**THE USE OF THE REFERENCE ENERGY
SYSTEM AND EEMIS TO ANALYZE SOME
CAUSE-EFFECT RELATIONSHIPS**

J. D'ACIERNO AND A. HERMELEE

MASTER

November 1979

**TECHNOLOGY ASSESSMENT GROUP
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ABSTRACT

The Energy Emergency Management Information System (EEMIS) and the Reference Energy System (RES) form an ideal framework for analyzing cause-effect relationships in the petroleum and natural gas energy systems. This report presents four case studies that demonstrate the applications of EEMIS and the RES for analyzing (1) the relationships between weather and the demand for energy in regions of the U.S., (2) the effect of a refinery outage on oil product distribution, (3) the impact of transportation outages on the flow and supply of petroleum, and (4) the relationship between income and energy usage.

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I. INTRODUCTION

The Reference Energy System (RES) and the Energy Emergency Management Information System (EEMIS) are two important tools which can be used to relate different activities in the U.S. petroleum and natural gas energy systems. The RES is an analytical representation of the many activities in the U.S. energy system and it shows the interrelationships between activities in this network using energy flows. The actual interfuel relationships are represented for the activities where they exist in the physical systems. The RES is therefore an ideal framework for relating causes and effects which pertain to every form of energy, including petroleum and natural gas. The design of EEMIS was based on the RES with details added to refining, conversion, transportation, and storage activities in order to provide timely energy information necessary to manage short-term emergency situations.

Four cause-effect relationships are presented in this report. First, the relationship between weather and the demand for energy in regions of the U.S. is discussed using actual information from the RES. In Section III the EEMIS data structure is used to determine the effect of a refinery outage on oil product distribution. The application of EEMIS for evaluation of the impacts of transportation outages on the flow and supply of petroleum is discussed in the third section. Finally, the relationships between income and energy usage are shown and the relevance of these relationships to EEMIS is discussed.

II. WEATHER - DEMAND

The RES contains considerable detail on energy demand and energy services at the state, regional, and national levels of aggregation. To analyze the effect of variations in weather upon the demand for energy, the RES can be used to compute alternative patterns of energy consumption that are dependent upon weather abnormalities. The end-use sector that is most directly affected by deviations from normal weather patterns is residential and commercial space heating. Energy service levels for space heating are specified on the RES in terms of unit energy requirements and building inventories (see Figure. II-1). End-use device efficiency and fuel mix are also contained on the RES. Forecasts of energy consumption computed from these values generally assume normal weather conditions.* Energy savings or increased energy consumption due to deviations from the norm can be computed directly from the energy service levels specified on the RES.

Heating season forecasts of demand for No. 2 fuel oil by oil industry experts and natural gas by natural gas industry spokespersons assume normal weather patterns. Any deviations from this norm will require adjustments in energy supply. In the natural gas industry, for example, all pipeline and

*"Normal weather" is defined by the National Oceanic and Atmospheric Administration (NOAA) as the 30-year average of the mean day temperature from 1941 through 1970. The mean day temperature is defined as the mean of the daily minimum and maximum temperatures.

REFERENCE ENERGY SYSTEM, YEAR 1977

Figure II-1

distribution companies must report deliveries and curtailments of natural gas to end-use customers by month for the current and projected years in the Natural Gas Curtailment System (EIA-50). Instructions for the system specify that normal weather patterns should be assumed in developing forecasts. If deviations from this pattern occur, perturbations in the flow of energy required for space heating can be estimated by computing change in heat loss in residential and commercial buildings due to abnormal weather.

Energy requirements for space heating are a function of heat loss in a building and can be computed from the coefficient of heat transfer, area, and temperature as follows:

$$\text{Heat Loss} = U \times A \times HH \times \Delta T, \quad (\text{II-1})$$

where

U = coefficient of heat transfer (U-value or 1/R-value for transmission heat losses),

A = surface area,

HH = heating hours,

$$\Delta T = 65^{\circ} - \frac{\text{degree days}}{\text{heating days}}.$$

Thus, heat loss due to abnormal weather patterns is proportional to ΔT and can be computed once average temperature is given.

