social and economic cost of changing energy use patterns. For example, to analyze energy use within an industry, data can be collected on energy and material inputs and outputs, capacity expansion plans, equipment type and age, and process energy efficiencies. To analyze the interindustry impacts of energy conservation actions, the data system can contain data on generic industrial processes, intermediate products, links between product outputs and inputs, energy content of products, and product substitution possibilities. For analyzing the social and economic implications of energy-use changes, data can be gathered on production costs and employment requirements.

To satisfy these information needs in a cost-effective manner, an industrial energy data system must have three essential characteristics. The system must be:

- Comprehensive -- reflecting energy uses throughout the industrial sector. This feature permits comparison and analysis of industrywide and nationwide impacts.
- Detailed -- drawing on information collected at the plant level, including data on all energy-consuming operations in a plant. This attribute provides insights into the energy-use patterns of a plant, assures data validity, and provides flexibility in comparing energy uses at detailed and aggregated levels.
- Manageable -- utilizing concepts that simplify data aggregation, use computer processing effectively, and permit meaningful comparisons within and across industries. This feature assures that useful outputs can be developed at reasonable cost.

However, even a well-designed data system will be ineffective unless it is implemented properly. To ensure the effectiveness of the data system, data collection procedures must be designed carefully and the continuity of the data system guaranteed over time. In addition, the system should protect the confidentiality of all information obtained. Finally, the system must have the confidence of both participants and end users.

Setting up a comprehensive, detailed, and manageable industrial energy-use data system for a developed country involves designing expensive, innovative systems, surveying thousands of plants, reviewing hundreds of industrial processes, and reappraising the data system on a regular basis. In addition, it requires the cooperation of numerous organizations in the public and private sectors.

To date, only one such data system exists. In France, Le Centre d' Etudes et de Recherches Economiques sur l'Energie (CEREN) has maintained a comprehensive data base on French industrial energy consumption for more

than 15 years. Since its creation in 1958, this nonprofit organization, whose members include all the energy suppliers in France, has played a major role in providing the critical information needed by the French government to develop its industrial energy policy.

The U.S. government is interested in developing a data system as an aid to its own industrial energy conservation planning. Accordingly, the Office of Industrial Applications and Commercialization of the Department of Energy contracted with Resource Planning Associates, Inc. (RPA), to review the CEREN data collection system. A case study of the CEREN system can provide useful insights into the unique features of such a system. In addition, this review may assist in examining the issues involved in setting up a system that will meet the same needs in the United States.

In the following document, a case study of the CEREN system is provided. Chapter 1 outlines the foundation of the system design, that is, the concepts that ensure the system's comprehensiveness, detail, and manageability. Chapter 2 focuses on implementation of the system, in particular, the data collection and data processing methodology. Chapter 3, reviews applications of the CEREN energy information system for analyzing energy use, cross-industry impacts, and social and economic impacts of changing energy-use patterns.

1

SYSTEM DESIGN

The CEREN approach to designing its industrial energy-use data system reflects a clear understanding of the requirements for comprehensiveness, detail, and manageability of the data.

ENSURING COMPREHENSIVENESS

To ensure the comprehensiveness of the data system, CEREN analyzes all industries and surveys all plants consuming more than 20 billion Btu per year. By covering the entire industrial sector, and not just energy-intensive segments, CEREN is assured of enough information to analyze the interdependencies among industries. Approximately 5,000 plants are included, representing 85 percent of the total industrial energy consumption in France.

ACHIEVING AN ADEQUATE LEVEL OF DETAIL

To achieve an adequate level of detail and thus provide a complete overview of plant operations, CEREN focuses on all energy-consuming industrial operations in the plants surveyed. Data at this level can generate valuable insights into plant energy use. In addition, this procedure ensures that trends in changes of such variables as energy-consuming equipment and plant capacities can be measured. Moreover, because primary data are detailed, potential statistical discontinuities between surveys can be reconciled.

Specifically, CEREN collects information on:

- Aggregated energy inputs and product outputs at the plant level

- Energy and material inputs and outputs for all operations within a plant
- Plant equipment characteristics
- Operating conditions.

