Energy Coefficients and Fuel Substitution Possibilities in The Copper Nickel Area

FINAL REPORT

Data and Analysis, Forecasting
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Regional Copper Nickel Project
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Summary and Recommendations

This report presents work completed by the Forecasting Group of the Data & Analysis Division of the Minnesota Energy Agency (MEA), as required by work agreement M6431, July 1977, executed between the MEA and the Minnesota State Planning Agency (SPA).

The specific objectives of the project were:

(1) to develop a set of energy and fuel use coefficients for major users and industries in the copper-nickel area for a base year, 1974.

(2) to develop a fuel substitution model for large industries in the area, and

(3) to provide additional data or technical personnel as requested by the Regional Copper-Nickel Study Staff of the Minnesota Environmental Quality Council (MEQC).

The overall purpose of the project was to provide the MEQC with base-year fuel consumption data which could be used to forecast future fuel demands in the Copper-Nickel Study Area. Consumption estimates were combined with industry gross output estimates from SIMLAB, the University of Minnesota's economic model of the area, to produce energy and fuel use coefficients. These fuel use coefficients and fuel substitution relationships could then be used by MEQC to tie SIMLAB projections of industry outputs to future fuel demands.

The Copper-Nickel Study Area was defined as Minnesota Economic Development Region 3, plus Douglas County, Wisconsin. A 62-sector grouping for industries was specified to MEA by the Regional Copper-Nickel Study Staff, to coincide with SIMLAB-defined sectors. Early in the project, the benchmark year was changed from 1974 to 1976. Thus, fuel consumption estimates were made for 1976 using all data sources available to MEA. Results of direct inquiries to industries and energy suppliers, and of a fuel use survey conceived and carried out jointly by MEQC, MEA, and the University of Minnesota, were used to supplement consumption estimates compiled on the MEA data base.

A fuel substitution model was built to translate forecasts of industry gross outputs into demands for various fuels, considering such factors as differential energy intensities among industries, changes in relative fuel prices, varying use-efficiencies among fuels, and process rigidities in existing industries. This model was written by MEA as a computer subroutine for SIMLAB.

In accordance with objective 3 of the agreement, residential, gasoline, and electric energy demand models were built by MEA. A structural approach was used because energy intensities are hardly applicable for these end uses and fuel types. In addition, fuel sources and long-term energy supply outlook for Minnesota and Region 3 were examined, and are discussed in this report. Natural gas appears to be the most constraining fuel, both for the state and for Region 3. Shifts to coal are already proceeding in taconite processing, electric power generation, and other large industries. The possibility for alternate energy sources and processes such as coal gasification and peat gasification are also explored for the study area.

Recommendations

Aside from the shift in base period from 1974 to 1976, a significant change affecting the application of MEA fuel use controls and forecasting methods was a redefinition of the specified 62 sectors into the 53 sectors of SIMLAB late in the project. The fuel substitution model has been estimated using survey data on 62 industry sectors. Transformation into 53 sectors was attempted and a computer subroutine of the model was incorporated into SIMLAB. However, lack of time and manpower allowed only rough transformations of the fuel consumption data and fuel substitution parameters from 62 sectors into 53 sectors. It is recommended that survey data be reaggregated to the 53 sectors and regressions performed in order to derive new parameters for the fuel substitution model.

Energy intensities (Btu per dollar output) used by the fuel substitution model may be understated because fuel consumption of industries in Douglas County, Wisconsin cannot be disaggregated with the status of present data. SIMLAB gross outputs include production by industries in Douglas County. Energy intensities should be recomputed by dividing consumption for Region III shown in this report by gross output of industries in Region III only. Alternatively, employment data for Douglas County, Wisconsin should be disaggregated to 53 sectors and used to estimate industry fuel consumption. The sum of Region III and Douglas County fuel use could be divided by SIMLAB output to derive industry energy intensities for the Copper Nickel Area.

Residential, gasoline and electric energy demand models were built for the Copper Nickel Area using all data available to MEA. It will require considerable programming work to incorporate these forecasting procedures into SIMLAB. Predictor variables such as number of household and personal income are not directly forecasted by SIMLAB. Hence, it is recommended that the University of Minnesota revise SIMLAB to forecast these variables and write computer subroutines into SIMLAB using the residential, gasoline and electric energy demand equations given in this report.

As part of its regional forecasting responsibility, MEA will continue to collect and verify energy, economic and demographic data for Region III. Forecasting models built thus far will be consolidated into a regional fuel demand model. To establish reliable fuel control totals at the regional level, industries other than food processing and energy utilities will be grouped according to a 2-digit Standard Industrial Classification (SIC) code. Food processing industries will be specified at the 3-digit level while energy industries will be linked with consumer demands for end-use energy. It is recommended that MEA verify the 1976 results and demographic-economic forecasts of SIMLAB, relative to actual 1976 conditions and forecasts from other sources. This will provide for more rational assumptions regarding the behavior of predictor variables of energy demand in the area.

1.0 Introduction

1.1 Background for the Study

Socioeconomic impact assessment of copper nickel development in Northeast Minnesota is organized around a computer simulation model built at the University of Minnesota. SIMLAB II, the demographic-economic model of the study area, forecasts the level of economic activity and population based on a set of assumptions about the competitive position of local industries, linkages among sectors of the economy, and extent of future copper nickel development. In order to predict impacts on fuel demands, this model requires a set of base year consumption patterns, energy use intensities and fuel substitution possibilities.

The Minnesota Energy Agency (MEA) executed an agreement with the Minnesota State Planning Agency (SPA) for specific work in energy (Attachment 1). This effort was intended to provide SIMLAB with data inputs and submodels for forecasting demands for various fuels in the area. Discussions on forecasting methods, levels of detail, and incorporation of the fuel substitution model into SIMLAB were held among the MEA forecasting group, the Socio-Economic Impact Assessment Staff of the Regional Copper Nickel Environmental Impact Study, and the Department of Agricultural Economics Staff of the University of Minnesota.

MEA is interested in building fuel demand forecasting submodels into SIMLAB. Methods for regionalization of fuel demands can be devised in an area where economic data are not very restrictive. In addition, the state model can be verified upon completion of economic and energy forecasts for all regions. However, inadequate verification of responses from the fuel consumption survey, changes in industry sectors of SIMLAB later in the project, and programming difficulties in incorporating the fuel substitution computer model into SIMLAB delayed the project and limited the scope of this report to the specific requirements of the work agreement. The MEA Forecasting group does not have the responsibility for building operational fuel submodels into SIMLAB, but specifies in this report the input requirements and structure of feasible fuel demand models for the area.

1.2 Objectives of the Study

The work agreement specifies three goals of the project

(1) To develop a set of energy and fuel use coefficients for major users and industries in the copper nickel area for a 1974 base year.

(2) To develop a fuel substitution model for large industries in the area.

(3) To cooperate with MEQC in providing or collecting additional information, data or technical personnel, upon request of MEQC.

The work agreement was first revised by moving the base year from 1974 to 1976. Survey data and direct inquiries to energy suppliers were used to estimate fuel use of major consuming groups in the area. Combined with measures of economic activity for 1976, energy coefficients were derived from the consumption totals.

A fuel substitution model was estimated from survey data organized by the Copper Nickel Study Staff. Problems in obtaining a useful set of primary data set back the schedule and involved significant editing work for MEA Forecasting (Attachment 2). A 62 order industry breakdown specified for the project (Attachment 3) was later revised into the 53 sectors of SIMLAB necessitating reaggregation of industry sectors for the fuel substitution model.

Fuel supply outlooks for Minnesota and Region III are discussed in this report, upon the request of MEQC. The 1978 Energy Conservation and Policy Report of MEA, natural gas curtailment list and other MEA sources were used to project long term supply for traditional fuels.

1.3 Organization of the Report

Section 2 deals with the long term supply outlook for traditional fuels in the state and Region III. Alternative sources are indicated, particularly for the energy intensive taconite industry.

Section 3 discusses methods used to estimate fuel consumption by major end users for 1976. Energy intensities (BTU/employee) of primary fuels are compared with statewide and national averages. Due to limited substitutability, electric energy intensities (kwh/employee) are derived separately. Energy use per dollar output are not calculated because of the difficulty in breaking down industrial energy consumption in Douglas County, Wisconsin, into 62 or 53 industry sectors.

Section 4 shows the structure, estimation methods and forecasting procedures of the fuel substitution model. Also, fuel demand forecasts are presented from a computer run of SIMLAB with a fuel substitution subroutine. Industry gross outputs from SIMLAB drive the model, showing operational status of the computer program. However, the energy intensities may be understated because industry energy consumption in Douglas County, Wisconsin, is not included with the 1976 estimates.

Demand equations and forecasting flow charts for the residential, gasoline and electric energy models are discussed. Data inputs are specified in the appendix along with the computer programs of the fuel substitution and residential models.

2.0 Fuel Supply Outlook

2.1 Statewide

The decline of natural gas supplies is the most crucial energy problem facing Minnesota today. Natural gas supplies transported to the state have declined since 1972. Northern Natural Gas, supplying 93 percent of the state's natural gas, is projecting its supplies to drop 21 percent from 1976 to 1981. Northern expects to offset their dwindling traditional sources partially with the addition of offshore natural gas. This offshore natural gas will peak by 1981 and decline at approximately 10 percent per year to 1995. The remaining 7 percent of natural gas supplies to the state come from Canada. These supplies should begin to decline in 1984 and reach zero by 1992. New supplies can be expected from Alaska as early as 1982 and will remain fairly constant through 1995. Another potential source of gas is a proposed peat gasification plant in 1984. This remains highly uncertain, however, due to environmental considerations.

The overall picture for natural gas is a 5-10 percent annual decline in supplies starting in 1980. This decline could be delayed until 1985 with the successful completion of a small scale peat gasification plant.

A declining gas supply coupled with a moderate growth in residential and small commercial customers has meant heavy curtailments for large industrial users. The first to be curtailed were the electric utilities. The utilities have switched to coal as they are now almost completely curtailed of gas. The second group to be hard hit were large industrial users with alternative fuel capabilities. Many of these have already switched to coal or fuel oil while others face curtailments in the near future.

As natural gas curtailments continue, demand for petroleum products will increase. Long-term availability of petroleum as a substitute fuel for curtailed gas remains highly uncertain.

Petroleum products made from crude oil totaled approximately 45 percent of the state's energy needs in 1976. Minnesota can expect both short-term and long term shortfalls of petroleum supplies.

Canadian crude oil accounts for over 50 percent of our total petroleum needs. With the scheduled curtailments of Canadian crude oil, these foreign supplies will be reduced by 1981 to between 0-12 percent of Minnesota's total petroleum needs. This becomes critical for petroleum suppliers and refinery employment in the state because Canadian crude supplied over 80 percent of Minnesota's refining requirements in 1977. New supply routes for crude oil must be developed to insure the continued production from Minnesota's four area refineries.

Until these new supply routes are developed, the refineries will seek to supplement their crude oil supplies through exchange agreements. These are arrangements by which a U. S. refinery exchanges domestic or U. S.-owned foreign crude oil for Canadian crude oil.

Two crude oil pipelines have been proposed to transport crude oil to Minnesota to replace the Canadian crude. The Northern Pipeline will carry crude oil from the Gulf Coast to Minnesota. It may be operational by 1980. The other is a west coast pipeline designed to bring Alaskan and foreign crude oil to Minnesota and other Northern Tier states. Three alternative routes have been proposed, yet all have encountered resistance. This pipeline is not expected to be completed before the early 1980's.

When these short-term problems are overcome, Minnesota will face the long-term petroleum supply outlook -- declining world reserves. Total petroleum supplies to Minnesota will begin to decline in 1986.

The demand for petroleum in the state is directly tied to declining natural gas supplies. As large industrial users shift from natural gas to fuel oil, petroleum demand could increase faster than the 7 percent historical rate. Although residential demand for petroleum should increase only slightly, commercial and industrial demand could double and triple, respectively, by 1995. Total demand for petroleum will probably outpace supply by 1987.

Again, industry will face the brunt of the petroleum shortfall. Many small industrial users may switch to electricity while the larger users will probably switch to coal. Both present concerns. The switch to electricity for small industrial users may be due to the price structure of electricity, lack of technical know-how and difficulty securing capital. Should large industries substitute electricity for petroleum, it would mean construction of as many as 20 additional generating plants by 1995. In light of recent opposition towards newly planned or constructed generating plants, it seems unlikely that this many plants could be built.

To avert this problem, large industries will choose to switch to coal as a substitute for natural gas and petroleum. Most will burn coal directly while a few will construct on-site low BTU coal gasification facilities. Unlike natural gas and petroleum, the supply of coal to the state is not limited by the amount of coal reserves in the ground. Instead, supply is limited by the actual amount that can be mined, transported and burned without detrimental environmental or social effects. Should Minnesota's large industries successfully switch to coal, consumption would double by 1985 and triple by 1995. Much of this increase will result from additional coal fired power plants.

With the long-term outlook of declining natural gas and petroleum supplies and the uncertainties surrounding doubling or tripling coal use, conservation and alternative energy sources remain as the most effective tools for managing the long term energy crunch. Each of these can fill one-half of the shortfall between supplies and demand by 1995. Although conservation programs exist today, there is still a potential for greater energy savings. These savings could be achieved if prices, government support and consumer cooperation are all aligned to bring about an effective conservation program.

The alternative energy sources that need to be developed include solar, wind, wood, agricultural wastes, wetland plants, urban solid wastes and peat. Most of these are technologically feasible today. Institutional and economic problems remain the major obstacles to rapid commercialization.

In the coming years a dynamic and diversified plan to meet the energy problems should be developed. There must be dramatic improvements on the efficiency level at which energy is consumed. As new energy sources are developed, care must be taken to insure that each form of energy is closely matched to the work that must be done. With this type of effort, a supply and demand balance for fuels could be managed over the long term without several economic sacrifices for the state.

Declining energy supplies and rising residential consumption may become a severe constraint on future growth in the taconite and lumber industries.

Direct energy inputs in iron mining are related to three end use categories: production, transportation and overhead activities. The taconite industry relies primarily on electricity (magnetic separation stage of pellet production) and natural gas (pelletizing and heat treatment)for production and on diesel for transportation. Coal is used almost exclusively for electricity generation by the Reserve and Erie Mining Companies. Future scarcities of natural gas and dramatic changes in price ratios among alternative fuels will require substitution of other fuels for natural gas in the heat hardening process. As coal is substituted, an entirely new set of problems will appear, including: need for large investments in coal transportation facilities, conversion of taconite plants to enable coal burning, and pollution abatement equipment.

The lumber and forest products industry faces restraints to growth similar to the taconite industry. The problem does not lie with wood and lumber, as these industries are labor intensive. Pulp and paper, however, utilizes the bulk of the industry's energy, and will be most affected. As the industry is curtailed from natural gas (which accounts for 80 percent of total fuel use) it probably will look to wood waste materials to fuel the boilers. Capital must be invested in converting boilers to handle wood wastes. Another problem is the uncertainty whether there is adequate wood waste to replace the curtailed natural gas.

The long term-trend in the wood products industry is to use more energy and not less as more energy-intensive electrical equipment is installed. The pulp and paper industry is currently struggling with this while it is stressing conservation to stay ahead of declining supplies and rising fuel prices.

2.2 Region III - Northeast Minnesota

Figure 2.1 shows the natural gas, petroleum and coal supply network in the copper nickel area. Figure 2.2 maps the electric utility plants and transmission lines serving the region.

Natural Gas

Natural gas is a mixture of naturally occurring gaseous hydrocarbons. It is obtained in much the same way as petroleum - through exploration and drilling. The gas delivered to homes and businesses is primarily methane which has a heating value of 1000 Btu per cubic foot.

A direct pipeline system exists between the gas well and the user of natural gas. This system requires careful control to insure that pressures and flows are maintained. At times of lower demand, natural gas can be stored underground as liquid natural gas (LNG) in cryogenic containers. During the winter, this stored gas is then fed into the distribution system at times of peak demand. Propane from propane/air peak shaving facilities is also used to supplement pipeline gas supplies.

Region III is served by three natural gas pipelines (See Figure 2.1).

Northern receives its gas supplies from wells in Texas, New Mexico, Oklahoma, Kansas, and Montana. The Northern Pipeline extends to the Twin Cities and northward to Duluth. From Duluth there is a branch that extends northeast to Two Harbors and one extending northwest to Hibbing and Virginia.

Inter-City Minnesota Pipelines, LTD and Great Lakes Gas Transmission Company both receive their gas from Canada. The Inter-City pipeline barely extends into Minnesota and only serves the communities of International Falls and Ranier. The Great Lakes pipeline enters the state in the extreme northwest corner of the state and gently sweeps southeast to Duluth and Superior, Wisconsin. This pipeline serves Grand Rapids and Cloquet.

Fig. 2.1 Natural Gas, Petroleum, and Coal Supply Network, Copper Nickel Area

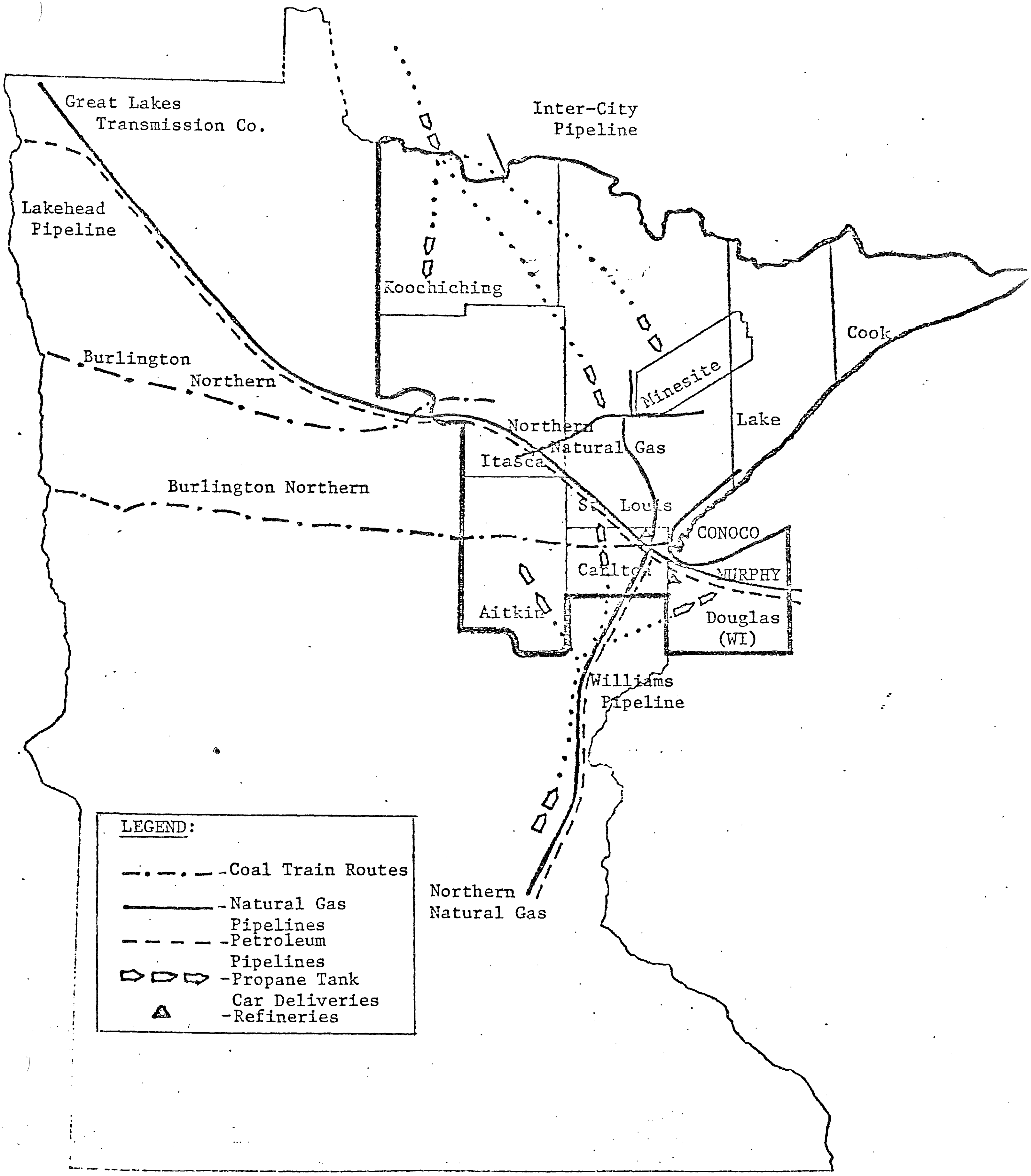
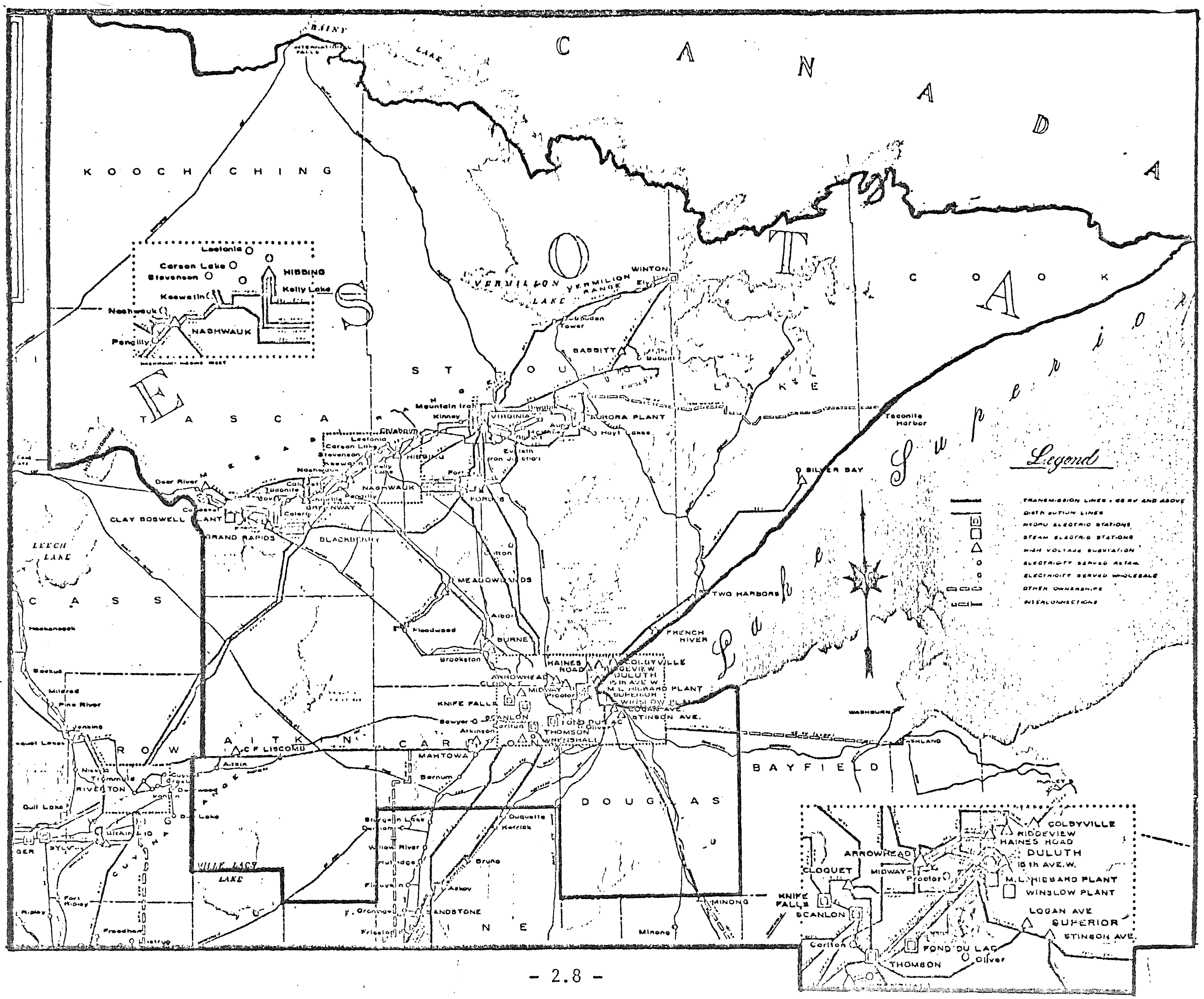