In the case of the 1976-77 winter, record cold temperatures occurred along the East Coast and in the East North Central States (Illinois, Indiana, Ohio, Michigan, and Wisconsin). The West Coast and Mountain States, on the other hand, experienced a relatively mild winter as evidenced by the heating degree-day data shown in Table II-1 for two weather stations.

Table II-1
1976-77 Heating Degree-Day Data*

Location	1976-77	Normal	Departure from Normal
Cincinnati, OH	6286	5070	+24%
Denver, CO	5563	6016	- 8%

*The "heating degree-days" for a given date is the number obtained by subtracting the average of the minimum and maximum temperatures for that date from 65. The 1976-77 season runs from July 1, 1976, through June 30, 1977.

Source: Weekly Weather and Crop Bulletin, NOAA.

To compute additional heating requirements in the East North Central States during the 1976-77 winter let us assume that heating degree-days in the region averaged 24% above normal, as was the case for Cincinnati, OH. Then, from Equation (II-1), heat loss is also increased by 24%. Of course, wind, hours of sunshine, and humidity also must be factored into actual heating requirements, but assuming these variables remain constant, energy requirements for residential/commercial space heating during the 1976-77 winter can be computed using energy service levels specified on an RES for the East North Central Region as follows:

$$E = [(E_u \times B)_{\text{res}} + (E_u \times B)_{\text{com}}] \times \Delta \text{HDD}, \quad (\text{II-2})$$

where

- E = energy requirements for residential/commercial space heating in the East North Central Region during the 1976-77 heating season,
- E_u = region-specific energy requirements for space heating per household or square foot of commercial floor space assuming normal weather,
- B = basis, number of household or commercial inventory in the region,
- ΔHDD = deviation from normal heating degree-days.

Thus,

$$E = (73.1 \times 10^6 \frac{\text{Btu}}{\text{HH}} \times 12.8 \times 10^6 \text{ HH}) + (33,700 \frac{\text{Btu}}{\text{ft}^2} \times 4.7 \times 10^9 \text{ ft}^2) \times 1.24,$$

$$E = 1.36 \times 10^{15} \text{ Btu.}$$

Energy requirements for space heating during the 1976-77 winter in the East North Central Region were approximately 1.36×10^{15} Btu compared to 1.09×10^{15} Btu during a normal heating season, an increase of 0.27×10^{15} Btu. To convert these Btu values to delivered energy in terms of barrels of oil, cubic feet of natural gas, or kilowatt-hours of electricity, they are divided by end-use device efficiency and the building inventory disaggregated by fuel type. This results in 400,000 bbl/day of No. 2 fuel oil, 1500 million Mcf of natural gas, and 24.3 billion kWh of electricity consumed for space heating in the region during the 1976-77 heating season. Assuming normal weather in the region, 77,000 bbl/day of oil, 300 million Mcf of natural gas, and 4700 million kWh of electricity would have been saved in the region that year.

A similar analysis can be performed for states in the Mountain Census Region (Montana, Idaho, Wyoming, Utah, Nevada, Colorado, Arizona, and New Mexico) assuming heating degree days in the region averaged 8% below normal

during the 1976-77 season, as they did in Denver, CO (see Table II-1). This results in an energy savings of 3000 bbl/day of heating oil, 19 million Mcf of natural gas, and 500 million kWh of electricity relative to a normal year.

As illustrated in the example cited above, weather-related effects of energy consumption tend to be regional in scope. In the event of a natural gas shortage due to a sudden increase in demand because of cold weather, natural gas transmission and distribution companies will reallocate natural gas from a region of adequate supply to those requiring additional supplies. Gas companies routinely reallocate supplies in this manner, both as a part of their everyday operations and in the event of a major supply shortfall. Oil companies similarly reallocate supplies of heating oil in the event of regional shortages caused by unusually cold weather. Data contained within the EEMIS structure will provide sufficient information to monitor these allocations by the oil and gas industries. In the event industry allocations are not adequate to meet demand, causing plant shutdowns, school closings, and a threat to residential/commercial energy supplies, the EEMIS structure will be used as a basis for allocating supplies. Using data from the EEMIS transportation network and oil and gas sectors in conjunction with demand data calculated from energy service levels in the RES, the EEMIS user can assess the impact of alternative allocation schemes. In consultation with industry, oil and gas can then be rerouted so as to minimize regional supply shortfalls.