Aggregated energy inputs are accounted for and categorized as fuel or electric power uses (see Exhibit 1.a). For each plant surveyed, information is gathered on coal, gas, oil, and other fuel consumption. Twenty-nine types of fuel, including waste fuels, and purchased and self-generated electricity are characterized in detail.

For product outputs at the plant level, both total production and classifications of products are reported. Production levels are also recorded for the 2 years preceding the survey. Seasonality is taken into account to identify peak production months and to characterize the production peak as a percent of the average yearly production.

Data on energy and material inputs and outputs are collected for all plant operations. All equipment in the plant associated with these operations is inventoried and information is obtained on equipment age, manufacturer, and performance characteristics such as load factors, power outputs, and exhaust energy form and temperature. (Exhibit 1.b).

To complete the overview of the plant operations, fuel consumption and production output in a given year must be related to the operating conditions of the plant. For that purpose, data are collected on the number of hours of operation during the year, number of employees including temporary employees, the nature and frequency of plant shutdowns, and recent plant expansions. This information helps to ensure an understanding of potential statistical discrepancies between surveys. In addition, production plans up to 5 years in the future and projected fuel consumption information are obtained.

ENSURING MANAGEABILITY

CEREN collects data on thousands of plants. Each plant produces one or several products using one or several

Exhibit 1.a

Fuel Input Matrix

	Nature of the Fuel Most Used	Total Yearly Consumption	Conversion Factor	Energy Equivalence
Purchased Fuels				
Solid				
	Black coal			
	Brown coal			
	Bituminous coal			
	Coke			
	Semi-coke			
Liquid				
	Heavy No. 2			
	Heavy No. 6			
	Distillate			
Gas				
	Natural gas			
	Coke gas			
	Refinery gas			
	Blast-furnace gas			
	Low Btu gas			
	Butane/propane			
Waste Fuels				
Solid				
Liquid				
Gas				

	Electricity Produced On Site	Electricity Purchased	Total Electricity Consumed	Energy Equivalence
Electricity				

CEREN Equipment Data Sheet

EEO identification	Equipment unit and code identification	Brand and comments on specific commer- cial type	Number of units installed	Unit power	Yearly y load factor	Average fuel consumption by unit	Input temperature level	Average age/unit
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processes; each process, in turn, consists of numerous operations for which energy, material, and equipment information is collected. Consequently, the disaggregated data, although rich in detail, are far too extensive to manage.

To ensure the manageability of the system, CEREN employs two important concepts that guide data collection efforts at the plant level, simplify data aggregation, and serve as a basis for useful comparisons within and across industries. These concepts are:

- Categories of elementary energy operations (EEOs)
- Product/processes.

The identification and characterization of EEOs is critical to the CEREN system. The activity of a plant is broken down into a series of physical operations, or EEOs, that are characterized in a standardized way (see Exhibit 1.c). Each EEO involves a specific piece of equipment (e.g., a furnace) that uses a given type of energy and materials in processing a specific type of intermediate product. Thus, measuring EEOs yields energy and material inputs and outputs, and a range of information about equipment (see Exhibit 1.d).

EEOs are characterized by equipment because each type of equipment is likely to have a different energy profile and perform a different function in an industrial process. Two similar items of equipment (e.g., two furnaces in a brick-manufacturing plant) that use different types of energy (e.g., oil for one, gas for the other) will be considered two different EEOs. Furthermore, two similar pieces of equipment, that run on the same fuel but are characterized by different forms of exhaust energy (e.g., at different temperatures) will be differentiated.

CEREN identified certain features common to the thousands of EEOs. These features make it possible to establish typical categories of energy operations, thus reducing the number of EEOs. The regrouping of EEOs was the subject of studies conducted over several years. CEREN has identified 10 EEO categories that are

Exhibit 1.c

**Plant Activity as Series of
Elementary Energy Operation (EEO)**

- * Operating Conditions:
- level of production
 - variations in work
 - load (seasonality)
 - production costs
 - employment level

Exhibit 1.d
Elementary Energy Operation

considered comprehensive and useful because of the insights they provide into all major energy-using activities. These categories, which represent energy end uses, are:

- 0 Electricity self-production
- 1 Thermal mass transfer
- 2 Liquid heating
- 3 Metal and alloy thermal treatment
- 4 High-temperature ($>450^{\circ}\text{C}$) heating of various materials*
- 5 Low-temperature ($<250^{\circ}\text{C}$) heating of various materials
- 6 Space heating
- 7 Lighting
- 8 Mechanical drive
- 9 Electrolysis.