Fig. 2.2 ELECTRIC ENERGY SUPPLY NETWORK, COPPER NICKEL AREA



Natural gas is distributed to all counties in Region III except Aitkin and Cook (breakdown of sales shown in Figure 2.3). Peoples Natural Gas is the largest distributor, accounting for 28,838 billion Btu (53.5 percent). Peoples receives all of its gas from Northern. The second largest distributor is Inter-City Gas LTD., Inc., accounting for 18,603 (34.4 percent). Inter-City receives approximately 62 percent of its gas from Canadian sources. The remaining 12 percent of the total gas consumed in 1976 was distributed by the following four municipals: Duluth (9.8 percent), Hibbing (0.8 percent), Two Harbors (0.8 percent) and Virginia (0.7 percent).

Region III consumed 53,906 billion Btu of natural gas in 1976, which was 18.75 percent of the State total. The two most energy intensive resource related industries, iron ore mining and the pulp and paper industry, accounted for 44,306.7 billion Btu (82 percent). The mining industry alone accounted for 30,894 billion Btu (57 percent).

10.46% of state total

The third largest consumer was the residential sector with 4048 billion Btu (8 percent). The remaining gas was consumed by all other industrial and commercial sectors, the largest of which included electric utilities, lumber and furniture, educational facilities and petroleum refining.

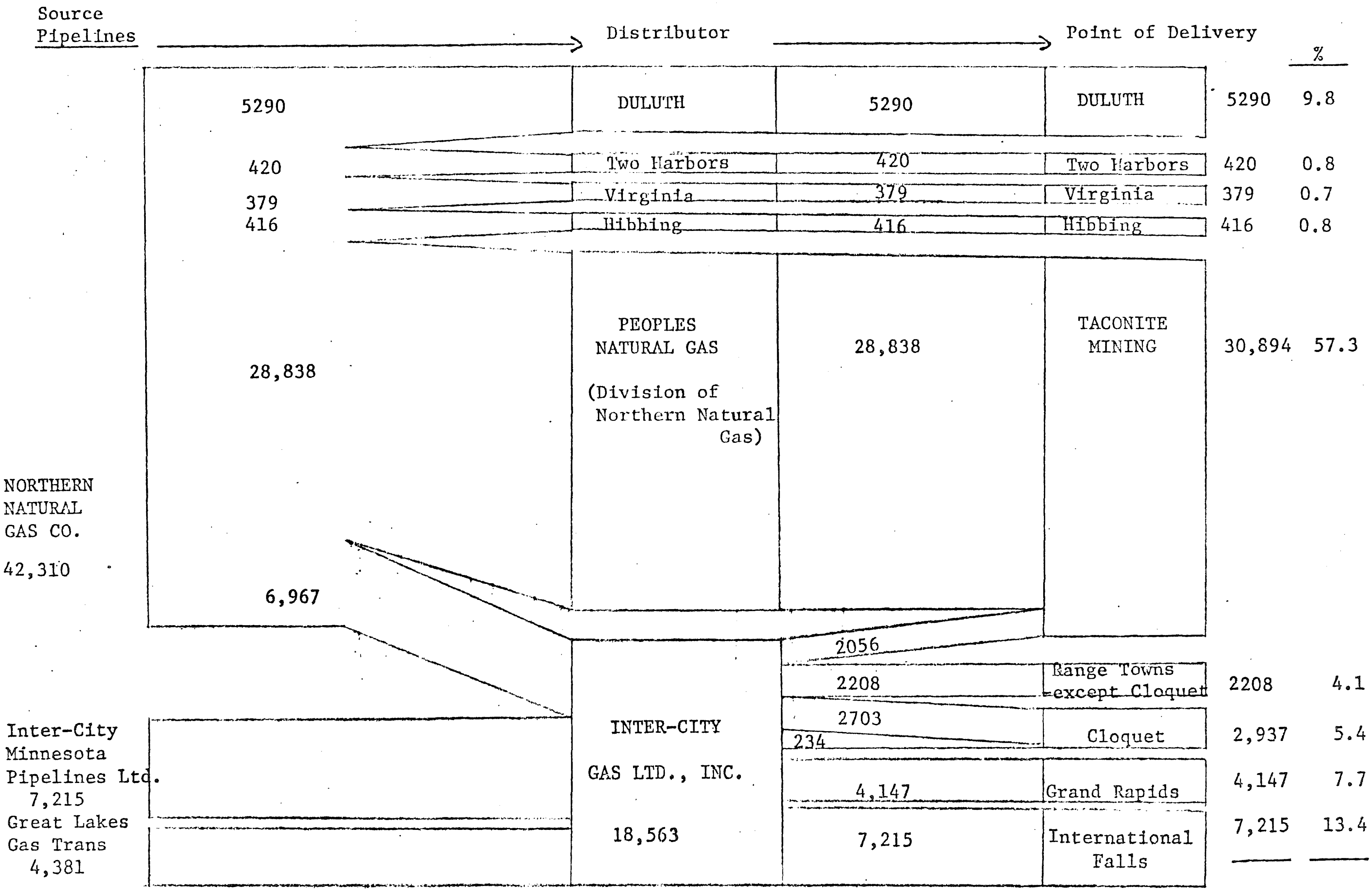
Minnesota expects its gas supplies to decline slightly from 1976 to 1981 (8 percent) but then rise again by 1983 to the 1976 level. From 1984 to 1995, supplies should decline approximately 5 percent each year. This decline will be a result of declining domestic supplies from Northern Natural (offset slightly with projected Alaskan supplies beginning in 1982) and Canada.

Region III is in a slightly different situation due to increased dependence on Canadian Gas -- 21.5 percent compared to 7 percent for the state. Natural gas

Figure 2.3

REGION III NATURAL GAS SALES, 1976

(10^9 Btu)



Total 53,906 100%

Source: REIS, Federal Power Commission Form 2 (1976).

curtailments to the Region will occur in two stages. The first began in 1973 when Northern served notice to large industrial users that they would soon be curtailed of gas. Gas consumption in Region III dropped 7.5 percent from 1974 to 1976, approximately the same as the state decline.

From 1976 to 1977, however, regional gas consumption dropped almost 7 percent and is projected to continue declining at about 6 percent per year through 1982. The heaviest curtailments will occur in the industrial sector, as consumption is projected to decline almost 33 percent by 1982. Within the industrial sector, taconite and iron mining will feel the biggest curtailment of 50 percent by 1982. In the short run, this gas shortage will be made up by fuel oil, while in the long run, the taconite firms may switch to coal or coal gasification. The electric utilities are almost completely curtailed and have successfully switched to coal. Other sectors that can anticipate problems include the lumber sector, petroleum refining, stone, clay and glass products, and the Duluth Steam plant. Here again, petroleum products will be the first alternative for many smaller firms while the large users will go to coal or electricity.

The second stage of curtailments should begin in 1984 when Canadian supplies are projected to drop. Canada is expected to have difficulty meeting its demand after 1984 and will probably reduce exports to Minnesota by 10-15 percent per year starting in 1984. Canadian supplies could drop to zero by 1992.

For the two towns in Region III served solely by Canadian gas -- Grand Rapids and International Falls -- these curtailments present serious problems. Over 90 percent of this gas (10.7 million MCF's) is consumed by the two large paper industries. Approximately 40 percent of this total is for electrical generation and may be replaceable by coal. The power plants could also be closed and the two firms could purchase their electricity. The remaining 60 percent may be more difficult to replace.

Another serious effect of this gas curtailment could be that the residential and commercial sectors may be cut off around 1990. These customers may be forced to switch to an alternate fuel if domestic gas does not replace Canadian supplies. Coal gasification plants and peat gas from the proposed peat gasification plant to be located in the Region may be potential sources, however.

Potential Gas Sources

Although Minnesota's traditional sources of natural gas are declining, three new gas sources may be available in the near future. The first and most likely is Alaskan gas. In the 1980's -- possibly as early as 1982 -- Minnesota may receive new gas supplies from the Prudhoe Bay area in Northern Alaska. A moderate amount of Alaskan gas was included in the supply picture for the Region. The amount Minnesota actually receives may be lower if a new pipeline is not built and higher if Minnesota receives a larger share of the gas than it expects.

The second potential new source is coal gas. This involves a process whereby gaseous fuels are produced from coal. The technology has been available and used successfully in Europe and South Africa. Either high Btu gas (1000 Btu/cu.ft.) that can be shipped via a pipeline or low Btu gas (200 Btu/cu.ft.) that must be used at the location where it is generated can be produced from coal.

Low Btu gas holds particular promise for the taconite companies which are searching for a replacement for curtailed natural gas. Erie Mining has proposed building a small low Btu coal gasification plant with the aid of a grant from the federal government. This demonstration plant, scheduled for completion in 1981 or 1982, could supply up to one-third of Erie's fuel requirements for pelletizing (almost 2 trillion Btu). If the project proves successful, Erie would probably triple the size of the plant in order that it could supply all energy needs for pelletizing. In addition, the other taconite companies may choose to build their own on-site coal gasifiers.

A smaller coal gasification (238 billion Btu/year) plant is being built on the campus of the University of Minnesota, Duluth. This gas will be used primarily for space heating.

The third potential source of new gas is from the peatlands in northern Minnesota. Minnesota has an estimated 7.2 million acres of peat land containing some 16.1 billion tons of peat (at 35 percent moisture) with an estimated heating value of 6000 Btu/lb. If 10 percent of peat lands were developed for energy, the amount of energy available would be 19.5 quadrillion Btu or enough energy to satisfy all the energy demand in Minnesota for 16 years. However, the technology remains unproven in the United States and some very serious environmental questions need to be answered.

Minnegasco plans to build a demonstration plant by 1985 that would produce 28 billion cubic feet per year. If this is successful, a full scale plant producing up to 84 billion cubic feet of gas per year could be built by 1992.

Petroleum Products

There are two crude oil refineries in the Copper-Nickel area - Continental Oil Company in Wrenshall (23,500 barrels/day) and Murphy Oil Company in Superior, Wisconsin (45,400 barrels/day). These two refineries were completely supplied by Canadian crude oil in 1976 via the Inter-provincial-Lakehead Pipeline System extending from Edmonton, Alberta to Superior, Wisconsin. A new Williams Line from Mason City, Iowa was completed in December, 1977, and began supplying 53,000 barrels/day of crude oil to the Twin Cities area refineries and the Conoco refinery at Wrenshall.

Petroleum products not refined locally enter Minnesota through product pipelines connecting out-of-state refineries to Minnesota distributors. Minnesota is served by two pipeline systems: the Williams Pipeline Company and an Amoco Oil Company pipeline. However, only the Williams system supplies northeastern Minnesota via a pipeline extending from St. Paul to Duluth/Superior.

Most of the propane consumed in Region III is shipped from Canada in 30,000 gallon tank cars. In addition, a small portion is produced in the two local refineries.

Coal

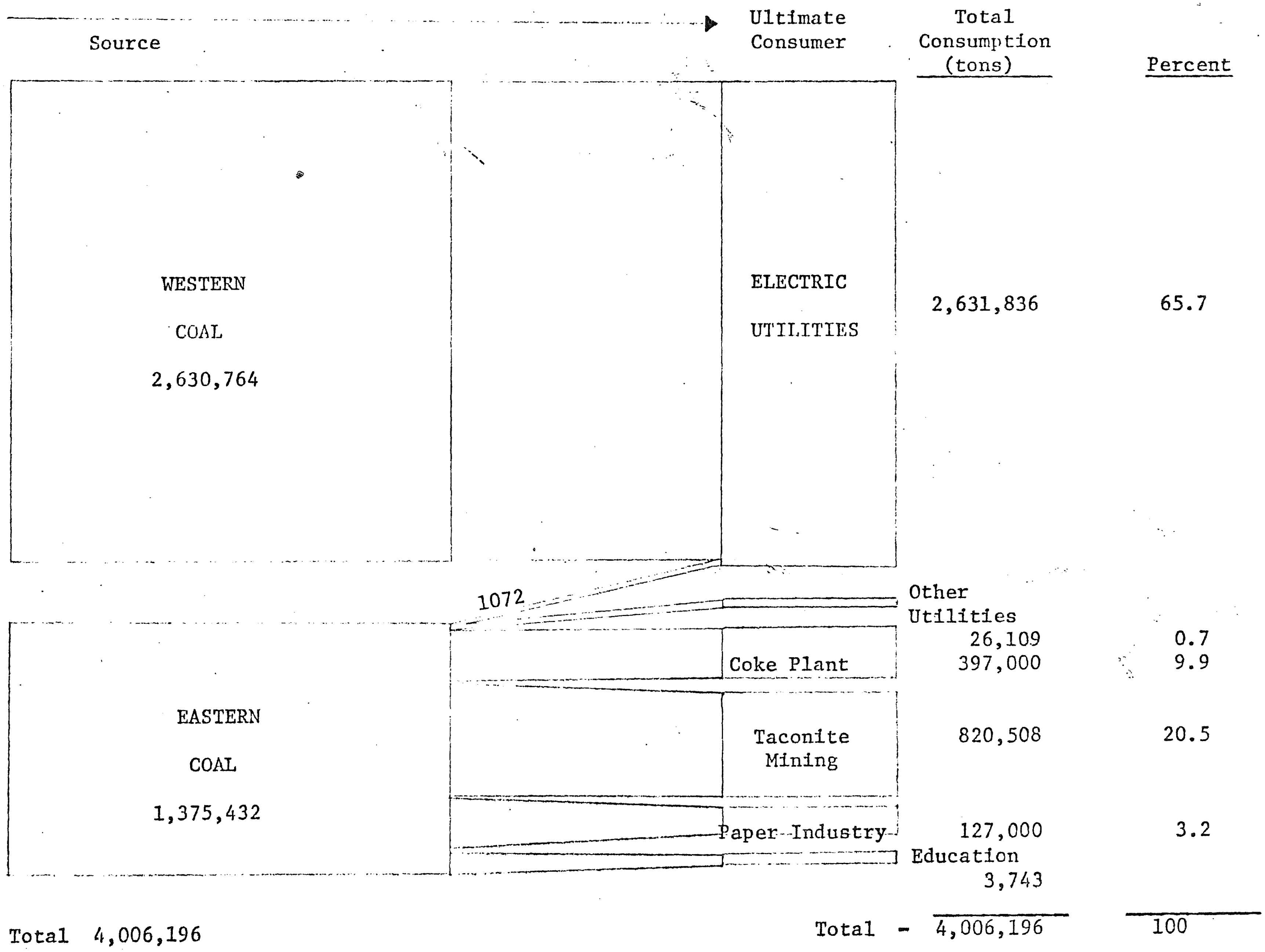
Region III was the second largest coal-using region in Minnesota in 1976, consuming 4 million tons (30 percent of the state's total).

Approximately 65 percent of this coal comes primarily from Montana. The remaining 35 percent is eastern coal that is shipped from Kentucky, Tennessee, West Virginia and Illinois.

The principal mode of transporting coal into the region is via Burlington Northern Railroad. The Burlington train enters the state in East Grand Forks and continues to Cohasset. The remaining 25 percent is shipped by either barge or railroad while less than 1 percent is shipped by truck.

Coal consumption in Region III, as in the entire state, is dominated by large users (figure 2.4). The 5 largest users - 2 electric generating plants, 2 taconite firms, and a coke plant - account for 90 percent of regional coal consumption. The remaining 10 percent is divided between smaller electric generating plants, the lumber and paper industry, a steam plant and educational facilities. Overall, more than 85 percent of coal consumed in 1976 was for the generation of electricity.

Figure 2.4
1976 Coal Use, Region III
(all figures in tons)



Coal consumption by present users in the Region is projected to double by 1985 and triple by 1995. Tons burned will increase from 4 million in 1976 to 10 million in 1985 and 14 million in 1995. The major increases will be from mining expansion and new power plants to be built by MP&L.

This increased coal use will require additional railroad facilities and barge traffic. In order for this increase to occur, many environmental and economic questions need to be resolved.

Electric Energy

In 1976 there were 29 electric power plants in the Region with a total capacity of 1,296,000 kw. These plants generated 7.02 billion kwh of electricity. Included are 12 steam electric, 9 internal combustion and 8 hydro plants:

	Capacity (KW)	Generation (KWH)
Steam Electric	1,176,250	6,668,371
Hydro	101,110	338,743
Internal Combustion	18,573	9,147
	1,295,933	7,016,261

Most of the electricity (95.1 percent) was generated by steam electric plants while internal combustion and hydro plants accounted for 0.1 percent and 4.8 percent respectively. In 1976, 97 percent of the electricity generated by steam electric plants was produced from coal. With the exception of the steam electric generating plants of paper companies, natural gas is used primarily for flame stabilization. Similarily, oil is used primarily for peaking purposes with the exception of the MP&L Hibbard plant.

While there are 29 electric power plants within the Region, the 4 largest account for over 85 percent of the total electricity generation. They include two MP&L plants - Clay Boswell (3,296,637,000 kwh) and Syl Laskin (479,279,000 kwh) and two private industrial generators - Erie (1,237,890,000 kwh) and Reserve Mining (992,911,000 kwh).

Rising demand for electricity in the Region will be met with the addition of two large power plants to be built by MP&L. The first, a 500 MW addition to the Clay Boswell plant, is scheduled for completion in 1980. The second is an 800 MW plant originally scheduled to be built at Floodwood by 1984. With the completion of these plants, Regional capacity will amost double.

3.0 Fuel Consumption estimates for 1976 and Fuel Coefficients for Major Users

Consumption data for 1976 were obtained from energy suppliers in the form of standard reports to federal and state agencies. Direct inquiries by MEA verified and supplemented the data set.

3.1 Sources of Energy Data

Regional Energy Information System (REIS) - Natural Gas and Electric Energy

Most of the data in this report were obtained from the Regional Energy Information System (REIS). The REIS consists of two data bases which contain annual and quarterly data from Minnesota's natural gas, electricity and primary petroleum suppliers. Included in the data bases are transmission and distribution of energy, energy production and storage, and large customer statistics.

The energy transmission and distribution data provide a series of pictures about the flow of energy into the state, its transmission to the distribution suppliers and its final disposition when it is delivered to Minnesota consumers.

Production and storage information in REIS consists of annual summaries on the amount of electricity generated by each of Minnesota's generating plants, the type and amount of fuel used to produce electricity, some detailed data items on the size and efficiency of the plant, and the ratings of all individual generating units. Similar data is collected for substitute natural gas facilities and petroleum refineries, as well as storage facility information on the latter two energy types.