III. REFINERY OUTAGE - PRODUCT DISTRIBUTION

The distribution of oil products to consumers in the U.S. is a complex process which originates at oil refineries in both the U.S. and foreign countries. Domestic refineries, which produced 16.8 MMbbl/day of oil products during 1978, are by far the most important source of supply for the nation. This represents 89.4% of total demand and the remaining 10.6% originated in foreign countries, notably those located in the Caribbean, Europe, South America, and the Middle East.

There was a total of 311 oil refineries in the U.S. as of January 1, 1979, and refinery data are often presented in a framework of thirteen refining districts (Figure III-1), which are subdivisions of PAD districts. The district with the smallest area is the Texas Gulf Coast District; however, it contains the largest total crude oil distillation capacity of all the districts, over 4.2 MMbbl/day which is 24% of the total refining capacity for the U.S. Other major refining districts are as follows: the West Coast, 17% of total capacity; Indiana, Illinois, Kentucky, etc., 16%; and the Louisiana Gulf Coast, 14%. Together with the Texas Gulf Coast these districts account for over 70% of total refining capacity in the U.S.

The East Coast has about 10% of the total U.S. refining capacity, which is small relative to the East Coast population and the demand for oil products there. Much of the East Coast is totally void of oil refineries. For example, in all of New England there is only one small refinery with a distillation

PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICTS

Figure III-1

Refining Districts of the United States

capacity of 13,400 bbl/day. In New York there are only three refineries and these are located upstate in Buffalo and Albany. As a result of the disparity between refinery location and demand in the Northeast, it is not surprising that one or a few refineries are the major source of supply for the region. For example, the Linden, NJ, Exxon refinery processes 290,000 bbl/day of crude and is a major supplier in the Northeast.

The disparity between the location of refining centers and demand is not unusual in many parts of the U.S. There are no refineries in Iowa and negligible refining capacity exists in Wisconsin, Missouri, Arkansas, and Tennessee. These states are supplied by pipeline or barge and small tanker shipments from refineries in Illinois, Kansas, Oklahoma, and along the Gulf Coast. South Dakota has no refineries and North Dakota has only one. These states can receive supplies from Kansas, Oklahoma, and Texas by pipeline.

Since refining centers are often located far from areas of demand, the oil product transportation and distribution system is an important part of the oil industry. This system moves gasolines, jet fuels, distillate and residual fuel oils, and other products from oil refineries to end users. There is a major oil product pipeline system which carries products from the Texas and Louisiana Gulf Coast area to the Middle Atlantic States, the Midwest, and the Northeast. The Mississippi and Ohio Rivers are used to carry products by small tanker and barge into the center of the country from refineries and terminals on the Gulf of Mexico. Tankers also move from this area to the Northeast using the Atlantic Ocean and intercoastal waterways.

The largest portion of refinery shipments is sent to large wholesalers, called bulk terminals, which in turn distribute the products to smaller wholesalers, called jobbers, and retail distributors. Only a fraction of shipments is sold directly to end users. The EEMIS data structure was designed to capture information concerning the flow of oil products in the most efficient manner with regard to data collection. As a result, refineries and product terminals are monitored at the individual plant (i.e., "facility") level. EIA's definition for the product bulk terminal is used: "a facility which is primarily used for storage and for marketing of gasoline, kerosene, distillate, and residual fuel oils and which (1) has total bulk storage capacity of 50,000 barrels or more, or (2) receives its petroleum products by tanker, barge or pipeline."* Monitoring of every such product bulk terminal facility will capture the flow of product imports to the U.S. as well as the major flows from domestic oil refineries into terminals and out to end users and distributors (Figure III-2). Since EEMIS is a supply-driven system, demand for oil is derived by integrating output quantities from all primary suppliers (oil refineries and bulk terminals) to demand sectors which are disaggregated by state. Destinations for outputs from primary suppliers are the crucial data elements needed to derive demand in this fashion.