All plant data are regrouped into these 10 categories.

The second important concept is the product/process. A product/process involves a succession of EEOs needed to transfer a given product A into a product B. An individual plant may have one or many product/processes. These can be illustrated in several ways. For example, such product/processes as cement/dry process and cement/wet process share a common product manufactured by different processes. Conversely, with brick and tile, the same process is used to produce different products. In the case of welded tubing and continuously casted tubing, the product/process deals with similar, competitive products produced by different processes.

* Because few heating applications were found between 250°C and 450°C , this temperature range was not formally reflected in any EEO category.

This differentiation enables CEREN to gain insights into the marketplace.

To identify product/processes, products are first characterized by CEREN at a level equivalent to the 4-digit SIC code. Next, each product is differentiated further by process. To date, CEREN has identified and works with 257 product/processes that represent 95 percent of industrial energy consumption in the 5,000 plants surveyed by CEREN.

Following product/process identification, plant data are regrouped at the product/process level (e.g., all plants producing bricks, or all plants producing cement by the wet process).

The two-step aggregation, by product/process and EEO category, is justified because plants characterized by the same product/process are also characterized by similar sets of EEOs. The product/process concept, in combination with the EEO concept and detailed data collection, contributes to an understanding of the impacts of process changes, product and process substitutability, and product competition.

Brick manufacturing can provide an example of the application of the product/process and EEO concepts. As Exhibit 1.e illustrates, the brick product/process at the plant level can be viewed as a series of EEOs. Raw materials are transported in the plant on a conveyor system; then the material is slurried, compacted, dried, and baked. Each operation represents a separate EEO. Space heating and lighting in the plant are also considered EEOs.

In the brick product/process, only six EEO categories of the ten previously described are represented as shown in Exhibit 1.e. By performing the EEO category distribution for all brick manufacturing plants and summing the results, CEREN can obtain the energy consumption profile in the generic brick product/process.

Aggregating data using the product/process and EEO category concepts enables CEREN to characterize fully the use of energy in brick manufacturing at the national level.

Exhibit 1.e

Example of Product/Process EEOs and EEO Categories
for Brick Manufacturing

As shown in Exhibit 1.f, this aggregation provides an overview of fuel and electricity inputs and energy end uses (EEO categories). Exhibit 1.f depicts energy flows for a general product/process, with energy flows for the brick case highlighted with shading.

The sample data matrix for brick manufacturing shown in Exhibit 1.g is representative of the type of information CEREN collects for a product/process. It indicates some of the detail and diversity of information that can be achieved through the product/process and EEO category concepts. The first and second columns in the exhibit show the EEOs and EEO categories associated with the brick product/process. Under the "Fuel" columns, an example of the specific consumption of energy per ton of brick production is shown in each EEO category. These data help identify the energy-intensive stages in brick manufacturing. All of the data in the matrix are available after processing in the form of averages, medians, or statistical distributions.

This framework is used to evaluate all 257 product/processes reviewed by CEREN. It can also be applied to an industry with a number of product/processes. In that case, by adding energy-use profiles for each product/process within the industry, the planner can calculate the aggregated industry consumption profile. This approach can also be followed to derive energy-use profiles by industry group.