The large customer statistics include: all electric consumers who use over 600,000 Kwh per year as well as many smaller users down to 9,000 Kwh per year; natural gas customers who consume more than 200 MCF on a peak day and 6000 MCF per year, as well as small volume interruptible users; and all large petroleum wholesale purchase customers.

Fuel Use Survey

Fuel use questionnaires were included in an economic survey conducted by the University of Minnesota. Inquiries dealt with current fuel consumption and fuel shift intentions of various industries in the area (Appendix 1). However, the quality of responses and coverage did not allow estimation of industry consumption totals from survey results alone.

Natural gas and electricity consumption totals were determined using REIS for control totals and a combination of REIS and survey data to apportion consumption by industry sector.

Total regional consumption as well as the split between residential, commercial and industrial users were determined by aggregating sales of six gas utilities serving Region III.

After separating the residential sector, sales to ultimate consumers as listed by the utilities were assigned to the 62 sectors. These figures were compared to the survey data which covered 50 percent of the total natural gas consumption, and the larger of the two figures became the sector totals. This accounted for all but 0.4 percent which was then apportioned to the commercial sector based on employment.

Electricity was estimated in the same manner as natural gas. It was slightly more difficult, however, because there were almost 25 utilities and six private industrial firms generating electricity. Again, customers were assigned to 62 industry sectors as reported by the utilities. These totals were compared to the survey data and in each sector the larger of the two figures was used. After this procedure, all except 0.8 percent was accounted for. This was apportioned to the commercial sector by employment.

Northwest Petroleum Association Yearbook - Fuel Oil

Sales of fuel oil are available by town for 1973 from the 1974 Northwest Petroleum Association Yearbook. The original source was the Petroleum Tax Division of the Minnesota Department of Revenue. Only monthly state totals are available from Petroleum Tax Division since 1973, so that 1976 estimates for the area were derived by applying the state growth rate for fuel oil. The additional fuel oil needed to replace curtailed natural gas was then added to arrive at a regional consumption total.

Consumption by the residential sector was estimated through a residential fuel demand model of the Region. The remaining fuel oil was allocated to the 62 industry sectors, based on results of the fuel use survey and a list of large customers for 1974 from REIS.

For each sector, a Btu/employee ratio was calculated using energy consumption and employment by responding firm in the fuel survey. Total Btu by sector were determined by multiplying this ratio by total employment in the industry sector. Since there were few responding firms, an alternate procedure was devised. Consumption estimates for 1974 were adjusted to 1976 using the state growth rate for fuel oil. The larger of these two numbers became the total consumption estimate by sector. The totals by sector were then aggregated and found to equal the region control total estimates.

Petroleum Tax Division - Gasoline

Gasoline data was similar to fuel oil in that the most recent county estimates available were for 1973 from the Petroleum Tax Division. These county estimates were adjusted to 1976 using the state growth rate. The total was then separated according to motor freight transportation and all other uses.

Propane Dealers

Propane was more difficult to trace than either fuel oil or gasoline. No county or regional estimates were available for control totals. Therefore, a phone survey of all Region III propane dealers was conducted. From this, a regional control total was developed and the residential sector was isolated.

The remaining propane was assigned to the 62 industry sectors using employment and energy consumption from the survey similar to the method for fuel oil.

Minnesota Coal Study

The Minnesota Coal Study Group conducted a survey of coal users and reported detailed coal use by large customers in each economic development region. This study covered over 99 percent of all coal consumed in the region. Coal consumers were then assigned to the 62 sectors.

Wisconsin Energy Use by County - Douglas County, Wisconsin

The Wisconsin Office of State Planning and Energy issued a county breakdown of fuel consumption. Since electric utilities were not covered, a telephone inquiry was made for the three electric companies that furnish power to the area.

Douglas County estimates were added to Northeast Minnesota consumption for an area-wide fuel use control total.

3.2 Fuel Consumption Estimates for 1976

Table 3.1 shows 1976 consumption estimates by major end user in the Copper Nickel Study Area. Totals for Douglas County, Wisconsin, are presented also but adjustments are necessary due to an apparent overestimate on residential use of natural gas. Residential fuel use totals were compared with housing stocks, energy intensities and state consumption-housing stock data.

Fuel use by 62 industry sectors in Northeast Minnesota were estimated using the fuel use survey, natural gas and other utility reports in REIS, and direct industry inquiries (Table 3.2). Similar disaggregation of the commercial-industrial sectors for Douglas County, Wisconsin, was not warranted by the quality and quantity of fuel data controls, and the lack of detailed employment data for Douglas County.

Table 3.1 Fuel Use Estimates by Major End-Use,
Copper Nickel Study Area, 1976.

	Natural Gas	Fuel Oil	LPG	Gasoline	Coal	Electric
			(billion BTU)			
Northeast Minnesota						
Residential	4,048	12,745	2002	20,693	-	2,804
Commercial	2,127	4,615	570		80	1,597
Industrial	46,300	16,512	245		30,107	20,410
Electric Generation	896	2,434	12		48,301	551
Transportation	102	2,039	57	2,019	-	148
Others*	433	44	18		583	80
Total	53,906	38,389	2904	22,712	79,071	25,590
Douglas County, Wisconsin						
Residential	707(1414*)	847	195		33	318
Commercial	312	)	)		198	236
Industrial	1,390	) 6,979	) 108		9	730
Electric Generation	267					10
Transportation	-			3,042		
Other	717(10*)					11
Total	3,393	7,826	303	3,042	240	1,305
Copper Nickel Study Area						
Residential	4,755	13,592	2,197		33	3,122
Commercial	2,439	)	)		278	1,833
Industrial	47,690	) 28,106	) 923		30,116	21,140
Electric Generation	1,163	2,434	12		48,301	561
Transportation	102	2,039	57			148
Other	1,150	44	18		583	91
Total	57,299	46,215	3,207	25,754	79,311	26,895

* Communications sector, gas utilities and other utilities.

** Reported by Wisconsin State Planning and Energy. Residential consumption appears overstated because residential units on natural gas for Douglas County sum to only 12% of Northeast Minnesota. The other category was increased by the amount of the overestimate.

Table 3.2 Estimated Fuel Use by 62 Industry Sectors, Northeast Minnesota, 1976.

		Natural Gas	Coal	Fuel Oil	Propane	Gasoline	Electricity
		- (billion BTU) -					
	AGRICULTURE, FORESTRY, FISHERY						
1.	Forestry			24.9	2.4		0
2.	Logging camps & logging contractors	.9		87.9			2.3
3.	Sawmills and planing mills	18.7		123.4	1.0		13.8
4.	All other agricultural, forestry and Fishery products & services	43.9		20.3	111.6		370.2
	MINING and CONSTRUCTION						
5.	Iron and Ferroalloy Ores	30,894.0	17,477.0	10,079.2	49.7		16,299.5
6.	Copper Ore Mining						
7.	Other Nonferrous Metal Mining						
8.	All Other Mining and Quarrying			230.4			
9.	Construction	2.2		100.3	29.7		9.7
	MANUFACTURING						
10.	Food and Kindred Products	100.2			6.8		96.0
11.	Other Lumber and Furnitures	573.3		153.6	1.4		190.1
12.	Paper and Allied Products	13,432.7	2,705.0	893.4	28.5		2,701.3
13.	Printing, Publishing and Allied Industries	7.5		184.5			32.3
14.	Chemical and Allied Products	4.5					182.9
15.	Petroleum Refining & Rel. Industries	264.1		2,948.3	12.7		219.4
16.	Stone, Clay, Glass & Conrete Prod.	711.5		496.0	0.9		28.6
17.	Primary Smelting & Refining of Copper						
18.	Primary Production of Aluminum						
19.	Other Primary Metal Industries	12.1		467.5			35.7

		Natural Gas	Coal	Fuel Oil	Propane	Gaso-line	Electricity
20.	Rolling. Drawg. & Extruding of Copper						
21.	Rolling, Drawg. & Extruding of Alum.						
22.	Rolling, Drawg. & Extruding of Non-ferrous Metals						
23.	Fabricated Metal Products	109.8	9,925.0	551.3			176.7
24.	Machinery, Except Electrical	79.4		55.7			28.4
25.	Electrical & Electronic Machinery	1.5					.7
26.	All Other Manufacturing	43.9		95.7			21.9
27.	Railroad Transportation	74.6		1,114.6			43.5
28.	Motor Freight Trans. and Warehousing	6.7		924.4	57.2	2,019	22.4
29.	Other Transportation	20.9				20,693	81.9
30.	Communications			43.2	17.7		43.3
31.	Electric Utilities	895.5	48,301.0	2,434.4			551.0
32.	Gas Utilities	13.2			12.3		35.3
33.	Other Utilities	419.8	583.0				.9
	TRADE, FINANCE AND SERVICES						
34.	Wholesale Trade - Durable Goods	21.9		425.6	32.4		32.9
35.	Wholesale Trade - Nondurable Goods	2.2		125.9			46.3
36.	Building Materials and Hardware	13.4		84.7	93.0		8.2
37.	General Merchandise Stores	79.6		110.9	156.7		170.0
38.	Food Stores	17.5		47.4	66.8		150.0
39.	Automotive Dealers	20.8		104.7			13.0
40.	Gasoline Service Stations	6.2		131.5	15.7		22.5
41.	Apparel and Accessory Stores	142.5					23.2
42.	Furniture and Home Furnishing Stores	7.9		190.4			11.2
43.	Eating and Drinking Places	46.0		226.3			92.8
44.	Miscellaneous Retail	32.2		321.2	23.2		49.1
45.	Finance, Insurance, and Real Estate	32.6		99.1			65.4
46.	Hotels, Motels and Tourists Courts	61.0		920.4	96.9		69.0
47.	Camps and Trailering Parks	10.0		0.6	.7		1.7

		Natural Gas	Coal	Fuel Oil	Propane	Gaso-line	Electricity
48.	Personal Services	297.3		527.1			
49.	Business Services	32.2		190.8	42.7		12.8
50.	Automotive Repair, Service & Garage	9.6		102.8			9.7
51.	Miscellaneous Repair Services	32.3		14.6	18.6		10.4
52.	Motion Pictures	16.1					5.2
53.	Outfitters	59.4		18.8	22.8		5.1
54.	Other	1.4		.5			44.5
55.	Health Services	77.1		83.1			53.3
56.	Hospitals	317.0		31.8			122.6
57.	Educational Services	612.2	79.7	160.7			225.8
58.	Social Services	22.1					22.2
59.	Membership Organizations	30.3		342.0			21.9
60.	State and Local Government Enterprise	56.1		26.7			141.6
61.	Federal Government Enterprise	69.3		327.3			166.6
62.	Dummy Industries	.4					

3.3 Energy Intensities by Major End-Users

Residential

Residential consumption of various fuels depends on heating degree days, purpose and type of equipment.

Space heating dominates all end uses and this can vary according to climate, housing structure, building insulation and indoor temperature setting. Average requirements for heating and other residential uses of energy were estimated by MEA for Region III (Table 3.3).

In order to use this information for forecasting residential energy requirements, an inventory of housing stock and forecasts of housing needs should be done. SIMLAB does not have this data nor forecast capability. Hence, MEA derived all the necessary data and built an end-use residential model for the Copper-Nickel area. The structure of this model is given in section 4.2.

Industry Sectors

Late in the project, the industry sectors were redefined from 62 industry sectors to 53 sectors. This required aggregation on the fuel consumption data and adjustments on the fuel substitution model. Energy use intensities were not calculated for copper nickel mining and smelting sectors; these are specified for SIMLAB by the Copper Nickel Study staff.

The forecasting of fuel demands by various industries requires energy intensities for a base year. Applied to changes in gross output, these intensities project industry energy requirements. Adjustments on energy intensities to account for price-induced conservation and varying process efficiencies for different fuels are discussed in section 3.1.

Due to substitutability between natural gas and fuel oil and long term shift to coal for large industries, energy intensities should be derived by dividing the sum of primary fuels (coal, natural gas, fuel oil) by gross output of SIMLAB.

Table 3.3 Estimated Energy Requirements Per Household for Various End Uses in The Residential Sector, Region III

End Uses	Natural gas, Fuel Oil & LPG	Electric
Single family	million BTU	kilowatt hrs
Spaceheating	183	24898
Water heating	32	5700
Cooking	9	1476
Others (clothes drying)	8	996
Multi Units		
Spaceheating	81	12449
Water heating	14	2523
Cooking	9	1476
Others	8	996
Mobile homes		
Spaceheating	124	16939
Water heating	22	3878
Cooking	9	1476
Others	8	996

Source: Janet Peterson, "Residential Energy Prices in Minnesota", Minnesota Energy Agency, St. Paul (Draft September 1977).

Energy consumption totals for these substitutable fuels are given in Table 3.4. Energy use per dollar output is not presented because reliable consumption estimates for industries in Douglas County, Wisconsin cannot be produced with present data. In order to demonstrate the operational status of the fuel substitution computer program built into SIMLAB, energy intensities are derived using consumption totals for Region III and 1976 gross output from SIMLAB. This understates the intensities because industry fuel consumption in Douglas County, Wisconsin are not included.

Since there are unique uses for propane and electric energy, estimates of current consumption, energy intensities and forecasts should be determined independently for these energy forms.

Further adjustments are needed before energy intensities are applicable to forecasting. The portion of primary fuels used for self-generation of electricity should be deducted if additional electric energy will be purchased from electric utilities in the future. Capital investment and pollution control requirements presently discourage industries from increasing in-plant electric generation facilities. Expansion of Minnesota Power and Light Company is predicated on increased power purchases by taconite industries.

Hence, energy intensities that predict additional energy requirements due to increased output should exclude the fuels used for electric generation. Electric intensities are then adjusted upwards to include self-generated power.

Comparison of Energy Intensities in Industry - Region III Minnesota and U. S. Averages

Transformation of the 62 industry sectors into 53 sectors of SIMLAB presented difficulties to MEA. It was not until fuel consumption controls and fuel substitution parameters were estimated that the 53 sector redefinition was communicated to MEA forecasting. Rough adjustments on the fuel substitution model were done in order to forecast at the 53 level, but MEA feels that parameters of the

Table 3.4 Energy Consumption Estimated for SIMLAB II
53 Industry Sectors, Copper Nickel Area, 1976.

INDUSTRY 53 SECTORS		DEFINITION 62 SECTORS	Natural Gas, Fuel Oil & Coal	Propane	Purchased Electric	Nat. Gas Fuel Oil & Coal Except Elec Gen.	Purchas & Self-Generat Power
			- (billion BTU) -				
1	LIVESTOCK						
2	OTHER AG.						
3	PEATLAND A						
4	AG. FORFIS	4	64.2	111.6	370.2	64.2	37(
5	IRON ORE	5	58,450.2	49.7	16,299.5	35,251.4	23,95
6	OTHER METO	7					
7	COPPER ORE	6					
8	MNC.PPEHOP						
9	MNC.PPEPUG						
10	NONMETALMI	8	230.4			230.4	
11	AG. CHEMPE						
12	CONSTRUCTN	9	102.5	29.7	9.7	102.5	[illegible]
13	FOODKINDPD	10	100.2	6.8	96.0	100.2	9
14	APPAREL						
15	LOGGING	1,2,3	255.8	3.4	16.1	255.8	[illegible]
16	WOODPROD	11	726.9	1.4	190.1	726.9	19
17	PAPERPROD	12	17,031.1	28.5	2,701.3	10,424.3	4,88
18	PRINTING	13	192.0		32.3	192.0	3
19	CHEMICALS	14	4.5		182.9	4.5	18
20	PEATCHEM						
21	PETROLEUM	15	3,212.4	12.7	219.4	3,212.4	219
22	RUBBERPLAS						
23	STONECLAY	16	1,207.5	0.9	28.6	1,207.5	28
24	IRONMETAL						
25	COPPERMET	17					
26	COPPERROLL	20					
27	OTHERMETAL	18,19,21,22	479.6		35.7	479.6	35
28	METAL FAB	23	10,586.1		176.7	661.1	3,45
29	MACHINERY	24	135.1		28.4	135.1	28
30	ELECMACH	25	1.5		.7	1.5	
31	MISCMANUF	26	139.6		21.9	139.6	21
32	TRANSEXC	29	20.9		81.9	20.9	81
33	RAIL TRAN	27	1,189.2		43.5	1,189.2	4
34	LOCAL TRAN						
35	TRUCKTRAN	28	931.1	57.2	22.4	931.1	2
36	AIR TRAN.						
37	COMMUNICAT	30	43.2	17.7	43.3	43.2	4
38	ELECTRICAL	31	51,630.9		551.0	51,630.9	55
39	GAS SERVIC	32	13.2	12.3	35.3	13.2	3
40	WATER	33	1,002.8		0.9	1,002.8	[illegible]
41	WHOLE SALE	34,35	575.6	32.4	79.2	575.6	7
42	RETAIL	36-44	1,583.2	355.4	540.0	1,583.2	54
43	F. I.	45	131.7		65.4	131.7	6
44	REAL EST.						
45	HOTELS	46-48	1,816.4	97.6	70.7	1,816.4	7
46	BUSS SERVI	49	223.0	42.7	12.8	223.0	1
47	CAR REPAIR	50,51	159.3	18.6	20.1	159.3	2
48	AMUSEMENT	52-54	96.2	22.8	54.8	96.2	5
49	MEDICAL ED	55-59	1,756.0		445.8	1,756.0	44
50	FED. GOVT	61	396.6		166.6	396.6	16
51	ST. LOC. G	60	82.8		141.6	82.8	14
52	OTHER	62	.4			.4	
53	[illegible]						

model should be reestimated using the 53 sector definition.

Similarly, MEA estimated energy per employee ratios for Region III, state and national levels using the 62 industry sector definition (Table 3.5).

Employment data for Region III was provided by the Copper Nickel Study staff using Dun and Bradstreet and Minnesota Department of Employment Services data. Sector definitions and methods of estimating employment could cause differences in energy intensities. However, large differences for the manufacturing sectors could be due to different ages of plants, production processes and extent of self generation of electricity. For commercial sectors, space conditioning requirements vary dramatically according to climate. It appears inadvisable, therefore, to rely solely on energy intensities at the national or state levels in estimating energy and fuel use for small areas. Forecasts using adopted energy intensities would be misleading.

TABLE 3.5

ESTIMATED ENERGY USE PER EMPLOYEE,
COPPER NICKEL AREA, MINNESOTA AND U.S.