*Instructions for Preparation of the Monthly Bulk Terminal Stocks of Finished Petroleum Products Report (FEA-P321-M-0).

Figure III-2
Representation of the Physical Flow of Petroleum Products in the U.S.

EEMIS provides data for tracking the flow of oil products by systematically monitoring operations at individual refineries and bulk terminals. Output quantity, product type, and destination are key data elements which are collected from refineries to track the flow. The destination for refinery shipments is the state and demand sector where the products will be consumed. For bulk terminals it is necessary to monitor quantity, product type, source and destination for both inputs and outputs. Sources are specific oil refineries and, in the case of imports to a terminal, foreign countries. Destination data are the same for both refineries and bulk terminals.

It is very important for EEMIS to systematically monitor individual oil refineries and product bulk terminals in this way so that the actual flows, which can be extremely complex, can be structured in order to link a specific refinery or foreign country with distributors and consumers in distant states. Figure III-3 is a diagram showing the actual flow of oil products from a refinery and a foreign country for two states. As can be seen, the actual flows are often very complex. Outputs from both the refinery and the foreign country are often commingled in storage at the product terminal and then shipped to distributors and end users in both states. EEMIS combines data from

Figure III-3

Schematic Diagram of the Distribution of Oil Products in Two Adjacent States

different facilities to provide the data links for movements, so that the actual supplier for each state and demand sector is known. For example, refinery shipments often go to a bulk terminal, and in this case the refinery dispatcher does not know the ultimate destination. EEMIS data for the bulk terminal specifies the destination of shipments so that when this information is combined with refinery data the ultimate destination can be derived. This type of information can only be synthesized when refinery and terminal data are gathered with an overall systematic approach, such as is provided by the EEMIS data structure.

EEMIS can evaluate the impact of refinery outages due to work stoppages, sabotage, or a natural disaster such as a fire or an earthquake. EEMIS data can quickly identify the states and regions affected, and determine the magnitude of the lost supply for each state and region. This information can be quickly determined because the flow of oil products from individual refineries to bulk terminals, distributors and end users is systematically monitored. Figure III-4 shows an example of the energy flows which are provided by EEMIS using facility level refinery and bulk terminal data. A supply analysis is done for this simplified example to show how EEMIS can be used to determine the effect of the loss of refinery 4 on the supply of a given oil product in four states. The result of the analysis gives the quantity and percentage of supply that flows from this refinery to each state so that the EEMIS user can determine the impact of the loss. By virtue of the complex transportation and distribution system, including approximately 1850 product bulk terminals, which efficiently supplies every user from the 311 domestic refineries and from 48 foreign countries, the actual suppliers for each state are seldom as obvious as those in Figure III-4. Nevertheless, these analyses can be performed on EEMIS data to pinpoint all refineries and bulk terminals which supply each state.

Monthly supply analyses can be performed by EEMIS so that the user can quickly identify potential suppliers. The contacts file can be used to get in touch with these suppliers for up-to-the-minute information and to implement reallocation or product rerouting. Historical data can also be used as a basis for a supply analysis so that all previous suppliers for the affected states are known. The EEMIS user can look at the current storage levels and outputs for all potential new suppliers to plan an allocation or product rerouting scheme. Such options to remedy the shortages caused by the outage of a major refinery will usually have secondary effects. For example, the states normally supplied by the refineries and terminals ordered to allocate or redirect outputs will experience shortages as a result of the orders. The historical and current EEMIS flow data for all candidates for redirection and allocation can be carefully studied and, with the overall objective of minimizing secondary shortages, the optimum candidates can be selected. Alternatively, flow data can be used to create a "shortage" of one fuel in an area where alternate fuels can replace fuels being redirected.