Exhibit 1.f

The CEREN Approach: A General Flow Analysis of Energy Use in a Product/Process

Energy Inputs

Energy End Uses
EEO Categories

Sample Flow of Energy Use
for Brick Manufacturing
(EEO)

Exhibit 1.g

Sample Data Matrix for Brick Manufacturing

Year: 1975
 Industry group: Construction Materials
 Industry: Brick and Tile
 Product/process: Brick
 Production: $7,885 \times 10^3$ Tons
 No. of plants: 75
 Employment: 6,500

EEO	EEO Category	Fuel				Electricity		
		Specific Consumption (1,000 Btu/ton)	Percent	T° (C) (Operating)	Equipment Age	Specific Consumption (kWh/ton)	Percent	Equipment Age
Drying of bricks	1	1,080	39.7	150	6	20	43.5	3
Hot-water system	2	160	5.9	80	10	—	—	—
Baking	4	1,440	52.9	850	10	14	30.5	5
Space heating	6	40	1.5	20	10	—	—	—
Lighting	7	—	—	—	—	3	6.5	—
Mechanical drive	8	—	—	—	—	9	19.5	5
Total		2,720	100.0			46	100.0	

2

IMPLEMENTATION OF THE CEREN SYSTEM

The design of the system is not the only unique feature of the CEREN's approach: the effectiveness of the system is in part attributable to the way it is administered. To implement its industrial data system, CEREN must first collect data on energy use in 5,000 plants. This task is accomplished by means of a 12-page questionnaire (one questionnaire per plant) that is divided into two parts. Part 1, General Statistics, focuses on total energy consumption data, plant operating conditions, capacity expansion plans, and labor resources. These data provide an analysis of how the plant secures its energy supply (e.g., the nature of supply contracts with utilities). In Part 1, energy uses are not broken down by product/process; instead, aggregate energy data are provided for the entire set of processes. This macroview permits direct compilation of data at the plant level and is useful for deriving operating ratios based on the size of plants. These ratios can be used to review possible economies of scale within each industry. Part 2 of the questionnaire, Plant Equipment Survey, identifies energy uses by product/ process and inventories equipment in relation to the EEOs.

Given its scope, the implementation effort is relatively efficient. Compiling 5,000 questionnaires requires about 60,000-75,000 person-hours. The data collection process lasts 2-3 months and employs up to 200 temporary surveyors; data evaluation and processing takes approximately 5 months, given the small size of CEREN permanent staff (currently under 50 full-time employees).

The CEREN survey is conducted every 4-5 years. To date, three surveys have been completed: in 1967, 1972, and 1976. The next is scheduled for 1980.

The cost per questionnaire is approximately \$100. However, the logistic features of the CEREN system explain this unusually low cost. In the data collection

phase, the low cost per questionnaire is the result of the low compensation for the temporary surveyors. Additional voluntary assistance from plant employees and managers also reduces costs. In the data processing phase, CEREN benefits from the use of computer facilities of the French Institute of Statistics and Economic Studies (INSEE) for a low fee. Without these special arrangements, the cost per questionnaire would range from \$400 to \$500.

Implementation involves three stages -- data collection, evaluation, and processing. These stages ensure the validity, quality, confidentiality, and completeness of the data gathered.

DATA COLLECTION

The data collection process involves both preparing and conducting the survey.

First, the design of the questionnaire must be reviewed. CEREN modifies previously used questionnaires to meet new information needs, taking into consideration any energy-related issues raised since the preceding survey. In modifying the questionnaire, CEREN takes care to ensure that the data can still be reconciled with information collected previously.

All plants consuming over 20 billion Btu at the date of the survey are surveyed. The list of these plants is updated for each survey, using data from (INSEE). INSEE maintains a file of partial or complete shutdowns and accounts of new plants installed since the last survey. On the basis of this information, CEREN also identifies plants that have increased their energy consumption to over 20 billion Btu per year. Before installing the updated list, CEREN checks the information with complementary data from various trade associations.

Before each survey actually begins, CEREN obtains trade association agreements to contact the selected plants. The CEREN central staff then assigns regional survey leaders

to recruit and train surveyors. Most of the surveyors are retired engineers from the companies that are members of CEREN. Since these companies are among the largest industrial companies and utilities in France, finding the necessary manpower is not difficult. If necessary, engineering students are also hired.