		Copper Nickel Area			Energy per Employee			Purchased Electricity		
		Primary Fuels	Purchased Electric	Employment	C/N (1976)	Minn. (1974)	U.S. (1974)	C/N (1976)	Minn. (1974)	U.S. (1974)
		-billion Btu -		#	- million Btu per employee -					
	AGRICULTURE, FORESTRY, FISHERY									
1.	Forestry	27.3		405	67.4					
2.	Logging camps & logging contractors	88.8	2.3	27	3288.9			85.2		
3.	Sawmills and planing mills	143.1	13.8	310	461.6		299.7	44.5		
4.	All other agricultural, forestry and Fishery products & services	175.8	370.2	295	595.9			1254.9		
	MINING and CONSTRUCTION									
5.	Iron and Ferroalloy Ores	58499.9	16299.5	13383	4371.2	5521.3	1705.9	1217.9	1538.8	538.0
6.	Copper Ore Mining									
7.	Other Nonferrous Metal Mining									
8.	All Other Mining and Quarrying	230.4		133	1732.3		2991.4			201.9
9.	Construction	132.2	9.7	8425	15.7		386.9	1.2		11.8
	MANUFACTURING									
10.	Food and Kindred Products	107.0	96.0	2242	47.7	843.4	512.7	42.8	48.4	83.3
11.	Other Lumber and Furnitures	728.3	190.1	2036	357.7	254.4	171.7	93.4	35.7	46.2
12.	Paper and Allied Products	17059.6	2701.3	3076	5546.0	1655.8	1844.1	878.2	278.4	360.6
13.	Printing, Publishing and Allied Industries	192.0	32.3	1319	145.6	34.7	55.5	24.5	22.9	28.5
14.	Chemical and Allied Products	4.5	182.9	141	31.9	465.2	2893.6	1297.2	113.4	563.3
15.	Petroleum Refining & Rel. Industries	3225.1	219.4	140	23036.4	10233.3	10130.6	1567.1	676.3	743.6
16.	Stone, Clay, Glass & Conrete Prod.	1208.4	28.6	586	2062.1	1184.7	1942.2	48.8	133.9	157.8
17.	Primary Smelting & Refining of Copper						4172.6			339.8
18.	Primary Production of Aluminum						5210.5			9535.8
19.	Other Primary Metal Industries	479.6	35.7	1160	413.4	441.6	1983.3	30.8	180.8	332.0

		Copper Nickel Area			Energy per Employee			Purchased Electricity		
		Primary Fuels	Purchased Electric	Employment	C/N (1976)	Minn. (1974)	U.S. (1974)	C/N (1976)	Minn. (1974)	U.S. (1974)
		-billion Btu -		#	- million Btu per employee -					
20.	Rolling. Drawg. & Extruding of Copper						650.0			204.7
21.	Rolling, Drawg. & Extruding of Alum.						1255.6			276.3
22.	Rolling, Drawg. & Extruding of Non-ferrous Metals						293.6			142.7
23.	Fabricated Metal Products	10586.1	176.7	999	10596.7		206.9	176.9	3.0	54.8
24.	Machinery, Except Electrical	135.1	28.4	1221	110.6		130.8	23.2	6.4	42.4
25.	Electrical & Electronic Machinery	1.5	0.7	214	7.0		93.8	3.3	33.4	47.7
26.	All Other Manufacturing	139.6	21.9	1690	82.6		145.3	13.0	36.7	53.4
27.	Railroad Transportation	1189.2	43.5	568	2093.7		382.6	76.6		7.7
28.	Motor Freight Trans. and Warehousing	3007.3	22.4	830	3623.2		3282.4	27.0		5.8
29.	Other Transportation	20713.9	81.9	1763	11749.2		13299.0	46.4		6.9
30.	Communications	60.9	43.3	1407	43.3		162.0	30.8	8.2	11.3
31.	Electric Utilities	51630.9	551.0	1250	41304.7			440.8		
32.	Gas Utilities	25.5	35.3	87	293.1		163.7	405.7	11.5	15.7
33.	Other Utilities	1002.8	0.9	116	8644.8			7.8		
	TRADE, FINANCE AND SERVICES									
34.	Wholesale Trade - Durable Goods	479.9	32.9	2983	160.9		29.6	11.0		30.3
35.	Wholesale Trade - Nondurable Goods	128.1	46.3	1677	76.4			27.6		
36.	Building Materials and Hardware	191.1	8.2	1108	172.5		41.8	7.4		6.5
37.	General Merchandise Stores	347.2	170.0	3764	92.2		11.5	45.2		18.6
38.	Food Stores	131.7	150.0	3036	43.4		126.8	49.4		14.2
39.	Automotive Dealers	125.5	13.0	1802	69.6		39.1	7.2		45.2
40.	Gasoline Service Stations	153.4	22.5	925	165.8		102.1	24.3		
41.	Apparel and Accessory Stores	142.5	23.2	1376	103.6		40.5	16.9		50.1
42.	Furniture and Home Furnishing Stores	198.3	11.2	704	281.7		66.8	15.9		57.5
43.	Eating and Drinking Places	272.3	92.8	6373	42.7		43.0	14.6		
44.	Miscellaneous Retail	376.6	49.1	2266	166.2		33.8	21.7		40.0
45.	Finance, Insurance, and Real Estate	131.7	65.4	3366	39.1		27.9	19.4		21.1
46.	Hotels, Motels and Tourists Courts	1078.3	69.0	2354	458.1		109.8	29.3		76.1
47.	Camps and Trailering Parks	11.3	1.7	74	152.7		23.2	23.0		13.4

		Copper Nickel Area			Energy per Employee			Purchased Electricity		
		Primary Fuels	Purchased Electric	Employ-ment	C/N (1976)	Minn. (1974)	U.S. (1974)	C/N (1976)	Minn. (1974)	U.S. (1974)
		- billion Btu -		#	- million Btu per employee -					
48.	Personal Services	824.4		1072	769.0		93.3	0		17.2
49.	Business-Services	265.7	12.8	1192	222.9		37.6	10.7		12.9
50.	Automotive Repair, Service & Garage	112.4	9.7	540	208.1		56.8	18.0		32.0
51.	Miscellaneous Repair Services	65.5	10.4	308	212.7		21.0	33.8		11.8
52.	Motion Pictures	16.1	5.2	196	82.1		60.6	26.5		34.1
53.	Outfitters	101.0	5.1	194	520.6		67.9	26.3		38.1
54.	Other	1.9	44.5	344	5.5		68.9	129.4		38.2
55.	Health Services	160.2	53.3	3080	52.0		42.9	17.3		14.7
56.	Hospitals	348.8	122.6	4588	76.0		188.2	26.7		32.8
57.	Educational Services	852.6	225.8	244	3494.3		95.8	925.4		32.8
58.		22.1	22.2	2382	9.3		40.5	9.3		32.8
59.	Membership Organizations	372.3	21.9	1321	281.8		117.8	16.6		40.3
60.	State and Local Government Enterprise	82.8	141.6	21954	3.8		68.8	6.4		
61.	Federal Government Enterprise	396.6	166.6							15.5
62.	Dummy Industries	0.4								

4.0 Fuel Demand Models

The work agreement with the State Planning Agency specified the building of a fuel substitution model for various industries in the region. Consumption controls, energy intensities and other parameters of the model were to be estimated for the 62 industry sectors. The model was adjusted to the 53 sector definition and a computer subroutine to SIMLAB II was prepared. This model forecasts fuel demands based on SIMLAB industry outputs but further refinements are necessary to cover all 53 sectors. This will involve substantial work on the 1976 consumption controls and reestimation of parameters of the fuel substitution model. Presently, these parameters are determined from survey data organized around the 62 sector definition.

A residential fuel demand model was built for the copper nickel area. Data work and computer programming were handled entirely by MEA forecasting. This model can be written into SIMLAB, but transformation of forecast population into number of households, savings into personal income, etc. are needed to run the residential model. Forecasting procedures for gasoline, propane and electric energy demands are outlined in this report.

4.1 Fuel Substitution Model - Industry Demands for Natural Gas, Fuel Oil and Coal.

The model consists of the following replacement equations:

$$Y_{i(t)} = b_i Y_{i(t-1)} + d_{i(t)} \sum_{j=1}^{n} (1-b_j) Y_{j(t-1)} + G_{(t)} \qquad (1)$$

$$d_{i(t)} = \frac{U_i}{1 + \exp(A_{i0} + \sum_{j=1}^{n} A_{ij(t)} \ln P_{j(t)})} \qquad (2)$$

subject to

$$\sum_{j=1}^{n} d_{j(t)} = 1 \qquad (3)$$

where $Y_{i(t)}$ = demand for fuel of type i, i=1,n,

b_i = market insensitive or lock-on portion of fuel i dictated by the present facilities and processes.

$G_{(t)}$ = growth of total energy demand due to output expansion,

d_i = allocator of market-sensitive fuel demand to fuel type i,

A_{io} = constant for fuel type i

A_{ij} = response parameter on allocator for fuel type i due to the effect of price of fuel j,

P_j = price of fuel j,

U_i = upper bound for fuel allocator, $0 \leq U_i \leq 1$.

Equation (1) represents the total demand for fuel type i at time t which depends on a 'lock-on' and a market sensitive demand. The 'lock-on' demand indicates the basic non-replaceable fuel requirement and is a technology factor. It may change, but is not, at least in the short run, directly responsive to economic changes. The term $\sum_{j=1}^{n} (1-b_j) Y_{j(t-1)}$ represents the current year total replaceable demand for all fuels.

The term G_t represents the exogenous net growth in total energy demand, determined by changes in (specific) industry output and its energy intensity. The net growth and existing substitutable components represent the total market-sensitive demand to be allocated among fuels. The allocator d_i is formulated as a function of relative prices among fuels subject to the constraint that $\sum_{j=1}^{n} d_j (t) = 1$. This constraint reduces the number of fuel substitution equations by making one fuel source fill the energy requirements remaining after demands for all other fuels have been satisfied. An upper constraint U_i can also be set for the allocator d_i as in equation (2). In most instances, U_i is set equal to 1.

The model cannot handle cases of declines in fuel usage, e.g. slow-down in production activity due to shrinking product markets. This is because application of the fuel allocation to negative growth is contradictory. In cases of industry shrinkage, fuel demands are reduced proportionately according to output reductions and previous year fuel mix.

Parameter Estimation

An estimation procedure is required to derive the 'lock-on' coefficient b_i and allocator d_i. Rearranging terms in equation (1):

$$Y_{i(t)} = d_{i(t)} + b_i \, (1-A_{i(t)}) \; Y_{i(t-1)} + \sum_{j\neq 1} d_{i(t)} \, (1-b_j) \, Y_{j(t-1)} + d_{i(t)} \, G_{(t)} \qquad (4)$$

Because there is no constant term in equation (4), ordinary least square regressions through the origin were used for estimation. Only (n-1) equations were needed to estimate parameters for n substitutable fuels. The dependent variable is $Y_{i(t)}$ and the independent variables are $Y_{j(t-1)}$, j=1,n and $G_{(t)}$. The unknown parameters (b_j and d_i) can then be derived from the estimators.

Source of Data

The MEA project worksheet accompanying the contract specified a first stage fuel substitution model built with data from the natural gas curtailment list and secondary sources of information. However, available data were found insufficient for the 62 industry sector detail specified to MEA. Model building was deferred until survey data were collected.

A fuel use and intentions survey of industries in Region III was conducted in 1978 as part of an economic survey by the University of Minnesota. The Survey form included inquiries on the consumption of natural gas and substitutable fuel in 1976, and expected fuel requirements from 1979 to 1985 (See Appendix 1). Responses were mixed and substantial editing was required. Useable data were then grouped into industrial sectors upon which parameters of the fuel substitution model were estimated. A transformation into 53 sectors was attempted without reworking the data and running regressions, given the time and manpower constraints of MEA forecasting. Table 4.1 shows the parameters of the model for the 53 industry sectors. Appendix 2 presents the regression results on survey data.

Forecasting Uses

In forecasting, estimates of the parameters are used to split primary energy requirements into requirements for various fuels, i.e. natural gas, fuel oil and coal. Industry growth forecasted by SIMLAB translates into additional energy requirements through industry-specific energy intensities (Figure 4.1). These are combined with substitutable components of current year consumption and allocated among fuels based on relative fuel prices. Forecast fuel consumption is the sum of the present non-substitutable component, and the additional requirements due to fuel substitution and industry growth. Further, short term price elasticities and fuel price projections (Appendix 7) are applied to the estimated fuel requirements in order to account for price-induced conservation in industry. Mandatory conservation measures can also revise future energy intensities.

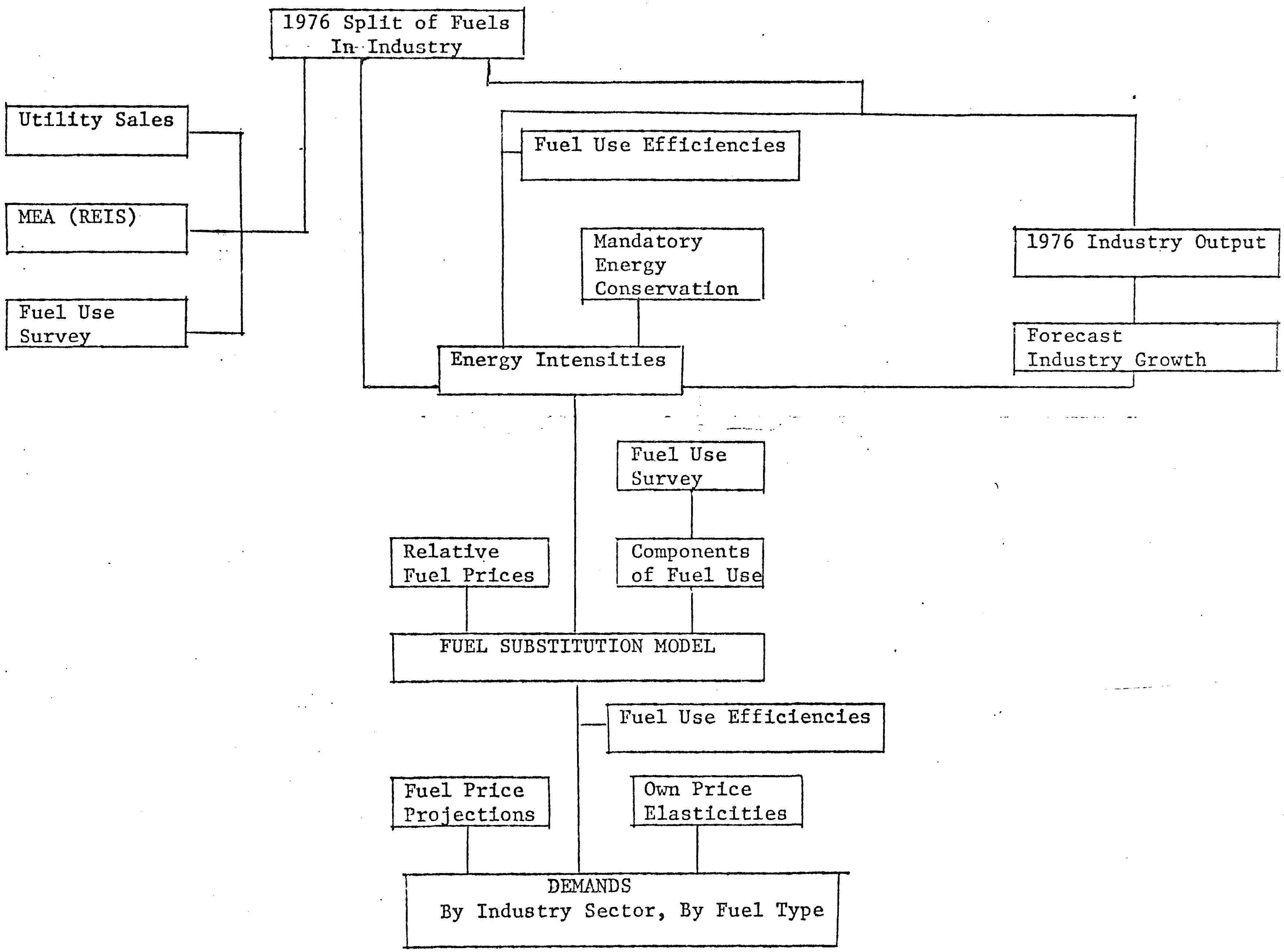
Energy intensities are calculated for each forecast year in order to account for different efficiencies of fuel use (Appendix 3) and secular gains in energy efficiency with price induced-conservation. In addition, fuels used for electric generation are not included in the allocation framework. It was assumed that present self-generation facilities will be maintained, coal being its primary fuel. Industry growth will require additional electric energy which will be purchased from electric utilities.

The fuel substitution model was written into SIMLAB II by MEA Forecasting. Industry demands for natural gas, fuel oil and coal consistent with output projections of SIMLAB are produced (Table 4.2). However, the quality of the forecast suffers from inaccuracies in transforming data and parameters from 62 industry sectors to 53 sectors. Energy intensities may be understated because industrial

Table 4.1 Estimated Parameters of the Fuel Substitution Model, 53 Industry Sector, Copper Nickel Area, 1976.

INDUSTRY ; 53 SECTORS	Lock-On Properties			Market Allocators		
	b_1 Natural Gas	b_2 Fuel Oil	b_3 Coal	d_1 Natural Gas	d_2 Fuel Oil	d_3 Coal
1 LIVESTOCK	1.0	1.0	1.0	0	1.0	0
2 OTHER AG.	1.0	1.0	1.0	0	1.0	0
3 PEATLAND A	1.0	1.0	1.0	0	1.0	0
4 AG. FORFIS	0.205	0.998	1.0	0.827	0.173	0
5 IRON ORE	0.800	1.0	0.639	0.240	0.200	0.560
6 OTHER METO	0.248	1.0	0.639	0.240	0.200	0.560
7 COPPER ORE	0.248	1.0	0.639	0.240	0.200	0.560
8 MNC.PPEROP	1.0	1.0	1.0	0	1.0	0
9 MNC.PPERUG	1.0	1.0	1.0	0	1.0	0
10 NONMETALNI	1.0	1.0	1.0	0	1.0	0
11 AG. CHEMPE	1.0	1.0	1.0	0	1.0	0
12 CONSTRUCTN	0.990	1.0	1.0	0	1.0	0
13 FOODKINDPD	0.778	1.0	1.0	0.861	0.139	0
14 APPAREL	1.0	1.0	1.0	0	1.0	0
15 LOGGING	0.387	1.0	1.0	0.603	0.397	0
16 WOODPROD	1.0	0.756	1.0	1.0	0	0
17 PAPERPROD	1.0	0.756	1.0	1.0	0	0
18 PRINTING	1.0	0.756	1.0	1.0	0	0
19 CHEMICALS	1.0	1.0	1.0	0.989	0.011	0
20 PEATCHEM	1.0	1.0	1.0	0	1.0	0
21 PETROLEUM	0.180	0.498	0	0.430	0.570	0
22 RUBBERPLAS	1.0	1.0	1.0	0	1.0	0
23 STONECLAY	1.0	1.0	1.0	0.517	0.483	0
24 IRONMETAL	1.0	1.0	1.0	0	1.0	0
25 COPPERMET	0.271	1.0	1.0	0.270	0.095	0.635
26 COPPERROLL	1.0	1.0	0	0.811	0.189	0
27 OTHERMETAL	1.0	1.0	0	0.244	0.756	0
28 METAL FAB	1.0	1.0	1.0	0.811	0.189	0
29 MACHINERY	0	1.0	1.0	0.898	0.102	0
30 ELECMACH	0.271	1.0	1.0	0.270	0.095	0.635
31 MISCMANUF	0.271	1.0	1.0	0.270	0.095	0.635
32 TRANSEXC	1.0	1.0	0	1.0	0	0
33 RAIL TRAN	1.0	1.0	0	0	1.0	0
34 LOCAL TRAN	1.0	1.0	1.0	0	1.0	0
35 TRUCKTRAN	1.0	1.0	0	0	1.0	0
36 AIR TRAN	1.0	1.0	1.0	0	1.0	0
37 COMMUNICAT	1.0	1.0	0	0.859	0.141	0
38 ELECTRICAL	0.051	1.0	1.0	0.510	0.210	0.280
39 GAS SERVIC	1.0	0	0	1.0	0	0
40 WATER	0.271	1.0	1.0	0.270	0.095	0.635
41 WHOLE SALE	0.989	1.0	1.0	0.0004	0.9996	0
42 RETAIL	1.0	1.0	1.0	0.140	0.860	0
43 F. I.	0.482	0.882	1.0	0.944	0.056	0
44 REAL EST.	0.482	0.882	1.0	0.944	0.056	0
45 HOTELS	1.0	1.0	1.0	0	1.0	0
6 BUSS SERVI	1.0	0.923	0.255	0.838	0	0.162
47 CAR REPAIR	1.0	1.0	1.0	0.140	0.860	0
48 AMUSEMENT	1.0	1.0	1.0	0.992	0.008	0
49 MEDICAL ED	0.972	1.0	1.0	0.086	0.914	0
50 FED. GOVT	1.0	1.0	0	0.859	0.141	0
51 ST. LOC. G	1.0	1.0	0	0.859	0.141	0
52 OTHER	1.0	1.0	0	0.859	0.141	0
53 OTHER GOVT	1.0	1.0	1.0	0	1.0	0

Fi e 4.1 Primary Fuel Demands
And Substitution In the Copper Nickel Area



consumption in Douglas County, Wisconsin are not included. In addition, low responses and poor quality of survey data cast some doubt in attaching confidence intervals to the estimated parameters and forecasts. Sensitivity tests were not pursued due to these difficulties.

Thus far, the effort demonstrates the feasibility of building an economic-energy demand model for an economic area. Parameters of the fuel substitution model can be reestimated for the 53 sectors, revised data inputted into the sub-routine, and this SIMLAB version rerun to forecast fuel demands. A computer printout of the fuel substitution subroutine is given in Appendix 4.

Table 4.2A Industry Fuel Demands and Gross Output Projections, Copper Nickel Area, 1976.

SECTORS	Fuel Demands (Million Btu)			Gross Output
	Natural Gas	Fuel Oil	Coal	(1000 1970$)
1 LIVESTOCK	0	0	0	47066.1
2 OTHER AG.	0	0	0	24953.8
3 PEATLAND A	0	0	0	0
4 AG. FORFIS	43.90	20.30	0	20021.5
5 IRON ORE	30894.00	10079.20	17477.00	534913.4
6 OTHER METO	0	0	0	1713.2
7 COPPER ORE	0	0	0	0
8 MNC.PPEROP	0	0	0	0
9 MNC.PPERUG	0	0	0	0
10 NONMETALNI	0	230.40	0	3334.4
11 AG. CHEMPE	0	0	0	0
12 CONSTRUCTN	2.20	100.30	0	183705.2
13 FOODKINDRD	100.20	0	0	303383.9
14 APPAREL	0	0	0	37388.5
15 LOGGING	19.60	236.20	0	47214.2
16 WOODPROD	573.30	153.60	0	41074.4
17 PAPERPROD	13432.70	893.40	2705.00	219914.9
18 PRINTING	7.50	0	184.50	27939.5
19 CHEMICALS	4.50	0	0	5216.6
20 PEATCHEM	0	0	0	0
21 PETROLEUM	264.10	2948.30	0	62570.7
22 RUBBERPLAS	0	0	0	2713.6
23 STONECLAY	711.50	496.00	0	8669.3
24 IRONMETAL	0	0	0	128344.5
25 COPPERMET	0	0	0	0
26 COPPERROLL	0	0	0	0
27 OTHERMETAL	12.10	457.50	0	5332.7
28 METAL FAB	109.80	551.30	9925.00	23002.9
29 MACHINERY	79.40	55.70	0	54977.0
30 ELECMACH	1.50	0	0	22499.2
31 MISCMANUF	43.90	95.70	0	37952.4
32 TRANSEXC	20.90	0	0	92621.7
33 RAIL TRAN	74.60	1114.60	0	71088.2
34 LOCAL TRAN	0	0	0	6474.4
35 TRUCKTRAN	6.70	924.40	0	18270.2
36 AIR TRAN	0	0	0	876.8
37 COMMUNICAT	0	43.20	0	36737.7
38 ELECTRICAL	895.50	2434.40	48301.00	103535.6
39 GAS SERVIC	13.20	0	0	16017.0
40 WATER	419.30	0	533.00	9017.0
41 WHOLE SALE	34.10	551.50	0	182164.1
42 RETAIL	366.10	1217.10	0	277747.3
43 F. I.	32.60	99.10	0	70625.2
44 REAL EST.	0	0	0	145789.5
45 HOTELS	368.30	1448.10	0	47440.5
46 BUSS SERVI	32.20	190.80	0	19519.2
47 CAR REPAIR	41.90	117.40	0	12547.0
48 AMUSEMENT	76.90	19.30	0	4907.8
49 MEDICAL ED	1058.70	617.60	79.70	200637.4
50 FED. GOVT	69.30	327.30	0	15658.9
51 ST. LOC. G	56.10	26.70	0	18376.1
52 OTHER	.40	0	0	20468.8
53 OTHER GOVT	0	0	0	173234.0

Table 4.2B Industry Fuel Demands and Gross Output Projections, Copper Nickel Area, 1985.