Stocks of finished products may not be available for allocation and it may not be possible to reroute shipments without imposing a serious secondary shortage. In these cases EEMIS refinery data can be used to locate refineries which have idle capacity and are capable of shipping products to the states

Figure III-4

Example of Application on EEMIS Data to Determine
Relationship Between a Refinery and Demand

(Units are 10,000 barrels of one oil product type for a given time period)

Object: Determine the effect of Refinery 4 outage on demand.

Assumption: It is not possible to obtain the true identity of the source facility for a given shipment from a terminal. (This is not unrealistic, since supplies of the same type of product from many different companies are usually commingled in the same storage vessel at a bulk terminal.)

Analysis:

- A. Determine the percent of supply to product terminal 2 which originates from refinery 4:

$$\frac{\text{Refinery 4 Supply}}{\text{Total Supply}} = \frac{10}{28} = 35.7\%$$

- B. Derive the portion of each state's total supply which originates from refinery 4:

State	Primary Supply Facility	Portion Supplied to the State by the Facility
NY	Bulk Terminal 2	8/20 = 40%
NY	Refinery 4	40% x 35.7% = 14.3%
RI	Bulk Terminal 2	2/2 = 100%
RI	Refinery 4	100% x 35.7% = 35.7%
CT	Bulk Terminal 2	15/15 = 100%
CT	Refinery 4	100% x 35.7% = 35.7%
NJ	Refinery 4	2/7 = 28.6%

affected by a major refinery outage. Allocation of crude oil to these refineries is an option that can be considered using crude oil supply analyses analogous to those for oil products.

IV. TRANSPORTATION OUTAGE - FLOW AND SUPPLY

The focal point of the U.S. oil industry is 300 or so oil refineries where about 8.5 MMbbl of domestic crude and another 6 MMbbl of imported crude oil flowed each day in 1978. In addition to the crude flow, 19 MMbbl of oil products moved from these refineries and port cities to consumers throughout the country. The transportation and distribution system consists of many operations which have evolved between crude oil production regions and refineries and between refineries and end users, to distribute crude oil and oil products in the most economical way.

Since it plays a key role in the supply of petroleum, the transportation system must not be underestimated. When the system is put in disarray a shortage can occur which will have an effect on processes and ultimately affect end users in one way or another. Two scenarios will be presented as examples of how outages in the transportation network can change flow patterns, and the effect of these outages on the supply of petroleum will be illustrated. In addition, the EEMIS data structure will be used as a tool to work out the problems that can arise from these outages.

Oil Products Transportation Outage

A major oil refinery along the Texas Gulf Coast provides a significant portion of oil products supply to bulk terminals located along the Mississippi River in Missouri. A series of product pipelines have been used occasionally in the past to move products to the terminals, but movement by water is preferred because it is more economical. Therefore small tankers and barges are normally used to transport products to the Missouri terminals. For this scenario we will impose the constraint that the Mississippi River becomes frozen at a point south of the terminals in January because of unusually cold weather.

At the time when the transportation outage occurs the EEMIS user first assumes the worst possible impact, that the river route cannot be used until mid-March when the ice begins to thaw. EEMIS data for the refinery indicate the volume of products which moved by barge and tanker (on the Mississippi) to the terminals in December, and historical data show that this is about the same as that shipped on the river during the last three years. Normal January, February, and March shipments along the river can be approximated from monthly historical data for the last three years. These shipments are therefore the amount of product shortfall that the terminals will most likely experience for the next three months because the refinery cannot ship on the normal river route.

Refinery output routes for the past five years can be used to determine the paths previously taken along the products pipeline network to reach the Missouri terminals. Alternate routes can be selected with this information and the EEMIS transportation network can now be used to study the new routes to the terminals to learn how much is normally carried along each link during January, February, and March. Capacity data for each link along these routes indicate the maximum amount that can be carried along each route. The difference between the capacity and the normal flow along the routes gives a measure of the excess capacity that would normally be available. Other routes can be drawn if this excess capacity is not adequate to make up the shortfall to the terminals. The data element, transportation links available, is required to determine these other routes between the refinery and the bulk terminals, since these are the first and last links along potential new routes. Excess capacity can be determined for these routes and the total excess capacity for all routes is the limiting amount for determining the actual shortfall that may be experienced in Missouri.