This recruiting approach guarantees a highly skilled, cost-effective work force for conducting the survey. Moreover, the surveyors are knowledgeable about the plants they will have to visit -- familiar with the history of the industry, the technology trends that affect it, and the various product/processes that are used. Furthermore, the surveyors tend to be involved in local industrial activities, since they frequently live in the areas where they will be conducting the surveys. In most instances, for example, the surveyors are personally acquainted with the engineers and plant supervisors employed in the plants they visit. This fact adds credibility to the entire effort.

Once the plants have been selected and the surveyors hired, the surveyors notify the various plants that a survey will be conducted and mail out blank questionnaires. This procedure gives plant managers time to review data needs, thus minimizing the time surveyors must spend on-site.

Before visiting a plant, the surveyors review historical records of the plant energy consumption (available through CEREN internal files and contact with regional utility headquarters) and the CEREN questionnaires completed during the previous surveys. This procedure guarantees that the surveyors have a good understanding of the past activities of the plant. With such an understanding, the surveyors are better able to identify any major changes that have occurred since the last survey and to gather information on new processes and equipment or changes in operating conditions of the plant.

Plant management will provide much of the information gathered in the questionnaire. The general statistics section is usually completed by the purchasing and production departments of the plants, with minor

participation by the surveyors. Most of the data for the plant equipment survey are collected from the manufacturing, maintenance, and cost accounting departments.

Generally, the surveyors spend 1 to 1-1/2 days visiting the manufacturing facilities and gathering information. The time spent depends mostly on the number of energy operations to review. For example, in a cement-manufacturing plant, where energy-consuming operations are limited, the data collection may require only an hour or two. But in a chemical plant with a wide variety of product/processes, a more time-consuming review of the manufacturing process flowcharts will be necessary.

In identifying EEOs within a plant, surveyors are guided by the following procedure:

- Categorize processes by product equivalent to a 4-digit SIC code level
- Group, within a given product/process, operations that are characterized by the same material output
- Identify, within these groups, those operations that use the same type of equipment
- Distinguish between types of energy consumed by these types of equipment
- Categorize equipment according to exhaust energy produced.

Generally, 80-300 EEOs are identified in each plant. In following this procedure, each surveyor will survey an average of 15-20 plants during the 2-3 month data collection period.

DATA EVALUATION

Quality control is an important feature of the CEREN system. The expertise of the surveyors is the primary

guarantee for gathering the largest amount of relevant and valid data. By developing an adequate dialogue with plant management, the surveyors evaluate the validity of the data provided and, depending on their findings, make additional calls as a result of their reviews. Each surveyor indicates his overall judgment of the validity of each questionnaire.

Next, all questionnaires collected are reviewed by CEREN staff. On the basis of their review and the review by surveyors, CEREN analysts evaluate and code the quality and quantity of information in each questionnaire. This step allows CEREN to evaluate the effectiveness of the questionnaire design in particular, the impact of recent changes in the design. Follow-on calls needed to complete the data gathering are done by CEREN staff.

DATA PROCESSING

The information from all satisfactory questionnaires is then processed according to complex procedures. First, CEREN staff regroup EEOs by EEO categories, making adjustments where necessary to reconcile data within the same product/process segment. Next, computer programs are used to derive energy-use breakdowns by EEO categories or by unit of output at the following levels of aggregation: product/process; all plants within a given industry; all plants within an industry group or within several industry groups; all industry groups within a region; the entire country (see Exhibit 2.a). Other programs separate energy-use data by sizes of plants to review concentration of energy consumption across industries or industry groups. CEREN also uses programs to derive statistical distributions of energy use.

As a result of applying these programs, CEREN generates four types of statistics after each survey. Overall consumption statistics are obtained by aggregating total

Exhibit 2.a

CEREN Industry Breakdown

Example

plant energy consumption data at a given level. These statistics are useful for gaining an overview of energy use in the French industrial sector. Plant energy-use patterns are obtained by aggregating plant energy-use data at the industry or industry-group level. From these statistics, CEREN can compare plants within the same industry. Profiles of energy-using equipment are obtained by aggregating plant data at the industry or industry-group level. Specifically, performance characteristics and age of equipment are averaged and statistical distributions computed by categories of equipment. Finally, CEREN develops product/process characterizations. Each product/process is summarized in a matrix containing a set of variables:

- Total output, production capacity, product added value, number of employees, and number of plants
- Total equivalent energy consumption by unit of output, energy used for process heat, process steam and electric generation on-site, and total use of raw materials
- Breakdown of energy use by EEO categories.