SECTORS	Fuel Demands (Million Btu)			Gross Output
	Natural Gas	Fuel Oil	Coal	(1000 1970$)
1 LIVESTOCK	0	0	0	47066.1
2 OTHER AG.	0	0	0	30267.3
3 PEATLAND A	0	0	0	0
4 AG. FORFIS	20.01	63.53	0	27295.2
5 IRON ORE	7480.29	15386.76	39017.38	664919.4
6 OTHER METO	0	0	0	1976.1
7 COPPER ORE	0	0	0	0
8 MNC.PPEROP	0	0	0	0
9 MNC.PPERUG	0	0	0	0
10 NONMETALNI	0	297.04	0	4423.8
11 AG. CHEMPE	0	0	0	0
12 CONSTRUCTN	1.95	142.72	0	274102.7
13 FOODKINDRD	67.05	47.10	0	363203.2
14 APPAREL	0	0	0	43242.7
15 LOGGING	18.33	309.34	0	62203.2
16 WOODPROD	921.69	12.04	0	53649.0
17 PAPERPROD	13477.58	70.03	6606.00	292735.4
18 PRINTING	75.74	0	179.29	33054.4
19 CHEMICALS	5.45	.04	0	6561.6
20 PEATCHEM	0	0	0	0
21 PETROLEUM	1227.26	2669.75	0	76816.5
22 RUBBERPLAS	0	0	0	3391.4
23 STONECLAY	845.07	823.79	0	12311.5
24 IRONMETAL	0	0	0	160853.4
25 COPPERMET	0	0	0	0
26 COPPERROLL	0	0	0	0
27 OTHERMETAL	37.83	540.02	0	6591.3
28 METAL FAB	234.22	615.59	9925.00	30130.6
29 MACHINERY	33.84	117.01	0	64035.8
30 ELECMACH	.02	.22	1.54	23011.7
31 MISCMANUF	1.76	97.77	60.43	43403.1
32 TRANSEXC	24.55	0	0	112041.6
33 RAIL TRAN	72.45	1366.66	0	88476.6
34 LOCAL TRAN	0	0	0	7492.1
35 TRUCKTRAN	6.51	1142.09	0	23191.8
36 AIR TRAN	0	0	0	1110.1
37 COMMUNICAT	14.12	44.57	0	50617.3
38 ELECTRICAL	2822.28	19224.93	49937.32	149554.1
39 GAS SERVIC	16.41	0	0	20504.0
40 WATER	6.66	84.91	1035.00	10970.6
41 WHOLE SALE	30.01	724.36	0	241615.0
42 RETAIL	382.49	1593.79	0	356972.5
43 F. I.	98.35	65.06	0	83027.0
44 REAL EST.	0	0	0	185079.0
45 HOTELS	357.70	2126.10	0	66734.3
46 BUSS SERVI	127.72	90.15	5.05	19519.2
47 CAR REPAIR	42.49	128.09	0	13775.3
48 AMUSEMENT	33.26	18.85	0	5337.6
49 MEDICAL ED	925.62	1346.28	77.45	266336.5
50 FED. GOVT	68.23	318.51	0	15658.9
51 ST. LOC. G	63.47	28.26	0	20827.2
52 OTHER	.39	0	0	20468.3
53 OTHER GOVT	0	0	0	215343.3

Table 4.2C Industry Fuel Demands and Gross Output Projections, Copper Nickel Area, 2000.

SECTORS	Fuel Demands (Million Btu) Natural Gas	Fuel Oil	Coal	Gross Output (1000 1970$)
1 LIVESTOCK	0	0	0	47066.1
2 OTHER AG.	0	0	0	49668.3
3 PEATLAND A	0	0	0	0
4 AG. FORFIS	7.31	93.33	0	36330.0
5 IRON ORE	1978.12	15965.70	56943.65	923034.9
6 OTHER METO	0	0	0	2772.7
7 COPPER ORE	0	0	0	0
8 MNC.PPEROP	0	0	0	0
9 MNC.PPERUG	0	0	0	0
10 NONMETALNI	0	446.92	0	6981.7
11 AG. CHEMPE	0	0	0	0
12 CONSTRUCTN	1.60	136.38	0	274102.7
13 FOODKINDRD	8.42	160.78	0	575939.7
14 APPAREL	0	0	0	111329.1
15 LOGGING	20.14	448.92	0	93293.7
16 WOODPROD	1324.81	.17	0	79859.6
17 PAPERPROD	19762.60	1.01	6606.00	448203.2
18 PRINTING	102.65	0	170.92	42762.3
19 CHEMICALS	7.09	2.07	0	11585.6
20 PEATCHEM	0	0	0	0
21 PETROLEUM	1845.11	4622.35	0	132821.8
22 RUBBERPLAS	0	0	0	5920.3
23 STONECLAY	829.57	1850.05	0	20753.1
24 IRONMETAL	0	0	0	226345.2
25 COPPERMET	0	0	0	0
26 COPPERROLL	0	0	0	0
27 OTHERMETAL	87.64	775.37	0	10275.2
28 METAL FAB	269.85	1083.18	9925.00	50151.0
29 MACHINERY	18.18	196.40	0	95789.6
30 ELECMACH	.04	.37	2.54	43347.8
31 MISCMANUF	3.58	93.21	166.22	73683.9
32 TRANSEXC	33.49	0	0	160445.8
33 RAIL TRAN	69.01	1877.17	0	125401.1
34 LOCAL TRAN	0	0	0	7492.1
35 TRUCKTRAN	6.20	1232.98	0	26240.8
36 AIR TRAN	0	0	0	2150.1
37 COMMUNICAT	59.90	56.56	0	102908.8
38 ELECTRICAL	5743.74	86176.10	47622.77	306539.9
39 GAS SERVIC	28.79	0	0	37759.3
40 WATER	.04	83.22	1040.07	10970.6
41 WHOLE SALE	24.22	1289.52	0	441077.1
42 RETAIL	369.93	3394.24	0	711420.2
43 F. I.	25.11	128.50	0	88027.0
44 REAL EST.	0	0	0	380316.3
45 HOTELS	340.70	5394.06	0	161755.6
46 BUSS SERVI	183.61	25.84	7.77	19519.2
47 CAR REPAIR	40.48	123.33	0	13775.3
48 AMUSEMENT	79.68	18.22	0	5337.6
49 MEDICAL ED	515.68	2125.21	73.83	337349.7
50 FED. GOVT	65.24	305.54	0	15653.9
51 ST. LOC. G	60.55	27.62	0	20327.2
52 OTHER	.37	0	0	20468.3
53 OTHER GOVT	0	0	0	474351.8

4.2 Residential Fuel Demand Model - household demand for natural gas fuel oil, propane and electricity.

The work agreement did not require a residential, gasoline or electric demand model. However, an increase in population with taconite expansion and copper nickel development will require additional housing, increased travel demands and other activities that, in turn, will require additional fuels. An end-use residential model was built by MEA forecasting for the region, requiring data on present housing distribution, forecast growth in number of households and settlement concentration with respect to the natural gas supply network. Only in this manner will forecast energy demands by the residential sector be specified according to fuel type.

Demographic-economic inputs to the forecasting program, which should necessarily come from SIMLAB, are specified in Appendix 5. The State Demographer's forecasts of household numbers and assumptions on rural-urban distribution of new households were used to show that the computer program is operational for attachment to SIMLAB. Since the example forecasts were based on demographic economic growth conditions not generated by SIMLAB, they cannot be interpreted as fuel demand forecasts for the area. Unfortunately, the SIMLAB baseline forecasts do not include the variables:

(1) Number of households

(2) Total Personal Income (1967 $)

(3) Temporary housing needs for construction crews

Forecasts of population, labor demand and labor earnings could be converted to the predictor variables required by the residential fuel demand model. MEA does not take responsibility for this effort; but a computer program listing is included in this report in case the University decides to attach the residential model into SIMLAB (Appendix 6).

Estimates of 1976 housing stock and residential sector fuel demand.
Housing stock by fuel type.

Estimates of 1976 fuel consumption by households in the area were obtained by projecting 1970 housing types and fuel use to 1976. Housing types are broken down into (1) one and two units for single family houses, (2) three and over for multi-units and (3) mobile or trailer homes. Construction permits provided data on new housing types, while procedures to adjust for incomplete coverage of housing permits, renewal rates and conversions were adapted from Office of Local and Urban Affairs, State Planning Agency, Minnesota Housing Needs, Housing Resources and Housing Resource Distribution Plans.

Energy requirements for space heating, water heating, cooking, clothes drying, lighting and other uses were estimated for these types of housing units (See Table 4.3). In forecasting, price elasticities and price projections are used to account for consumer voluntary conservation (Appendix 7).

Specifically, the following procedures were used:

(1) From the 1970 Census of Housing county data, all year-round structures classified under mobile homes and multiple units were multiplied by their vacancy rates to estimate occupied numbers of these housing types (Table 4.4). These occupied units were subtracted from total occupied units to estimate single family (1 & 2 unit) occupied structures in the area for 1970. The distribution of fuels among owner-occupied units in the various counties were applied to the single family and mobile home stock. Similar distribution for renter-occupied units were used for the multi-unit type.

Table 4.3 Estimated Fuel Requirements by the Residential Sector, Copper Nickel Area 1976

End Use	Natural Gas	Fuel Oil	LPG	Elec	Others
	(million cubic feet)	(million gallons)		(million kwhrs)	(billion BTU)
Spaceheating	3765	98	21	212	423
Water Heating	656	-	4	485	-
Cooking	189	-	1	141	-
Others (clothes drying)	145	-	-	75	-
Total	4755	98	26	913	423

Table 4.4 Estimated Occupied Housing Units By Type, Copper Nickel Study Area, 1970

	1970 All Year Round Units				Vacancy Rate*		1970 Occupied Units			
	Single Family	Multi Unit	Mobile Homes	Total	MU	MH	SF *	MU	MH	Total
Aitkin	4867	139	142	5148	5%	1%	3605	132	140	3877
Carlton	7923	431	356	8710	5%	1%	7352	409	352	8113
Cook	1263	54	83	1400	5%	1%	1041	51	82	1174
Itasca	11,105	641	536	12282	5%	1%	9610	609	530	10749
Koochiching	5050	635	255	5740	5%	1%	4360	603	252	5215
Lake	3899	288	266	4453	5%	1%	3415	274	263	3952
St. Louis	61,513	11,289	1945	74747	5%	1%	57527	10724	1925	70176
Subtotal	95,620	13,477	3583	112680			86910	12802	3544	103256
Douglas	12415	2430	621	15466	5%	1%	11286	2267	615	14168
Total	108035	15907	4204	128146			98196	15069	4159	117424

Sources:- U. S. Bureau of the Census, Census of Housing: 1970 Detailed Housing Characteristics (Final Report HC(1) 3-25 Minnesota." U. S. Government Printing Office, Washington DC 1972.
- Office of Local and Urban Affairs, State Planning Agency, "Minnesota Housing Needs, Housing Resources and Housing Resource Distribution Plans" St. Paul, Minnesota 1976.

* Estimated by subtracting occupied multi-units and mobile homes from 1970 total occupied units.

(2) Single family occupied units estimated in 1970 were adjusted for demolitions, new construction, and conversions for the period May 1970 to December 1975. Demolitions and conversions reduce the housing stock. Removal rates from the Minnesota Housing Needs study were applied on the stock of single family housing and then allocated over fuel oil and other (wood, etc.) heated houses according to their 1970 distribution. The 1970 stock of natural gas, LPG and electric heated homes were assumed relatively new and therefore kept in the 1976 count of houses.

Conversions from single family units to apartments were estimated by taking the Minnesota Housing Needs Study estimates of 1970-75 conversions for Region III (prorated to include Douglas County), and divided by four on an assumption that an average of four apartments are partitioned from a converted single family unit.

Additions to single family stock were derived from construction permit data inflated 5% for incomplete coverage of housing permit issuing places and adjusted downwards 2% for non-construction of permitted units, according to the Minnesota Housing Needs Study. The additional units were distributed among fuels; first to natural gas according to the percent of population served by gas utility companies in those counties, and the remainder to fuel oil or electric according to 1970-75 sales of heating furnaces in the state.

It was assumed that new units on LPG would eventually shift to natural gas or would have multiple uses on a farm, etc., to qualify for quantity discounts. Due to its low heat content, LPG is an expensive space heating fuel and new installations are observed in areas anticipating natural gas service. Further, wood and other fuel were considered supplementary fuels in new units; oil or electric units installed as backup systems.

(3) The number of multi-units were reduced for demolitions according to the Minnesota Housing Needs Study, and increased for conversions and new construction between May 1970 and December 1975. The fuel split of 1970 stock, additions and conversions by fuel type were estimated following similar procedures as for single family homes above.

(4) The number of mobile homes were reduced from the 1970 count of occupied units for demolitions, while additions between May 1970 and December 1975 were adapted from the Minnesota Housing Needs Study. The split into fuels followed similar procedures as in single family units.

Table 4.5 shows estimated number of residential units in the area by housing type and heating fuel for January 1976. Further, water heating, cooking and other uses were allocated among units according to the following:

(1) Eighty-eight percent of all units on natural gas use this fuel for water heating and other uses (clothes drying). Twelve percent of natural gas units were estimated to have electric ranges, and this proportion may increase with rising incomes.

(2) Fuel oil and electric heated units use electricity for water heating, cooking and other uses. Units on wood, coal and other fuels were also assumed using electricity for non-space heating uses.

(3) LPG was assumed to provide energy for water heating, cooking and other uses (clothes drying)as well as space heating.

Table 4.5 Estimated Number of Occupied Residential Units by Type of Heating Fuel, Copper Nickel Study Area, 1976

Fuel Type	Single Family	Multi Units	Mobile Homes	Total
Natural Gas	16,252	5,917	1,288	23,457
Fuel Oil	67,407	10,027	4,371	81,805
LPG	9,518	1,270	783	11,571
Electric	5,981	2,511	1,395	9,887
Others	2,177	0	271	2,448
Total	101,335	19,725	8,108	129,168

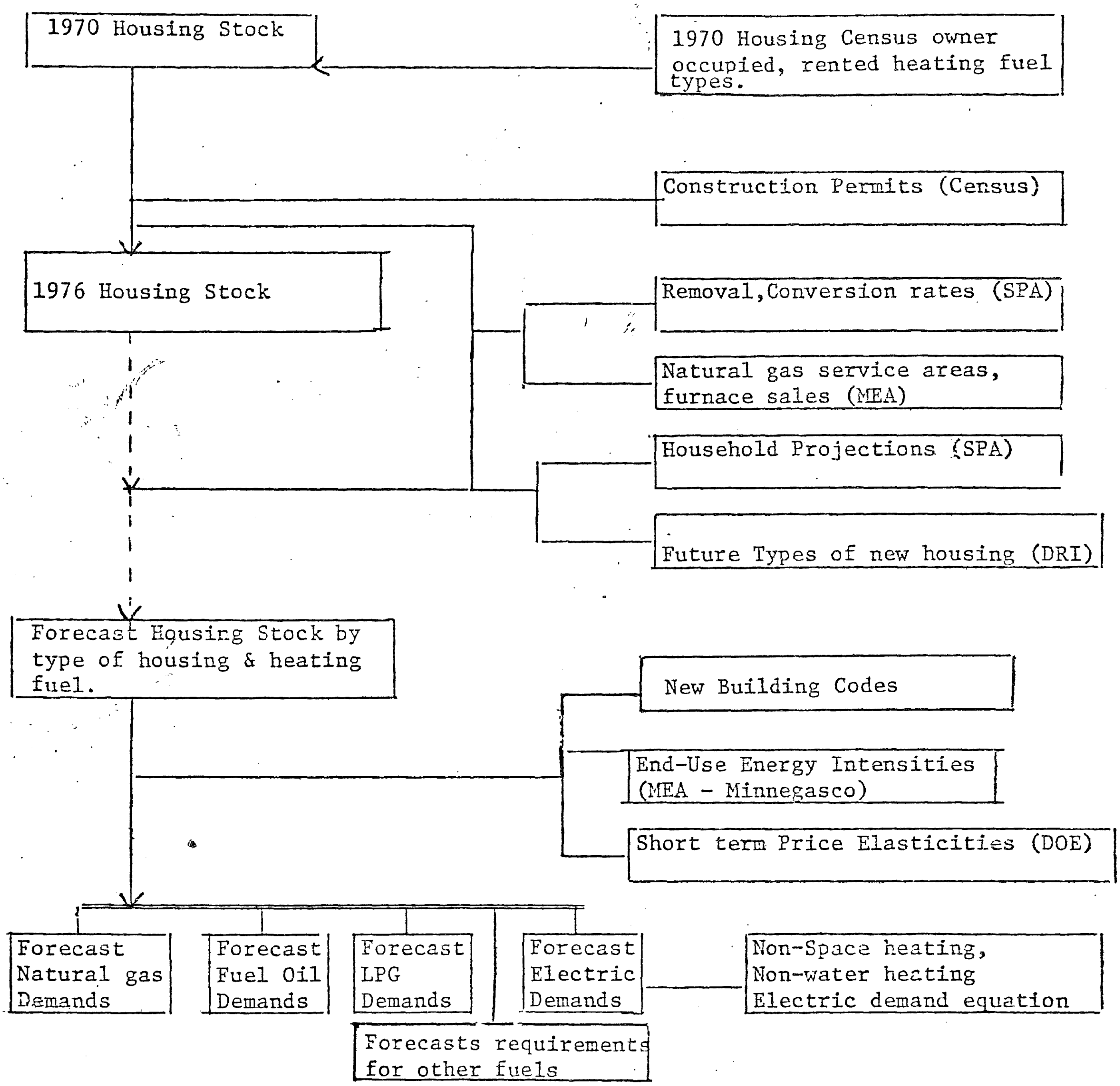
The rates of renewals and conversions used in estimating 1976 stocks were assumed to hold also for the forecast period.

Structure of the Residential Fuel Demand Model

The heat requirements for various fuels were applied to the 1976 stock in order to estimate fuel requirements by the residential sector (Table 4.3). In forecasting, new buildings were assumed better insulated according to the new energy building code. Future renewals and conversions were taken entirely from 1976 stock. In addition, fuel specific price elasticities estimated for U. S. Region V by the Department of Energy (in Appendix 7) were applied to translate fuel requirements into fuel demands for the forecast period.

Fig. 4.2 shows the updating and forecasting procedures of the residential model. Application of short term price elasticities and price projections convert fuel requirements into fuel demands for all energy sources except wood, coal, and misc. fuels. Electric energy demands for space heating and water heating were forecast by the residential model, while a residential electric demand model presented in 4.3 below was used to predict electric demands for all other uses.

Fig. 4.2 Residential Model - Copper-Nickel Area



(Census) U. S. Bureau of the Census
(SPA) Minnesota State Planning Agency
(MEA) Minnesota Energy Agency
(MEA-Minnegasco) Minnesota Energy Agency Estimates for the region based on Minnegasco Study and degree day differences
(DRI) Data Resources, Incorporated
(DOE) U. S. Department of Energy

Forecasting Uses

The residential model forecasts fuel and space heating electric energy demand based on housing structure types, energy intensities and consumer responses to rising prices. Table 4.6 shows fuel demand forecasts for the residential sector based on demographic-economic inputs in Appendix 5. The effects of new building codes and consumer responses to rising fuel prices constrain total Btu demands under the baseline scenario. Shifts among fuels are evident, as new units are built in urbanized natural gas service areas. Fuel oil, LPG and electric units also conserve energy. Such forecasts will change, however, given alternate predictions on number and location of new housing units. Fuel oil and electricity demands will rise faster than natural gas should new units be required in non-urbanized, non-natural gas service areas.

In addition, forecasts without the effects of new building codes or responses to increasing energy prices show that net conservation savings are not enough to reduce consumption in the area, given State Demographer household forecasts. Larger population changes due to rapid resource developments will increase fuel demands dramatically, offsetting conservation savings from new building codes and rising fuel prices.

Table 4.6 Fuel Demand Forecasts for the Residential Sector, Copper Nickel Region, 1976-2000

Year	# Households	Natural Gas	Fuel Oil	LPG	Electric space heating	Total
		(million cubic feet)	-(million	gallons)	(M-kwhrs)	
		Baseline (new building codes, price responses)				
1976	130,983	4755	98	26	212	915
1980	137,384	5421	96	25	242	970
1985	144,965	6111	93	24	272	1042
1990	147,667	6277	90	22	277	1095
1995	146,695	6216	86	21	273	1144
2000	145,306	6218	84	20	271	1213
		Business as Usual				
1976		4755	98	26	212	915
1980		5465	96	25	244	976
1985		6166	93	24	275	1048
1990		6339	91	23	280	1101
1995		6280	87	21	275	1150
2000		6285	85	20	274	1220

4.3 Electric Energy Demand Models

Minnesota Power and Light Company (MP&L) supplies 84% of all electric energy sold in Region III. Other suppliers for the area are municipal electric utilities and Superior Light, Water and Power Company for Douglas County, Wisconsin. In estimating forecasting equations for residential, commercial, industrial and other sectors, MP&L data were used entirely because this utility was able to break down electric energy sales according to MEA definitions of commercial and industrial. Other utilities report sales for these categories but their classification system is based on rate structures. Thus, large commercial customers appear as industrial while small industrial users are classified as commercial. MP&L made a separate tabulation to provide the Minnesota Energy Agency with 1960-1976 sales according to user class rather than rate structures.