The problem resulting from the frozen Mississippi has a large effect on supply in Missouri and other states north of the block in the river. The state level transportation network provides information which allows the EEMIS user to scope the overall problem. The state level network provides total movements by tanker and barge between refineries in the Gulf Coast States and terminals, electric utilities, and demand facilities in states north of the river block, so that a measure of the total supply problem for states and regions is known. The transportation network can give an estimate of the total excess pipeline capacity available to alleviate the problem by alternate routes. Therefore, the EEMIS user knows the overall extent of the problem, the maximum amount of products that can be moved on alternate routes to reduce the shortage, and the individual problems between specific facilities. This puts problems at individual refineries, terminals, and demand facilities into perspective, and the user has sufficient information to take action, if necessary, to redirect or allocate shipments where products are needed the most.

Crude Oil Transportation Outage

Crude petroleum produced in Oklahoma and Texas travels to a major refinery in Illinois by pipeline. The refinery processes 200,000 bbl/day of a crude slate that is a blend of 50% sweet domestic crude and 50% sour imported crude. Imported crude is transported up the Mississippi by barge and small tanker. EEMIS is called upon to determine the effect on operations at the refinery caused by the destruction of sections of two major pipelines which carry crude oil into Oklahoma.

Historical input route and source data for the refinery show that the destroyed pipelines are a link in the routes which carry almost 100% of the refinery's crude supply from Texas and Oklahoma. Using the contacts file a telephone call to the operations managers for the two pipeline companies can be made to determine how long the pipelines will be out of service. If the

pipelines will be out of operation for more than one week, which is the average amount of time a refinery can operate while drawing from crude stocks, the situation must be evaluated further.

Historical input route data for the refinery can be used to identify alternate routes used in the past and, using transportation network data, it is possible to derive the amount of crude that should be currently flowing on these routes. Capacity data for links along each route can be used to determine the excess capacity available to carry crude by the alternate routes. This is a measure of the amount of the crude shortfall that can be made up by using the new routes. If this is not adequate to prevent a crude shortage at the refinery, the applicable sections of the entire transportation network can be studied to determine other alternate routes to the refinery. Transportation links available for the refinery and crude oil production facilities are necessary to plan all other alternate routes.

The total excess capacity available to carry supplies along all alternate routes gives a measure of the quantity of crude which can travel to the refinery. If this excess capacity is adequate to satisfy the refinery's needs for crude, it is likely that normal rerouting activities by the pipeline companies will resolve the problem. However, this may not be the case because the outages most likely will affect other refineries. Therefore, it will be necessary to investigate activities for other refineries that may be affected by the transportation outage. Input quantity and route data for all refineries in Illinois will give an indication of the quantity of crude supplies that will be lost in that state, and the same analysis can be performed for the Midwest region, PAD 2. This information will show what the total effect will be on the supply of crude oil. This type of analysis might show, for example, that transportation has a major impact only in Illinois. In this case, depending on the magnitude of the problem, it may be necessary to exercise other options such as crude allocation to alleviate the shortage in Illinois. Information already extracted from the transportation network would be needed, in addition to crude stock information, to pursue these options.

V. INCOME - ENERGY USE

Energy use patterns differ markedly among households of varying incomes, with poor households using less energy than more affluent households. This analysis considers not only energy used by families in their homes, but also the energy used for private transportation. These two areas of consumption are jointly referred to as "household energy."

Differences in energy consumption for fuel oil, natural gas, gasoline, and electricity (in terms of primary energy) are shown in Figure V-1 for "poor," "lower middle," "upper middle," and "well-to-do" households.* Although the survey data used in this study to relate income to energy use were collected in 1972,** total energy consumption in the U.S. has increased at an annual rate of only 1.4% from 1972 through 1978. This suggests that relative energy use patterns among households of varying income have not changed significantly since then.