3

APPLICATIONS OF THE CEREN SYSTEM

The CEREN industrial energy-use data system can test a wide range of energy-related issues and energy conservation scenarios. By collecting disaggregated energy data and operating conditions at the plant level throughout the French industrial sector, and then aggregating this information using the concepts of product/process and EEO category, CEREN has created a data system of value to both public and private sectors.

Using the statistics on overall energy consumption, plant energy-use patterns, energy-using equipment profiles, and product/process characterizations, CEREN can analyze:

- Energy uses by industry
- Energy-use patterns across dependent industries
- Financial and social cost impacts of energy conservation actions (see Exhibit 3.a).

Since 1974, CEREN has conducted studies in more than 20 industries. Cross-industry analyses have been emphasized since 1976, while cost impact studies, the most complex of the three analysis areas, began more recently.

ANALYSES OF ENERGY USES BY INDUSTRY

CEREN has developed a systematic approach for analyzing energy use in a given industry. For that purpose, CEREN typically:

- Determines the energy content of finished products
- Assesses the overall potential for energy conservation improvement

Exhibit 3.a

**Synopsis of CEREN Analysis of
Industrial Energy Conservation Issues**

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- Analyzes the impact of process efficiency improvements
- Evaluates the impact of new technologies or new energy sources
- Forecasts energy consumption by industries.

CEREN determines the energy content of finished products by developing ratios based on energy use and production outputs. This calculation stems from a direct use of product/process analysis. Exhibit 1.g shows the type of information matrix that can be assembled for brick manufacturing. Bricks are manufactured through a succession of EEOs. By adding together the specific energy consumption of each EEO involved, CEREN can determine the energy content per ton of brick production. The specific type of energy resources embodied in each unit of output can also be derived (e.g., percentages of high- and low-temperature thermal energy, electric energy, fuel consumption). Energy data are also compared with type and age of equipment and operating conditions. These studies are useful in assessing the dependence of some products on a given type of energy or the performance of different plants compared with each other.

CEREN analyzes the potential for energy conservation improvements by reviewing the product/process and examining the distribution of temperature inputs and outputs for energy operations in a plant. Since product/processes are characterized by the relative amount of energy use and temperature profile for each category of EEO, CEREN's data bank includes this information. By matching energy uses between EEOs, energy conservation opportunities can be identified for such technical options as waste heat recovery, energy cascading, optimization of energy flow, and sequential control of heat transfer between EEOs. For example, if the CEREN characterization of a product/process indicates that the average exhaust temperature of high-temperature heating operations (EEO category No. 4) is close to the average input temperature of the thermal mass transfer operation category (EEO category No. 1), there may be an opportunity for heat recovery improvements. Once the

potential conservation techniques are identified and their technical feasibility assessed, CEREN can evaluate the market opportunity for new conservation technologies for entire industries and industry groups. CEREN followed this approach in analyzing the potential market for such technologies as heat pumps, bottoming cycles, and energy storage systems.

The impact of process efficiency improvements can be assessed by CEREN either at the product/process, plant, industry, or industry-group level. Because the data system contains all the information related to the EEOs of any given product/process, CEREN can aggregate energy data from EEOs, product/processes, and plants, and determine the compounded effect at any level. Studies of process efficiency improvements are critical to forecasting future trends in industrial processes within the same industry wherever several processes are used to produce the same product (e.g., dry and wet process cement). Once the contribution of each process to overall industry production is identified, estimates of expected energy savings compared to current industry performance can be derived.

Similarly, the impact of new technologies or sources of energy is evaluated by incorporating the appropriate changes at the EEO level and deriving compounded changes at either the product/process, plant, or industry level. The impact on use of scarce resources (e.g., oil and gas) and resulting energy savings (e.g., fuel type, by type of equipment; by time frame) can be determined. Impacts on the cost performance of each product/process can also be analyzed.