In its 1976 Certificate of Need application for a large electric power generating facility, MP&L presented user class demand models. Using MP&L consumption data for the reasons outlined above, MEA constructed more detailed demand models for the same sectors. A discussion and comparison of the respective models follows for each user class.

Residential Electric Energy Demand

Farm and nonfarm residential consumption represents only 14% of 1976 electric energy sales by MP&L. In its Certificate of Need application, this utility used an annualized growth rate equation to forecast future residential sales:

$$Elec_{R,t} = BG^{n}$$

where $Elec_{R,t}$ = electric consumption by the residential sector at time t

B = base year electric consumption by the residential sector

G = growth rate of residential electric consumption

n = number of elapsed years between base year and forecast year

This equation was fitted to historical data using regression techniques in order to derive the growth rate (G). In forecasting, base year (B) was pegged at the 1975 level, the growth rate was reduced 1.2 percent for conservation and (n) was varied according to the forecast year. Since the residential sector is a minor portion of the load, errors from this procedure, i.e. noncontinuation of historic trends, would not be a critical factor affecting the request for need certification of a large power plant. Residential space heating would be an important addition to load, but MP&L is not encouraging growth in this end use. The utility justified its request for certification primarily on projected growth of the mining-taconite processing industry.

The MEA fitted a residential electric energy demand equation to 1960-1975 data from MP&L:

$$\ln E_{R,t} = \underset{(0.974)}{1.998^{**}} - \underset{(5.953)}{11.446^{**}} (1/Y_{Rt}) - \underset{(.085)}{.0890} \ln P_{Rt} + \underset{(.329)}{0.312} \ln E_{R,t-1}$$

$$R^2 = 0.976 \qquad F = 152.667 \qquad D.W. = 2.157$$

where $E_{R,t}$ = residential electric consumption per household, year t

Y_t = real personal income per household for region III, year t.

P_t = real marginal price of electricity to the residential sector, year t

This equation assumes saturation of electric appliances through long term diminishing effects of incremental income on consumption. In other words, exponential growth of electric consumption occured because rising incomes led to purchases, accumulation and increased usage of electric appliances. As the number of appliances approach a saturation level, further increases in household income can have smaller effects on electric consumption.

The adverse effect of rising marginal price on consumption was expected but the coefficient was not significantly different from zero. There were periods during the historical series when marginal price of electricity to residential customers did not rise as fast as inflation. As more current observations accumulate, measurements on price effects may become statistically valid.

Previous year electric consumption was included as a predictor variable for current year demand in recognition of rigidities in tastes and habits as well as normal replacement of appliances.

The residential model includes electric space heating, water heating, cooking and other (clothes drying) uses, but uses other than space heating and water heating appear more discretionary and can be modeled using income, price and previous year's consumption as determinant (or predictor) variables. Data were available only from 1960 and 1970 housing censuses so that annual extrapolation using compound growth rates was done only for electric space heating and water heating. Energy requirements for these purposes were estimated and subtracted from residential electric energy demand. Regression was performed on estimated electric consumption exclusive of space heating and water heating:

$$\ln E^{1}_{R,t} = \underset{(1.386)}{-0.062} + \underset{(7.844)}{13.897^{**}} (1/Y_t) + \underset{(0.337)}{0.391} \ln P_{Rt} + \underset{(0.288)}{1.291^{**}} \ln E^{1}_{R,t-1}$$

$$R^2 = 0.812 \qquad F = 15.884 \qquad D.W. = 1.84$$

where $E^1_{R,t}$ = electric consumption per household except space heating and water heating, year t

$Y_{R,t}$ = real personal income per household in the region, year t

$P_{R,t}$ = real marginal price of electricity to the residential sector in the region, year t

The response coefficients on real income and marginal price showed the wrong sign. Linear-log forms were fitted but the signs of the coefficients remained contradictory to consumer behavior. It appears that extrapolations to remove the electric space heating and water heating components of residential consumption distorted the relationships. When better estimates of these end uses become available, the model can be tested appropriately.

Alternatively, the model fitted to total electric consumption was reestimated without the price variable:

$$\ln E_{R,t} = \underset{(0.889)}{1.572^{**}} - \underset{(4.631)}{7.511^{**}} (1/Y_{R,t}) + \underset{(0.244)}{0.544^{**}} \ln E_{R,t-1}$$

$R^2 = 0.970$ $F = 226.684$ D. W. = 1.878

This equation measures the effect of rising income and consumption rigidities in the region. In forecasting, the intercept should be adjusted for electric space heating and water heating for the base year 1976 in order to limit forecasts to other end-uses. The income coefficient may still overestimate consumer response because the data used in the regression includes all uses. The space heating and water heating components are handled systematically by the residential fuel demand model. In addition, response to rising prices can be included using short term price elasticities estimated for U. S. Region V by the Interface Model of the Department of Energy (Appendix 7).

Commercial Sector

MP&L used the same exponential growth rate equation for the commercial sector as in the residential sector to forecast electric consumption. The 10-year-averaged growth rate was then reduced 2 percent for conservation.

MEA fitted an equation to electric energy demand by the commercial sector:

$$\ln E_{c,t} = \underset{(0.5093)}{-09158^{**}} + \underset{(0.1214)}{0.3885^{**}} \ln EMP_{c,t} \underset{(0.1197)}{-0.2959} \ln P_{c,t} + \underset{(0.0859)}{0.7443^{**}} \ln E_{c,t-1}$$

$$R^2 = 0.995 \qquad F = 763.768 \qquad D.\ W. = 2.059$$

where $E_{c,t}$ = Electric consumption by the commercial sector at year t

$EMP_{c,t}$ = Employment in the commercial sector at year t

$P_{c,t}$ = Real electric price to the commercial sector at year t.

The estimated price coefficient was negative, but statistically insignificant. Strong correlation existed between the price variable and previous year's consumption. Dropping the previous year consumption variable yielded positive serial correlation (D. W. = 1.733). A linear filter was employed by regressing the residuals against their lagged values. The coefficient (equal to 0.708 on a regression fit forced through the origin) was used to reformulate the equation:

$$\ln E_{c,t} = \underset{(0.946)}{-3.550^{**}} + \underset{(0.138)}{1.344^{**}} (\ln EMP_{ct} - 0.071 \ln EMP_{ct-1})$$

$$\underset{(0.252)}{-0.643^{**}} (\ln P_{ct} - 0.071 \ln P_{ct-1}) + 0.071 \ln E_{c,t-1}$$

$$R^2 = 0.959 \qquad F = 140.544 \qquad D.\ W. = 1.883$$

This function can be used to forecast electric demand by the commercial sector. Price effects including short term price induced conservation are handled by the model.

Industrial except Mining and all other categories

MP&L developed forecasts for these categories

> "on a company-by-company basis through personal contacts, except for three miscellaneous groups. Historical records have shown that the central and western miscellaneous groups (of MP&L) are quite stable, therefore, only very nominal growth has been given to these groups. The northern region growth rate has been increased to about 1.0% to reflect additional growth of facilities to support the expanding taconite industry." (MP&L and UPA, Application for Certificate of Need for a Large Electric Generating Facility, 1976).

MEA built an electric energy consumption model for this sector by relating consumption to employment in selected industries in the area and the ratio of real labor wages to marginal price of electricity:

$$\ln E_{I,t} = \underset{(4.809)}{21.831^{**}} + \underset{(.165)}{0.968^{**}} \ln \text{Const}_t + \underset{(.094)}{0.254^{**}} \ln \text{Food}_t + \underset{(0.332)}{0.277} \ln \text{Lumb}_t + \underset{(0.200)}{0.491^{**}} \ln\left(\frac{\text{Wage}}{\text{Price}}\right)_t$$

$$R^2 = 0.957 \qquad F = 40.053 \qquad D.\ W. = 3.096$$

where E_{It} = Electric consumption by the industrial sector except mining, year t

$Const_t$ = Employment in Construction, year t

$Food_t$ = Employment in Food processing, year t

$Lumb_t$ = Employment in Lumber products, year t

$\left(\frac{Wage}{Price}\right)_t$ = Ratio of real labor wage to real marginal price of electricity for the industrial sector, year t

Since consumption is determined by the mix of industries, this form provides a method of linking differential industry growth to industrial consumption. Real marginal price is also postulated to affect industrial demands by way of price-induced substitution between energy-using capital and labor. However, the Durbin Watson statistic (D. W. = 3.096) was high, indicative of serial correlation problems. Selected industries represent only those with employment growth positively related to industrial electric consumption. This resulted in incomplete coverage of the industrial sector. Hence, the objective was limited to estimation of the effects of changing labor/electric price ratios on industrial electric consumption:

$$\ln E_{mt} = \underset{(1.416)}{0.852^{**}} + \underset{(0.241)}{0.383^{**}} \ln \left[\frac{wage_m}{price_m}\right]_t$$

$$R^2 = 0.872 \qquad F = 40.920 \qquad D.\ W. = 3.350$$

A linear filter was applied but results were not satisfactory; the price coefficient changed signs.

The formulation above implies that a 10% increase in the real labor wages-marginal electric price ratio would cause a 3.8% increase in electric demand by the industrial sector. Real wages increased while real marginal electric price fell during the historical period, prompting industries towards energy-using capital.

Iron Mining

> "In 1975, MP&L provided electric service to four taconite facilities with a total taconite pellet production of 19 million tons (47% of total). By 1985, MP&L is projecting sale of electricity to seven taconite plants with a total production of some 57.4 million tons." (Minnesota Power & Light Company and United Power Association, Application for Certificate of Need for a Large Electric Generating Facility, October 1976).

In 1976, MP&L supplied 2.5 billion kwhrs or 55% of total electric energy sales. It is expected that mining companies will purchase all additional electric power required in new taconite processing plants for the following reasons:

> "because fuel would be more expensive than that obtained in larger quantities by MP&L; because all of their equipment would be newer and therefore more expensive than MP&L capacity, part of which is older; because generating units owned by taconite companies would be of small, uneconomical size; and because they would necessarily be forced to supply their own backup, or contract with MP&L for backup, since they couldn't afford to let their taconite plants stand idle. Also, the cost of pollution control equipment on small units is higher. (Director's decision in the matter of the application of MP&L and UPA for Certification of Need for an 800 MW electric generating facility, p. 13, April 5, 1977).

Reserve Mining Company and Erie Mining Company generate some 1243 million kwhrs for their use, but

> "Reserve has gained approval to dispose of its tailings at an acceptable on-land site, Mile Post 7. Previous testimony from Mr. Sandbulte indicated that if approval were to occur, MP&L expected to contract with Reserve for about 35 megawatts". (Direct testimony of David G. Gartzke, p.6.).

and

> "Mr. Evanson, witness for Reserve Mining Company, testified that because of the age of their two generating units (50 and 80 megawatt units), Reserve plans upon purchasing 80 megawatts... in 1978, MP&L and Reserve will enter into a firm power contract for the 10 megawatts due to load growth and pollution control facilities on their generating facilities" (Ibid. pp. 6-7).

Erie Mining Company

> "... generates its own power at Taconite Harbor. However, like Reserve, their units are old and are required to operate at a high capacity factor due to the production requirements." (Ibid. p. 7).

Replacements of self generated power were later excluded in the MP&L forecast because

> "It is speculative at this time to state with certainty that the operation and maintenance expenses on the old

units would exceed the cost of purchasing power from MP&L in the years shown in the forecast submitted in the application. Therefore, the 18 megawatts in 1985 and the 37 megawatts thereafter have been removed from the forecast" (Ibid. p. 7).

The application was rejected by the Director of the Minnesota Energy Agency on April 5, 1977, with noncommittal of mining companies as a primary reason:

> "No witness from any mining companies appeared at the hearing to give testimony with regard to anticipated plant expansions or new mining operations. These witnesses would have been the most reliable sources of information regarding the expansions. Their failure to appear means that only heresay evidence is in the record to support the projected taconite demand....."
> (Directors Decision April 5, 1977 op cit).

Additional hearings were held where representatives of mining companies presented testimony on their expansion plans and future purchases of power from MP&L. Based on these testimonies, MP&L revised its sales forecasts to mining companies.

Copper Nickel development is expected to offset future reduction in energy demand by the declining natural iron ore mining.

> "Mr.Malcolm, Project Manager of the MINNAMAX Project, testified that they were still in the evaluation phase, and that the level of production would depend upon results of their studies. The power requirements, depending on the production sides as testified to by Mr. Malcolm, range from 90 megawatts to 160 megawatts. The simple average of the end points of this range would be 125 megawatts.

Mr. Malcolm testified that the production facilities could be completed by 1985." (Direct testimony by David G. Gartzke op cit, p. 8.).

In this study, MEA forecasts electric demand by iron mining companies based on industry growth, improvements in energy use and retirements of company-owned generators.

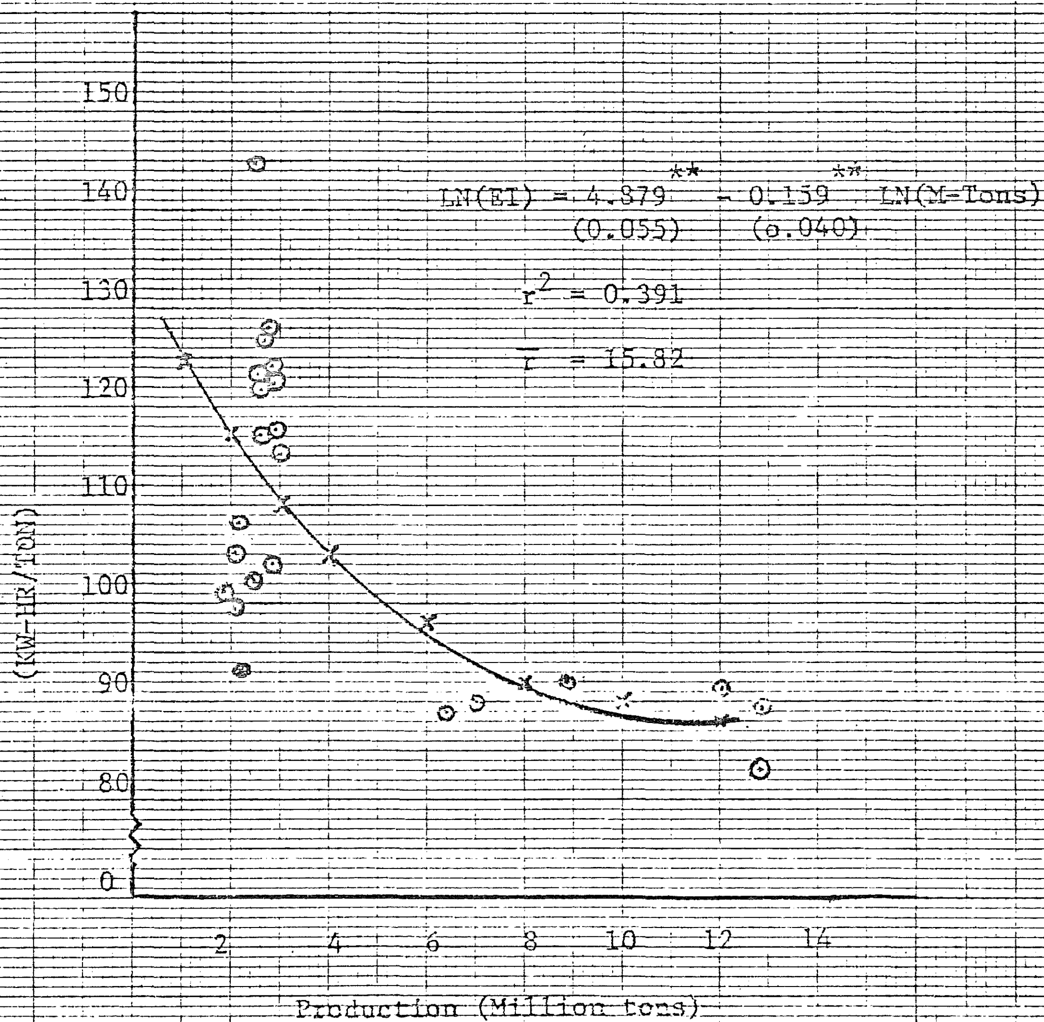
(1) Scenario 1 is a high growth condition where MP&L forecasts were adopted for expanding iron mining companies. Erie and Reserve are assumed to retire all generating facilities.

(2) Scenario 2 revises the electric energy intensities based on the (1970-75) observation that energy intensities decline with higher levels of production. A curve fitted to 1970-75 electric energy intensity data of mining companies shows significant effects of the production level on energy intensity (Fig. 4.3). The plot shows significant returns to scale above 6 million tons production. The future electric intensities were averaged over three size plants and applied to additional production from expansion plans:

	Electric Intensity (Kwhr/ton)	Taconite Production (million tons/year)
(a)	117.132	below 6
(b)	91.068	6-9
(c)	87.711	10 and above

Production rose rapidly in 1973 resulting in reduced electric consumption per ton production. In forecasting, the lowest electric intensities of each mining

Figure 4.3 ELECTRIC ENERGY USE PER TON OF TACONITE PRODUCTION AND LEVEL OF PRODUCTION, (1970-1974)



company during the 1970-75 period were assumed for existing plants. Production expansions plus rising electric prices could result in reduced electric intensities. Erie and Reserve electric power purchases were adapted from MP&L forecasts.

Between 1986 and 2000, electric energy intensities are maintained at 1985 levels. Thus, additional electric purchases will increase only as fast as output growth. The growth of steel demand (and taconite production) is forecast at 1.6% per year after 1985. (Direct Testimony of Horace T. Resso, p. 5.).

(3) Scenario 3 was derived from MP&L revised forecasts on coincident demand for winter seasonal period.

Table 4.7 shows MP&L forecasts of electric purchases by iron mining companies. Estimates for 1985 are lower than MP&L if efficiency improvements were instituted by mining companies (Scenario 2). On the other hand, forecasts will be substantially larger than MP&L if Reserve and Erie decide to retire their old generating plants (Scenario 1). Also, MP&L is allowing for 125 MW power for copper nickel development, generating some 931 million kwhrs per year (Scenario 3).

Table 4.7 Forecasts of Iron Mining Electric Energy Demand, Copper Nickel Area (million kwhrs.).

	1976	1980	1985	1990	1995	2000
			Scenario 1			
Taconite Companies		5663.0	7077.0	7661.6	8294.4	8979.6
Reserve-Silver Bay		595.7	1228.1	1330.1	1440.0	1558.9
Reserve-Babbitt		74.5	74.5	80.6	87.3	94.5
Erie		0	134.0	298.2	322.9	349.6
Total	2500.8	6333.2	8513.6	9370.5	10144.6	10982.6
Copper Nickel						
			Scenario 2			
Taconite Companies		4958.8	5737.5	6211.4	6724.5	7280.0
Reserve-Silver Bay		595.7	595.7	675.7	762.2	855.9
Reserve-Babbitt		74.5	74.5	80.6	87.3	94.5
Erie		0	0	0	0	0
Total	2500.8	5629.0	6407.7	6967.7	7574.0	8230.4
Copper Nickel						

Scenario 3 (MP&L)

	1976	1980	1985*	1986*	1987*
Taconite Companies	2500.8	5663.0	7077.0	8235.0	8235.0
Reserve-Silver Bay		595.7	595.7	595.7	595.7
Reserve-Babbitt		74.5	74.5	74.5	74.5
Erie		0	0	0	0
Total	2500.8	6333.2	7747.2	8905.2	8905.2
Copper Nickel	-	0	930.8	930.8	930.8
Total	2500.8	6333.2	8678.0	9836.0	9836.0

* Converted to electric energy from MW winter demand (MP&L revised) using sales to demand ratio in the MP&L and UPA Application for Certificate of Need for a Large Electric Power Generating Facility, Oct. 1976.