Figure V-1

Household Energy Use by Income Group

Source: Washington Center for Metropolitan Studies, 1972 Survey.

*Income categories in 1978 dollars:

Poor Households, defined as

1 or 2 persons with annual household incomes of \$4,000 or below;

3 or 4 persons with annual household incomes of \$7,000 or below;

5 or 6 persons with annual household incomes of \$10,000 or below;

7 or 8 persons with annual household incomes of \$13,000 or below.

Lower Middle Households, defined as those with annual incomes between the poverty level and \$17,999.

Upper Middle Households, defined as those with annual incomes between \$18,000 and \$23,999.

Well-to-do Households, defined as those with annual incomes of \$24,000 or more.

**A Time to Choose, Energy Policy Project of the Ford Foundation, 1974.

Differences in energy consumption by income group are smallest for natural gas and fuel oil, which are used almost entirely for essential functions such as space heating, cooking, and water heating. The gap between income groups is slightly greater for electricity, which serves basic needs such as lighting and other purposes such as air conditioning and dishwashing, and the gap is greatest for gasoline. Gasoline covers a wide range of needs, from travel to and from work to weekend visits and cross country vacations.

The variations in energy use levels among the different income groups are less pronounced than the differences in income. While the average household income among the poor is one-tenth as large as that of the well-to-do, poor families use almost half as much energy as families who are well-to-do. This means that energy, like other necessities such as food and housing, takes up a considerably larger share of a poor family's budget than an affluent family's. Table V-1 shows the relative portions of family income spent on energy by different income groups. This table shows that poor families spent roughly 20% of their income on fuel oil, natural gas, electricity, and gasoline in 1978, while the middle income groups spent 8 to 10%, and the well-to-do group spent only about 5%.

Table V-1
The Percentage of Family Income Spent on Energy

Income Status	Average	Average Annual Household Energy Use	Average Annual Cost/ Household	Percent of Total Annual Income Spent on Energy
Poor: Total	\$3,700	207 x 10 ⁶ Btu	\$742	20
Natural gas/oil		118 x 10 ⁶ Btu	339	9
Electricity		5040 kWh	217	6
Gasoline		272 gal	186	5
Lower middle: Total	\$12,000	294 x 10 ⁶ Btu	\$1153	10
Natural gas/oil		129 x 10 ⁶ Btu	372	3
Electricity		7330 kWh	316	3
Gasoline		680 gal	465	4
Upper middle: Total	\$21,000	403 x 10 ⁶ Btu	\$1674	8
Natural gas/oil		142 x 10 ⁶ Btu	410	2
Electricity		9900 kWh	427	2
Gasoline		1224 gal	837	4
Well-to-do: Total	\$37,000	478 x 10 ⁶ Btu	\$1977	5
Natural gas/oil		174 x 10 ⁶ Btu	502	1
Electricity		11370 kWh	490	1
Gasoline		1440 gal	985	3

Note: 1978 national average used in computing unit energy cost: \$.0431/kWh for electricity, \$2.62/Mcf for natural gas, \$0.684/gallon for gasoline, and \$0.494/gallon for No. 2 heating oil.

Source: Monthly Energy Review, EIA/DOE, June 1979.

The rapid increase in the price of energy during the 1970's has led to an increasing proportion of a poor family's income being spent on energy. In 1972 about 15% of a poor family's income was spent on energy compared to 20% in 1978, whereas about 4% of a well-to-do family's income was spent on energy in 1972 compared to only 5% in 1978.

The twofold increase in electricity consumption and more than fivefold increase in gasoline consumption per household, as a family moves from the poor to well-to-do income category, will affect the type and quantity of energy required for the future. These shifts in energy use patterns are generally long term in nature, taking a minimum of one year and more likely five or more years to discern at the state or national level, and should be accounted for in developing 5- to 25-year projections of U.S. energy consumption. They do not have a significant impact on the demand for energy over the short term (one year or less) and need not be considered in the short-term demand projections contained within the EEMIS structure. Factors affecting the short term demand for energy generally depend upon weather and fuel availability, rather than life-style changes resulting from increases in household income.