Forecasts of energy consumption by industries are derived by CEREN through the energy relationships established between production output and energy inputs for each product/process and its associated EEO categories.* About 15 industries have been analyzed to date using a simulation model designed for this purpose.

*Production output forecasts are generally provided by INSEE.

ANALYSES OF ENERGY USE ACROSS INDUSTRIES

To evaluate the full effect of conservation actions, the impact of these actions on energy use across industries must be examined. Interdependencies among industries affect not only the nature and vulnerability of the industry's product/processes but also its overall production output level. Different industries may have different access to scarce resources that result in different energy uses. Industries may rely entirely on the production of other industries for the primary input to their product. Finally, the production output level of any industry is geared to the level of market demand, which is affected by market competition from other related industries.

As a result of cross-industry analysis, the government may plan such actions as substituting one product for another that meets the same market requirements with different types and levels of energy inputs. In one case, CEREN studied opportunities for switching from copper to plastic pipe. The energy impact of such a switch was evaluated by comparing the increased energy consumption for producing more plastic pipe with decreased consumption resulting from producing less copper pipe. The impact of complete substitution or creation of a competitive market between interchangeable products can be evaluated in terms of both energy savings and incidence of changes in energy-using equipment and operating conditions in the competitive industries.

Cross-industry effects can also be important for identifying process improvements. An improved process that reduces demand for material input can reduce the dependency of the benefitting industry on its suppliers. When generalized, this process improvement is likely to reduce energy consumption and may change operating conditions and production capacity in the suppliers' industries. Understanding these consequences aids in evaluating overall benefits from process improvements.

FINANCIAL AND SOCIAL COST OF ENERGY-RELATED ACTIONS

Government actions aimed at increasing process efficiencies, introducing new technologies, or using new energy sources can alter production capacity level, capital needs, employment level, and import requirements within one or several industries. CEREN can assess these impacts at both the regional and national levels.

For forecasted changes in production in an industry or an industry group, CEREN data can help determine equipment needs and levels of investment required. This task is accomplished by tracing back the number of units of equipment needed for each EEO by unit of output and evaluating corresponding capital costs. Estimates of industry capacity and capital requirements can be derived to help plan or forecast future energy expansion.

Trade-off analysis between the cost of government actions (e.g., tax incentives and low interest loans) and benefits from energy conservation improvements (e.g., lower production costs, higher employment, better use of capital) can be performed on the basis of CEREN data. By trying various configurations of incentives on the trade-off analysis model, incentive policies can be selected and calibrated to achieve the desired effect. Insights into socially optimal levels of government actions can be gained using CEREN data in combination with estimates of long-term trends in capital cost, cost of energy, and economic growth.

CEREN has also begun to analyze the overall impact of energy use on industries by taking into account not only the level of investment but also the effects on employment, balance of trade, and import vulnerability. To address these issues, CEREN can evaluate for each product/process the quantity of domestic and imported energy, the quantity of domestic and imported raw materials, and the quantity of domestic and imported capital for industrial investment needed to produce one unit of output of the given product.

Through this understanding of the key foreign components embodied in a product, planners can assess the impact of increased production in one industry on the country's balance of payments, on its energy and critical raw materials dependencies (and therefore its vulnerability), and on its foreign investment situation.

This concept becomes critical when evaluating two or more products that could be substituted because they meet similar market requirements. By evaluating the advantages and disadvantages of the products along such dimensions as capital cost, unemployment, and foreign trade, it is possible to identify products that best fit with national policies and goals.

For example, CEREN evaluated the comparative trade and balance-of-payment benefits of production of metallic versus plastic bodies for automobiles in France. Several other studies are currently under consideration for the Delegation of Raw Materials and Energy under the French Ministry of Industry.

This new type of cost assessment is valuable in designing specific action plans for different industries. If one product is associated with a high "import value" content, government actions through regulations and incentives can influence the supply and demand for that product. However, the choice between substitutable products is generally not so straightforward; similar products rank differently according to different criteria such as import value, energy and raw materials dependencies, labor intensiveness, and capital requirements. Trade-off analyses are therefore frequently required.