Forecasting Uses

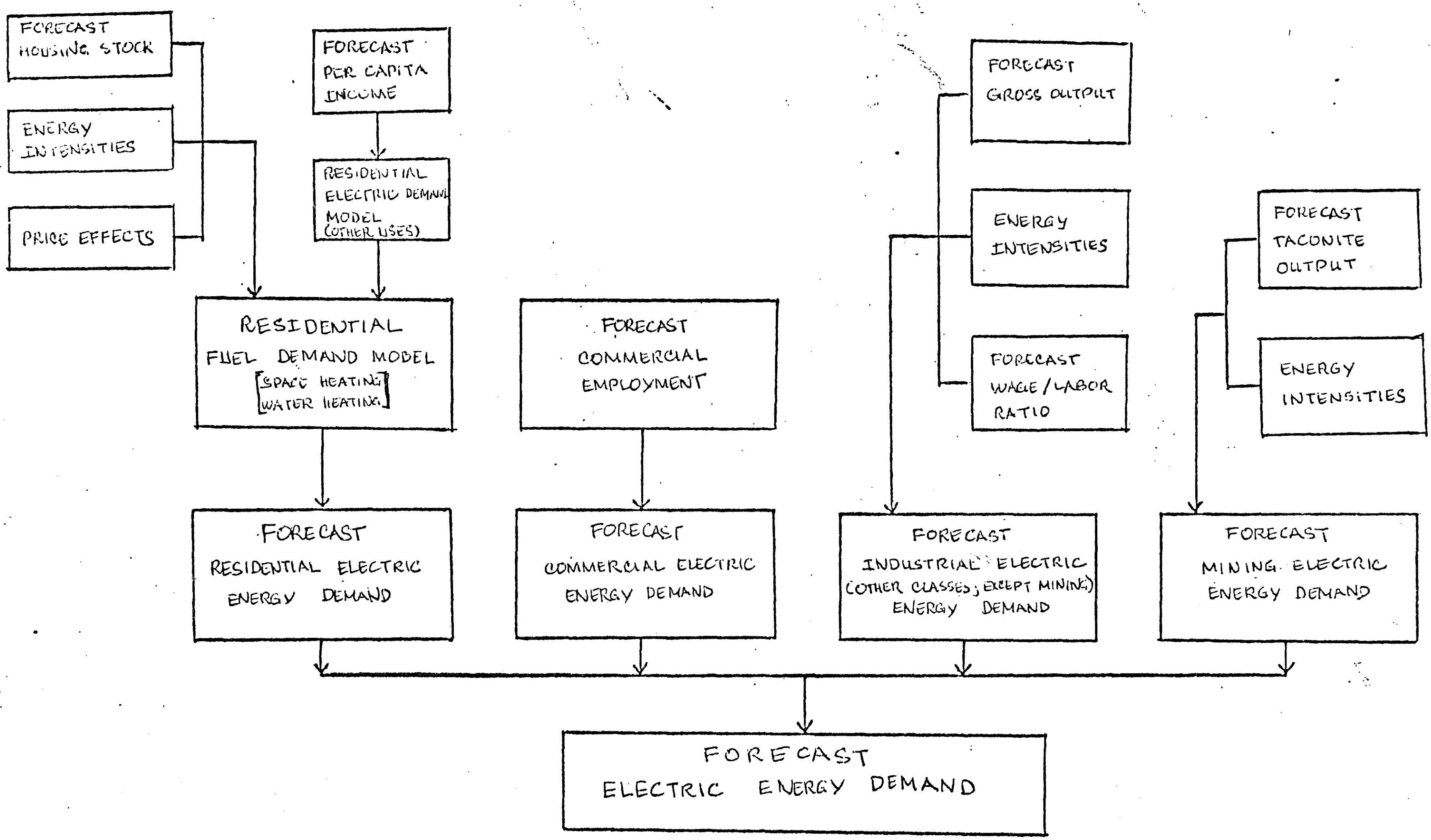
Parameters of electric energy demand equations in this section can be used to relate future demands to personal income, industry output and energy prices. It is recommended that these equations be incorporated into SIMLAB in order to augment the procedure of applying energy intensities.

Figure 4.4 shows a flow chart of an electric energy demand model for the region that can be written into SIMLAB. The residential electric demand model shows the relation of household income to electric demands for non-space heating and non-water heating uses. A residential fuel demand model discussed above predicts electric requirements for space heating and water heating.

The commercial model links employment and electric price to energy demand. The estimated parameter for marginal electric price and labor wages in the industry sector except mining can be used to translate additional energy requirements, due to industry growth, into industry demands for electric energy. Thus, the forecasting procedure may apply electric energy intensities to forecast industry output and the resulting requirements adjusted for specified changes in labor wage and electric prices.

The discussion on iron mining electric consumption deals with actual industry expansion plans and returns to scale relationships between production and electric energy use. Electric energy intensities corrected for scale economies may be applied to forecast mining out for SIMLAB.

Table 4.4 Electric Energy Demand For The Copper Nickel Area



4.4 Gasoline Demand Model

Demand for gasoline by private automobiles was modeled based on estimates of necessary travel and recreation-related activities. Buses, trucks and other end-uses account for 9% of gasoline consumption in the area. Growth of these modes are linked directly to forecast output of transportation industry sectors.

Modelling gasoline demand at the regional level was heavily constrained by available data on both historic consumption and predictor variables. State consumption data are available monthly since 1972 but county data are available only on an annual consumption basis. The monthly distribution for the state was used to derive average automobile consumption between January and March, when recreation-type driving was assumed minimal. Divided by total number of cars, this estimated average consumption per car for non-recreational (vacation) type travel. This ratio appeared stable, perhaps due to offsetting effects of increasing numbers of fuel efficient cars and higher average miles travelled.

The number of cars in Region III was multiplied by the state estimate of consumption per car for non-recreational travel. Subtracting this product from total gasoline consumption by private automobiles in the area yielded estimates of gasoline consumption for recreational type activity.

The data generated was used to estimate, for the region, consumption functions of the type:

Non-recreational gasoline consumption

$$\ln {}_R\hat{C}_{Nt} = -4.354^{*} + 0.375^{*} \ln {}_R E_t + 0.850^{**} \ln {}_R\hat{C}_{Nt}$$

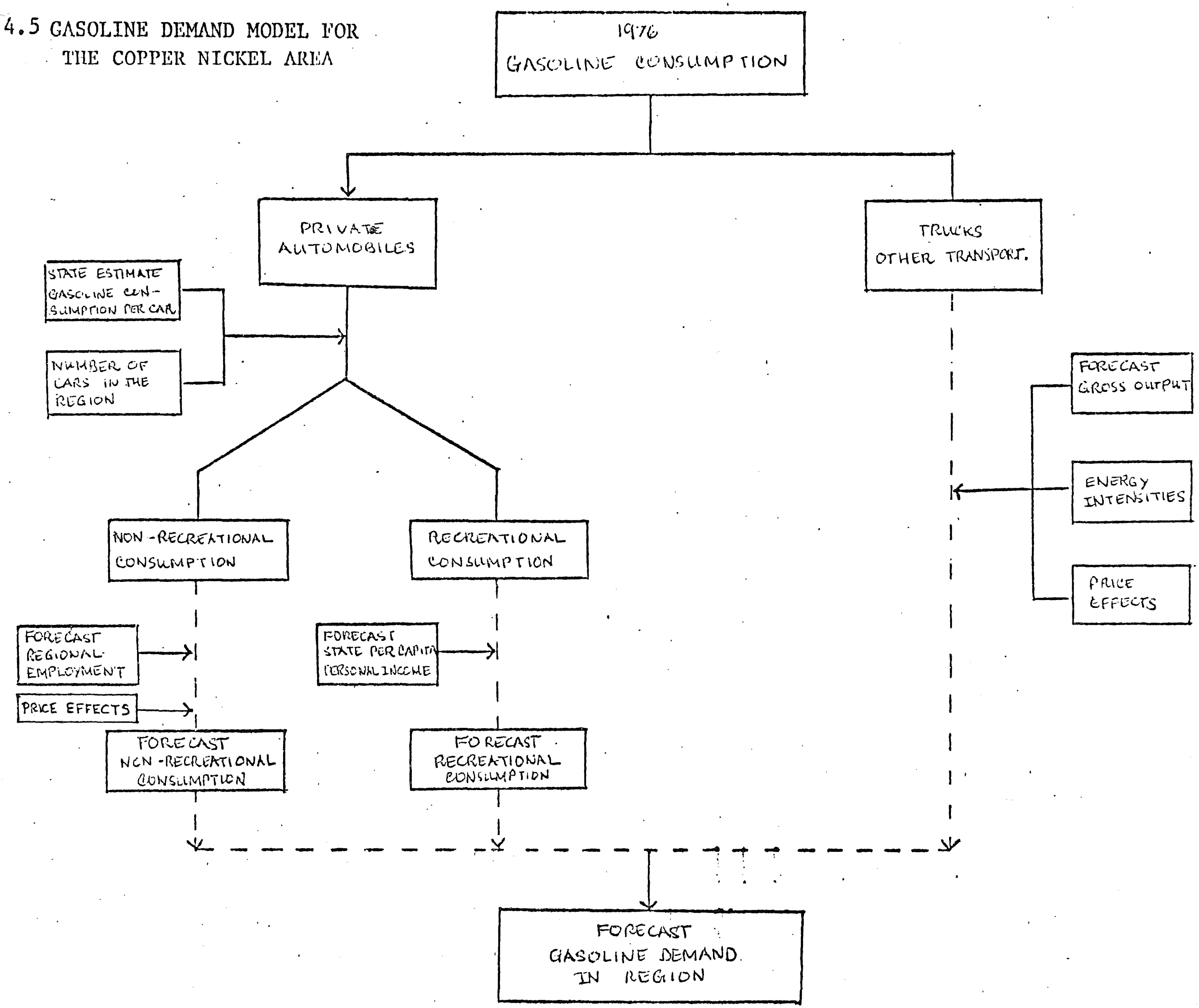
$$(3.046) \qquad (0.259) \qquad (0.124)$$

$$R^2 = 0.972 \qquad F = 171.766 \qquad D. W. = 2.553$$

where ${}_R\hat{C}_{Nt}$ = Estimated non-recreational travel divided by region population, year t

${}_R E_t$ = Employment in the region, year t

Figure 4.5 GASOLINE DEMAND MODEL FOR THE COPPER NICKEL AREA



Price of gasoline was dropped from the equation because of wrong sign of the coefficient. This coefficient was not significantly different from zero. Also serial correlation was a problem, but adding a linear filter did not substantially improve on the Durbin-Watson statistic.

Recreation related gasoline consumption

$$\ln_R \hat{C}_{Vt} = -3.472^{**} + 0.743^{**} \ln Y_{st}$$

$$(0.426) \qquad (0.532) \qquad R^2 = 0.946 \quad F = 194.970 \quad D.\ W. = 2.19$$

where $\hat{C}_{R\,Vt}$ = estimated consumption related to recreation activity in the area, divided by state population, year t

$Y_{s\,t}$ = per capita income in the state, year t

Price of gasoline and unemployment levels in the state were included and then dropped from the equation because of wrong sign and statistically insignificant coefficients, respectively. Since state population was found strongly correlated with personal income, consumption was converted to a (state) per capita basis.

Forecasting Uses

Consumption for commuting, shopping and other non-recreation activity can be related to economic conditions in the region (Fig. 4.5). Price elasticities applied to this end-use will account for consumer responses to rising gasoline prices. For vacation type activities, per capita personal income in the state may be used as a predictor variable. The region is a tourist-recreational area for the Twin Cities and non-region III population. For trucks and other transportation use of gasoline, energy use per dollar output can be adjusted for price effects and multiplied by forecast gross output from SIMLAB.

An alternative approach that extends the econometric method by decomposing further the structure of the model can be tested with more data at the state and regional level. This approach is outlined in Appendix 8.

Presently, a gasoline model for the state forecasts vehicle miles and car registrations. Monthly data are yet insufficient to differentiate between necessary travel and recreation-related travel.

5.0 Bibliography

Sources of data and methods in estimating energy and economic information for the Copper Nickel Study area are enumerated in this section. Citations are grouped according to topics. Note that duplicates appear where the same source was used in more than one topic.

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ATTACHMENTS

1. An Agreement between the Minnesota State Planning Agency (SPA) and the Minnesota Energy Agency (MEA).

2. Office Memorandum to Roy Tull and Don Newell from Ernie Venegas and Edwin Wong.

3.1 Minutes of the Meeting of August 29, 1977.

3.2 Letter to Ernie Venegas from Mark Donaldson.

3.3 Region III Samples by Sectors.

ATTACHMENT 1

M6431

DEPT. #30000
SEQ A √ AID
SEQ A AID
SEQ # AID
SPA # 8022

An Agreement
Between

The Minnesota State Planning Agency (SPA)
and the
Minnesota Energy Agency (MEA)

Relative to the Regional Copper-Nickel
Environmental Impact Study

For the Purpose of Developing Energy
Coefficients and Examining Fuel Substitution
Possibilities for the Copper-Nickel Region

A. Energy Studies (per attached MEQ Project worksheet)

1. The MEA will develop a set of energy and fuel use coefficients for major users and industries in the Copper-Nickel area for a 1974 base year.

2. The MEA will develop a fuel substitution model for large industrial users in the region.

3. The MEA will cooperate with the Regional Copper-Nickel Staff in providing or collecting additional information, data or technical personnel, upon request of MSPA.

B. Transfer of Monies

1. The MSPA agrees to transfer to MEA the sum of four thousand sixty-two dollars ($4062) for the above activities.

2. The MEA agrees to establish a special account for these monies and shall keep such records as will fully disclose the amounts and disposition of the above funds. The procedure developed must provide for the accurate and timely recording of the receipt of funds, expenditures and unexpended balances. Upon completion of the activities listed under paragraph A of this agreement, MEA shall submit to SPA a complete accounting of the cost incurred to complete these activities and transfer back to SPA the unexpended balance, if any.

C. Contract Agent

The Executive Director of the Regional Copper-Nickel Study, Robert Poppe, is the contract agent for SPA under this agreement.

In witness thereof, the SPA and MEA have caused this agreement to be duly executed in their behalf this day of July, 1977.

APPROVED:

Peter Vanderpoel
Director, SPA

7-21-77
Date

John Millhone
Director, MEA

7.15.77
Date

By: W.H.
Richard C. Brubacher
Commissioner of Administration

7-28-77
Date

Approved as to Form and Execution:
William E. Dorigan
Special Assistant Attorney General

Special Asst. Attorney General

7-25-77
Date

8-2-77

ENERGY AGENCY
WORKSHEET

DATE PREPARED June 14, 1977

TITLE:

Energy Coefficients and Fuel Substitution Possibilities Copper Nickel Area

ABSTRACT

In order to project fuel demands in the copper nickel region, a baseline energy and fuel consumption control totals specific by major consumers and industry will be required. In addition, national policies affecting fuel prices and end uses will induce fuel shifts among large users. Hence, it will be necessary to estimate fuel shift capabilities and intentions of different industries in the area.

PROJECT GOAL STATEMENT

To develop a set of energy and fuel use coefficients for major users and industries in the copper nickel area for a 1974 base year.

To develop a fuel substitution model for large industrial users in the area.

To cooperate with MEQC in providing or collecting additional information, data or technical personnel, upon request of MEQC.

PROJECT MANAGER	EXPECTED COMPLETION DATE	FUNDING SOURCE
E. C. Venegas		MEQC-Copper Nickel Project

REPORTS TO BE PRODUCED

TASK NO.	TASK DESCRIPTION	PERSONNEL REQ. PERSON	PERSONNEL REQ. DAYS	OTHER COSTS	IMPORTANT MILESTONE DATES
1.0	Develop energy and fuel coefficients for major industries	RA II	18½	ECV (time) 3	Typist 1
	Access REIS data for supplier information				
1.11	Natural gas consumption data from gas curtailment, by firm		½		
1.12	Natural gas data from Census, FEA, other sources by industry		2		
1.2	Fuel oil consumption data from Census, FEA, other sources, by industry		2		
1.3	Coal consumption data from BOM, Census, FEA, other sources		2		
1.4	Electric energy consumption data from utilities		3		
1.5	Tabulate, cross check and verify fuel consumption data from all sources		5	1	
1.6	Derive energy and fuel coefficients, cross check with national and other studies		4	2	1
2.0	Develop fuel substitution model for major industries		31½	15½	6
2.1	Review natural gas curtailment list, FEA-EPCA industry studies on fuel substitution possibilities and conservation		3		
2.11	Develop first stage fuel substitution model from secondary sources, state model, etc., yielding industry capabilities at national level		5	2	
[illegible]	Survey large industrial customers on gas and oil				
2.21	Acquire list of large industrial firms from U.M., BEA, etc.		1		
2.22	Check with MEQC on list of firms to be surveyed.			1	

GY AGENCY
SHEET

	TASK DESCRIPTION	PERSONNEL REQ. PERSON	DAYS	OTHER COSTS	IMPORTANT MILESTONE DATES
23	sign questionaire on post 1973 fuel consumption, el shift intentions, fuel prices	1½		½	
24	Survey large industrial users	University of Minnesota (Dr. Mak			
25	Assemble collected information, cross check and verify.	7		1	
26	Run statistical packages to estimate fuel substitution parameters	2			
27	Test model in comparison with first stage model	5		1	
30	Write report				3
31	First draft report, fuel consumption and fuel substitution possibilities	5		5	
32	Secure MEQC comments, revise report and model	1		2	2
33	Submit final draft report	1		3	1

Summary	Man Days	Rate	Cost	
RA II	50	8.09/hour	$3236.00	
Typist	7	5.81/hour	325.36	
ECV	18½	13.23/hour	+ 500.00	(Roger H.)
			$4061.36	

ADMIN 1000 (REV. 4/77)

ATTACHMENT 2

STATE OF MINNESOTA

C/N.

Office Memorandum

DEPARTMENT Energy

TO : Roy Tull, Don Newell

DATE:

FROM : Ernie Venegas, Edwin Wong

Ernie

Edwin Wong

PHONE:

SUBJECT: Data file from fuel survey of industrial-commercial firms in N E Minnesota.

After yesterday's meeting it appeared that substantial work has to be done on the data file before we can use it to build the fuel substitution model. We would defer running our statistical packages until your group has completed the modifications and editing of the files.

Since your group conducted the survey and transferred the information into a data file, your staff are in the best position to make all corrections or completions on the file.

Please immediately notify Edwin when the data problems he indicated to your group has been corrected. We are already past the deadline for our first draft report to the copper-nickel project.

cc: Mark Polich

Ernie

ATTACHMENT 3.1

Meeting of August 29, 1977

Participants: Roy Tull, Don Newell, Mark Donaldson, Ernie Venegas, Edwin Wong, Wilbur Maki

The purpose of this meeting was to resolve several questions surrounding the proposed Region III survey. The following resolutions resulted.

1. The economic portion of the East Range survey will accompany the energy questionnaire. Thus, the Region III survey will be essentially the same as the East Range survey.

2. The survey sample will be stratified at the 62 sector (Copper-Nickel Study classification system) level. The sample will be drawn on a random basis from the industry firms until the minimum number of employees have been drawn to meet the 95% ($\pm$ .05) confidence internal requirements. This list will then be submitted to the Energy Agency who will then determine if enough firms have been selected to meet their minimum date requirements. If the original sample does not meet these requirements, they will identify the deficient sectors and additional firms (if available) will be selected.

3. The base year selected for both the economic and energy questionnaires is 1976.

4. The Energy Agency will identify, by sector, those industries which will receive the short form (quetions 1,2, and 3 through 1980) of the energy questionnaire, and those who will receive the long form, (questions 1, 2, 3, and 4 through 1985).

If there are any additions to or misunderstandings about these resolutions, please contact Don Newell at Copper-Nickel.

ATTACHMENT 3.2

STATE OF MINNESOTA

ENVIRONMENTAL QUALITY COUNCIL
Copper-Nickel Project
138 Hennepin Square Building
2021 East Hennepin Avenue
Minneapolis, Minn. 55413

Phone: 612-378-7770

October 4, 1977

Dr. Ernesto Venegas
Minnesota Energy Agency
740 American Center Bldg.
160 East Kellogg Boulevard
St. Paul, MN 55101

Dear Ernie:

Enclosed you will find a summary of our Region III and Douglas County, Wisconsin sample as it was produced for us by Minnesota Analysis and Planning System (MAPS) from their Dunn and Bradstreet listing. As I understand it, you will review the sample with regard to your data needs and indicate if and in which sectors the sample may be insufficient. Could you also indicate which sectors whould receive the "long" form of the energy questionnaire and which sectors should receive the shorter form.

The East Range survey will be mailed out this week and we hope to mail the Region III survey in about two weeks so it is necessary to get your response quite quickly. We plan to mail a letter notifying the firms of the survey about one week in advance of the survey mailing. We will follow-up the the survey mailing with reminder postcards after two weeks and a second survey a week later if there is still no response.

If you have any questions, let me know. Hope to hear from you soon.

Sincerely,

Mark

Mark Donaldson
Economic Planner

cc: Roy Tull

MD/JJ

Enclosure

ATTACHMENT 3.3

REGION III SAMPLE

SECTOR	NUMBER OF EMPLOYEES IN SAMPLE	NUMBER OF FIRMS IN SAMPLE
1. Timber Production	23	4
2. Timber Operations	202	46
3. Sawmills	174	20
4. All other Agricultural, Forestry and Fishery Products and Services	151	33
5. Iron and Ferro Allo Ores	1400	1
7. Other Nonferrous Metal Mining	19	2
8. All other Mining and Quarrying	83	12
9. Construction	502	56
10. Food and Kindred Products	428	12
11. Other Lumber and Furniture	294	12
12. Paper and Allied Products	862	2
13. Printing, Publishing, and Allied Industries	305	9
14. Chemical and Allied Products	130	10
15. Petroleum Refining and Related Industries	165	3
16. Stone, Clay, Glass, and Concrete Products	182	20
19. Other Primary Metal Industries	365	2
23. Fabricated Metal Products	757	19
24. Machinery, Except Electrical	359	9
25. Electrical and Electronic Machinery	172	5
26. All other Manufacturing	431	8
27. Railroad Transportation	248	2
28. Motor Freight Transportation and Warehousing	261	43
29. Other Transportation	217	15
30. Communication	269	26
31. Electric Utilities	215	11
32. Gas Utilities	31	3

SECTOR		NUMBER OF EMPLOYEES IN SAMPLE	NUMBER OF FIRMS IN SAMPLE
33.	Other Utilities	44	7
34.	Wholesale Trade, Durable Goods	340	45
35.	Wholesale Trade, Non-durable Goods	313	44
36.	Building Materials and Hardware	285	48
37.	General Merchandise Stores	346	25
38.	Food Stores	323	38
39.	Automotive Dealers	314	41
40.	Gasoline Service Stations	265	54
41.	Apparel and Accessory Stores	287	40
42.	Furniture and Home Furnish-ings Stores	269	30
43.	Eating and Drinking Places	358	32
44.	Miscellaneous Retail	332	69
45.	Finance, Insurance, and Real Estate	308	67
46.	Hotels, Motels and Tourist Courts, Rooming and Boarding Houses	320	54
47.	Camps and Trailering Parks	53	18
48.	Personal Services	260	36
49.	Business Services	248	52
50.	Automotive Repair, Services, and Garages	218	47
51.	Miscellaneous Repair Services	214	61
52.	Motion Picutres	32	8
53.	Other Amusement and Recreat-ion Services	226	32
54.	Outfitters	30	12
55.	Health Services	366	23
56.	Hospitals	435	2
57.	Education Services	2000	1
	Miscellaneous Services	275	37
59.	Membership Organizations	375	25
60.	ALL OTHERS	383	10

APPENDICES

1A Fuel Use Survey Questionnaire for the Commercial Sector.

1B Fuel Use Survey Questionnaire for the Industrial Sector.

2 Regression Estimates of the Fuel Substitution Model for 53 Sectors.

3 Industrial Furnace Efficiency.

4 Fuel Substitution Computer Subroutine Attached to SIMLAB.

5 Data Requirements of the Residential Model.

6 Residential Fuel Demand Model for Region III and Douglas County, Wisconsin.

7 Fuel Price Projections and Elasticities.

8 An Alternative Approach to Gasoline Forecasting.

APPENDIX 1A

ENERGY QUESTIONNAIRE I (COMMERCIAL SECTORS)

1. How much energy did you use in 1976? Please report, by energy type, the total dollars you spent and the total energy used in 1976.

ENERGY TYPE	TOTAL DOLLARS SPENT	TOTAL UNITS USED
Electricity Purchased		kwh
Natural Gas		MCF
Fuel Oil		Gal
LPG		Lbs
Coal		Tons
Wood		Cords

2. Please indicate your best estimate of the percentage of energy requirements, by year, supplied by each indicated energy type. For example, if in 1976 and 1977 you expect 33% of your total indicated fuel use to be supplied by natural gas, 33% by coal, and 34% by fuel oil, the first two lines in the table would look like the following example:

YEAR	NATURAL GAS	COAL	FUEL OIL	LPG	TOTAL
1977					
1978					
1979					
1980					

	NAT. GAS	COAL	FUEL OIL	LPG	TOTAL
1976	33	33	34	0	100.
1977	33	33	34	0	100.

3. Please indicate your planned consumption of electricity based on 1976 levels (1976=100). For example, if you foresee a 10% increase in electricity purchased in 1977 over 1976 the first two lines should look like the following example:

	ELECTRICITY PURCHASED
1976	100.
1977	110.

YEAR	ELECTRICITY PURCHASED
1976	100.
1977	
1978	
1979	
1980	

APPENDIX 1B

ENERGY QUESTIONNAIRE II (INDUSTRIAL SECTORS)

1. How much energy did you use in 1976? Please report, by energy type, the total dollars you spent and the total energy used in 1976.

ENERGY TYPE	TOTAL DOLLARS SPENT	TOTAL UNITS USED
Electricity Purchased		kwh
Natural Gas		MCF
Fuel Oil		Gal
LPG		Lbs
Coal		Tons
Wood		Cords

2. Please indicate your best estimate of the percentage of total energy requirements, by year, supplied by each indicated energy type. For example, if in 1976 and 1977 you expect 33% of your total fuel use to be supplied by natural gas, 33% by coal, and 34% by fuel oil, the first two lines in the table would look like the following example:

EXAMPLE

	NAT. GAS	COAL	FUEL OIL	LPG	TOTAL
1976	33	33	34	0	100.
1977	33	33	34	0	100.

YEAR	NATURAL GAS	COAL	FUEL OIL	LPG	TOTAL
1977					100.
1978					100.
1979					100.
1980					100.
1981					100.
1982					100.
1983					100.
1984					100.
1985					100.

3. Please indicate your planned consumption of electricity based on 1976

YEAR	ELECTRICITY PURCHASED

APPENDIX 2

REGRESSION ESTIMATES OF THE FUEL SUBSTITUTION MODEL FOR 53 SECTORS

SECTORS	1	2	3	4	R^2
5	.83 (.10)	.01 (.3)		.83 (.2)	.88
10	.43 (.07)	.003 (.06)	.24 (.04)	.24 (.006)	.98
				.200 (.006)	.98
15	.76 (.06)	0 (0)		.60 (.47)	.76
16,17,18	.02 (.005)	.756 (.06)		.13 (.09)	.93
21	.54 (.07)	.22 (.06)		.43 (.07)	.81
23	.97 (.02)	-.4 (.05)		.72 (.02)	.99
38	1	0		1	1
41	.01 (.02)	1 (.005)		.9995 (.013)	.99
42	.998 (.77)	-.07 (.04)		1.06 (.014)	.99
43,44	.97 (.132)	.94 (.25)		.94 (.25)	.85
47	1 (.002)	-.003 (.003)		.14 (.06)	.99
49	.98 (.01)	-.03 (.03)		.198 (.73)	.99

Standard errors in parenthesis

Equation Form:

$$Y = \left(\alpha_1 + \beta_1 (1-d_1)\right) X_1 + d_1 (1-\beta_2) X_2 + d_1 (1-\beta_3) X_3 + d_1 G_1$$

$$Y = \alpha_1 X_1 + \alpha_2 + X_2 + \alpha_3 X_3 + \alpha_4 G$$

A second regression equation is needed in order to estimate d_2 when coal (indexed 3) is actually used as an alternate fuel. When there are 3 competing fuels:

$$d_3 = 1 - d_1 - d_2;$$

when there are only two fuels, (natural gas and fuel oil, indexed 1 and 2 respectively) only 1 equation is needed:

$$d_2 = 1 - d_1$$

APPENDIX 3

INDUSTRIAL FURNACE EFFICIENCY

Natural Gas -	74-78%
Light Oil (1 & 2) -	77-81%
Heavy Oil (4, 5, 6) -	78-82%
Coal -	75-78%

Based on minimum excess air in existing plants. Lower numbers indicate average plants. Maximum numbers indicate well maintained plants.

Source: Minnesota Energy Agency, Conservation Division, Technical Services.

APPENDIX 4

FUEL SUBSTITUTION COMPUTER SUBROUTINE ATTACHED TO SIMLAB

```
/LNH,F=EDMOD
FUEL809
*IDENT FUEL809                  MMC. 78/09/09.
*/    ****  THIS MODSET PUT FUEL MODULE INTO SIMLAB2.
*DECK SIM2P
*I U780807.42                   (4)
      COMMON/FUEL/YT(56),AA(55,3),DDUM(55,3),YB(56,3),PRICE(3),
     1PRATE(3),B(55,3),D(55,3),EIDOL(55)
*I 61
       DATA PRICE/.88,1.9,.55/
*I 200
       CALL OVERLAY(6HSIMLAB,21B,0)
*
*      FUEL MODULE CALLED.
*
*I U780807.142                  (640)
      COMMON/FUEL/YT(56),AA(55,3),DDUM(55,3),YB(56,3),PRICE(3),
     1PRATE(3),B(55,3),D(55,3),EIDOL(55)
*I 866
      PRATE(1)=1.08
      PRATE(2)=1.06
      REWIND 1
      PRATE(3)=1.06
      CALL GETPF(5HTAPE1,6HEDFUEL,0,0)
      DO 322 I=1,NIS
      READ(1,)N,(YB(I,J),J=1,3)
  322 CONTINUE
      DO 321 I=1,NIS
      READ(1,)N,(B(I,J),J=1,3),(D(I,J1),J1=1,3)
  321 CONTINUE
*I U780314.47
       IF(I.EQ.10) CALL OVERLAY(6HSIMLAB,11B,12B)
*I 5525
*
*
*
      OVERLAY(SIMLAB,11,12)
      PROGRAM BASE10
*
*
*
       COMMON/NAME1/INDUSN(67),NAME(26),NAMER,NAMER1
       COMMON/A0/AY,AY1,AY2,DUMMY(1),IB(12),IC(60),ICOUNT,IDATA(60),
     +          IDEBUG,IFORM,IFUTURE(20),IHELP,INI,IPRINT,IYB,
     +          IYE,IYEAR,IV,MASK1,MODTIME,MPRINT,NIS,NISM1,
     +          NISP1,NOC,NOCP1,T,T1,T2,T3,T4,T5,T6,RHRWPW(55)
       COMMON/A1/EXPORT(55),GROWTHR(5,55),REGMKS(55),REGMKSR(55),
     +          REGMKM1(55),USGO(55),USGOT,T5M(55),T6M(55),T7M(55)
       COMMON/A2/CAPOIR(55),CAPPAR(55),EINVOI(55),EINVPA(55),
     +          INVLMA,INVMAT(55,55),INVLMC,OICAP(55),PACAP(55),
     +          PCHCOR(55),RINVOI(55),RINVPA(55),OHRWPW(55),AWKWPY(55)
```

```
      COMMON/A3/BINCH(55),BINCHR(55),BINCHT,ELASIN(55),ELASONN(55),
     +          EXOGFD(55),EXOGFDR(55),EXOGOTT,EXOGOUT(55),EXPORTT,
     +          FD(55),FDT,FGOVE(55),FGOVER(55),FGOVET,GPCF(55),
     +          GPCFT,LELASIN(55),LELASON(55),PCE(55),PCESUBT,PCET,
     +          SGOVE(55),SGOVER(55),SGOVET,T5TM,T6TM,T7TM,T8TM
      COMMON/A4/ACNETBI(55),BUSINC(55),BUSINCT,BUSTAX,BUSTAXR(55),
     +          DEPROI(55),DEPRPA(55),DIT,DITM1,EARN(55),EARNT,
     +          EARPWK(55),EARPWKR(5,55),EMPCOM(55),EMPCOMR(55),
     +          EMPCOMT,IMPORT(55),IMPORTT,PCEIMP,PCER,PCHECR(55),
     +          PCHITR(55),PIDITR,PIEARNR,PIT,PITM1,PROPINR,
     +          REGIMPR(55),TMAX(55),TRANPYR,UNCOMPR,VALADR(55)
      COMMON/A5/EMPLOY(55),EMPLOYD(10),EMPLOYS(10),EMPLOYT,EMPM1T,
     +          EMPWFD(55),EMPWFDT,FCEMP,FCEMPR,FMEMP,HWORK,HWORKR,
     +          HRWPW(55),HRWPWR(55),HRWPY(55),OCUP(65,9),OGFDDIS(3),
     +          OUTPHW(55),OUTPHWR(5,55),OUTPWK(55),RFCEMP,
     +          RHWORK,RSGEMP,SGEMP,SGEMPR,UNEMP(10),UNEMPT,
     +          WKWPY(55),WKWPYR(55),T8M(55)
      COMMON/A6/LBFAGEG(12),LBFOCUR(10),LBFT
      COMMON/A7/ACFERTY(4,67),COMIN(10),COMINR(10),COMOUT(10),
     +          COMOUTR(10),CORTMVF(67),CORTMVM(67),
     +          DEATHRF(67),DEATHRM(67),FERTILY(67),INMIGF(67),
     +          INMIGM(67),INMIGOC(10),INMIGR(10),MFBIRTR,NEMDEPR,
     +          NMIGDIR(2,67),NMIGDIS(2,67),OTMIGOC(10),OTMIGR(10),
     +          OUTMIGF(67),OUTMIGM(67),POPF(67),POPFT,POPM(67),
     +          POPMT,POPT,POPTM1,RCOMINR(10),RCOMOTR(10),REMDEPR,
     +          RMIGDIR(2,67),RMIGDIS(2,67),RNEMDEP,RREMDEP
      COMMON/A8/LEMAT(55,55),X(55),XD(55),XDTOT,XLTOT,XM1(55),
     +          XS(55),XSTOT,XTOT,XTOTM1
      COMMON/A9/CHANGA(10),CHANGE(10),DUM(3,10),RIA(3,10),
     +          T1M(55),T2M(55),T3M(55),T1TM,T2TM,T3TM,
     +          LFPARF(12),LFPARM(12),LFPARFR(12),LFPARMR(12)
*
      REAL LBFMG,LBFFG
      REAL LBFT,IMPORTT,NBUSINC,INVLMC,INVLMA
      REAL LELASIN,LELASON,INVMAT,NEMDEPR,MFBIRTR
      REAL NMIGDIS,NMIGDIR,INMIGM,INMIGF,LBFOCUR,INMIGOC,LBFAGEG
      REAL LEMAT,LFPARM,LFPARMR,LFPARF,LFPARFR,IMPORT,INMIGR
      INTEGER AY1,AY2,AY
*
     COMMON/FUEL/YT(56),AA(55,3),DDUM(55,3),YB(56,3),PRICE(3),
    1PRATE(3),B(55,3),D(55,3),EIDOL(55)
     IF(IYEAR.GT.1975)GOTO 336
     PRINT 337
 337 FORMAT(//* FUEL SUBSTITUTION MODEL STARTS FROM YEAR 1976.*,
    1/5X,*NO OUTPUT IS GENERATED.*)
     GOTO 338
 336 CONTINUE
     PRINT 305,IYEAR
 305 FORMAT(1H1,//50(1H-),//5X,*TABLE 10.     FUEL CONSUMPTION*,
    1* BY FUEL TYPE BY SECTOR*,5X,I4,
    2//10X,*SECTOR*,10X,*NATURAL GAS*,5X,*FUEL OIL*,5X,
    3*COAL*,//50(1H-)//)
     DO 334 I=1,NIS
     PRINT 304,I,INDUSN(I),(YB(I,J),J=1,3),EIDOL(I),(D(I,J),J=1,3),X(I)
 304 FORMAT(I5,1X,A10,3F10.2,F9.4,3F5.3,F10.1)
 334 CONTINUE
     PRINT 332,(YB(NISP1,J),J=1,3)
 332 FORMAT(* TOTAL*,10X,3F10.2)
*
*
*
*
 338 CONTINUE
     END
*
```

```
*
*************************************************************
*
*
*I U780814.312
      IF(I.EQ.10) CALL OVERLAY(6HSIMLAB,12B,12B)
*I 6503
*
*
*
      OVERLAY(SIMLAB,12,12)
      PROGRAM BASS10
*
*
*
      COMMON/NAME1/INDUSN(67),NAME(26),NAMER,NAMER1
      COMMON/A0/AY,AY1,AY2,DUMMY(1),IB(12),IC(60),ICOUNT,IDATA(60),
     +          IDEBUG,IFORM,IFUTURE(20),IHELP,INI,IPRINT,IYB,
     +          IYE,IYEAR,IV,MASK1,MODTIME,MPRINT,NIS,NISM1,
     +          NISP1,NOC,NOCP1,T,T1,T2,T3,T4,T5,T6,RHRWPW(55)
      COMMON/A1/EXPORT(55),GROWTHR(5,55),REGMKS(55),REGMKSR(55),
     +          REGMKM1(55),USGO(55),USGOT,T5M(55),T6M(55),T7M(55)
      COMMON/A2/CAPOIR(55),CAPPAR(55),EINVOI(55),EINVPA(55),
     +          INVLMA,INVMAT(55,55),INVLMC,OICAP(55),PACAP(55),
     +          PCHCOR(55),RINVOI(55),RINVPA(55),OHRWPW(55),AWKWPY(55)
      COMMON/A3/BINCH(55),BINCHR(55),BINCHT,ELASIN(55),ELASOWN(55),
     +          EXOGFD(55),EXOGFDR(55),EXOGOTT,EXOGOUT(55),EXPORTT,
     +          FD(55),FDT,FGOVE(55),FGOVER(55),FGOVET,GPCF(55),
     +          GPCFT,LELASIN(55),LELASON(55),PCE(55),PCESUBT,PCET,
     +          SGOVE(55),SGOVER(55),SGOVET,T5TM,T6TM,T7TM,T8TM
      COMMON/A4/ACNETBI(55),BUSINC(55),BUSINCT,BUSTAX,BUSTAXR(55),
     +          DEPROI(55),DEPRPA(55),DIT,DITM1,EARN(55),EARNT,
     +          EARPWK(55),EARPWKR(5,55),EMPCOM(55),EMPCOMR(55),
     +          EMPCOMT,IMPORT(55),IMPORTT,PCEIMP,PCER,PCHECR(55),
     +          PCHITR(55),PIDITR,PIEARNR,PIT,PITM1,PROPINR,
     +          REGIMPR(55),TMAX(55),TRANPYR,UNCOMPR,VALADR(55)
      COMMON/A5/EMPLOY(55),EMPLOYD(10),EMPLOYS(10),EMPLOYT,EMPM1T,
     +          EMPWFD(55),EMPWFDT,FCEMP,FCEMPR,FMEMP,HWORK,HWORKR,
     +          HRWPW(55),HRWPWR(55),HRWPY(55),OCUP(65,9),OGFDDIS(3),
     +          OUTPHW(55),OUTPHWR(5,55),OUTPWK(55),RFCEMP,
     +          RHWORK,RSGEMP,SGEMP,SGEMPR,UNEMP(10),UNEMPT,
     +          WKWPY(55),WKWPYR(55),T8M(55)
```

```
      COMMON/A6/LBFAGEG(12),LBFOCUR(10),LBFT
      COMMON/A7/ACFERTY(4,67),COMIN(10),COMINR(10),COMOUT(10),
     +          COMOUTR(10),CORTMVF(67),CORTMVM(67),
     +          DEATHRF(67),DEATHRM(67),FERTILY(67),INMIGF(67),
     +          INMIGM(67),INMIGOC(10),INMIGR(10),MFBIRTR,NEMDEPR,
     +          NMIGDIR(2,67),NMIGDIS(2,67),OTMIGOC(10),OTMIGR(10),
     +          OUTMIGF(67),OUTMIGM(67),POPF(67),POPFT,POPM(67),
     +          POPMT,POPT,POPTM1,RCOMINR(10),RCOMOTR(10),REMDEPR,
     +          RMIGDIR(2,67),RMIGDIS(2,67),RNEMDEP,RREMDEP
      COMMON/A8/LEMAT(55,55),X(55),XD(55),XDTOT,XLTOT,XM1(55),
     +          XS(55),XSTOT,XTOT,XTOTM1
      COMMON/A9/CHANGA(10),CHANGE(10),DUM(3,10),RIA(3,10),
     +          T1M(55),T2M(55),T3M(55),T1TM,T2TM,T3TM,
     +          LFPARF(12),LFPARM(12),LFPARFR(12),LFPARMR(12)
*
      REAL LBFMG,LBFFG
      REAL LBFT,IMPORTT,NBUSINC,INVLMC,INVLMA
      REAL LELASIN,LELASON,INVMAT,NEMDEPR,MFBIRTR
      REAL NMIGDIS,NMIGDIR,INMIGM,INMIGF,LBFOCUR,INMIGOC,LBFAGEG
      REAL LEMAT,LFPARM,LFPARMR,LFPARF,LFPARFR,IMPORT,INMIGR
      INTEGER AY1,AY2,AY
*
      COMMON/FUEL/YT(56),AA(55,3),DDUM(55,3),YB(56,3),PRICE(3),
     1PRATE(3),B(55,3),D(55,3),EIDOL(55)
      IF(IYEAR.GT.1975)GOTO 336
      PRINT 337
 337  FORMAT(//* FUEL SUBSTITUTION MODEL STARTS FROM YEAR 1976.*,
     1/5X,*NO OUTPUT IS GENERATED.*)
      GOTO 338
 336  CONTINUE
      PRINT 305,IYEAR
  305 FORMAT(1H1,//50(1H-),//5X,*TABLE 10.     FUEL CONSUMPTION*,
     1* BY FUEL TYPE BY SECTOR*,5X,I4,
     2//10X,*SECTOR*,10X,*NATURAL GAS*,5X,*FUEL OIL*,5X,
     3*COAL*,//50(1H-)//)
      DO 334 I=1,NIS
      PRINT 304,I,INDUSN(I),(YB(I,J),J=1,3),EIDOL(I),(D(I,J),J=1,3),X(I)
  304 FORMAT(I5,1X,A10,3F10.2,F9.4,3F5.3,F10.1)
  334 CONTINUE
      PRINT 332,(YB(NISP1,J),J=1,3)
  332 FORMAT(* TOTAL*,10X,3F10.2)
*
*
*
*
 338  CONTINUE
      END
*
*
*
*
*
*
*****************************************************
```

```
*I 9995
      OVERLAY(SIMLAB,21,0)
      PROGRAM FUEL

       COMMON/NAME1/INDUSN(67),NAME(26),NAMER,NAMER1
       COMMON/A0/AY,AY1,AY2,DUMMY(1),IB(12),IC(60),ICOUNT,IDATA(60),
     +          IDEBUG,IFORM,IFUTURE(20),IHELP,INI,IPRINT,IYB,
     +          IYE,IYEAR,IV,MASK1,MODTIME,MPRINT,NIS,NISM1,
     +          NISP1,NOC,NOCP1,T,T1,T2,T3,T4,T5,T6,RHRWPW(55)
       COMMON/A1/EXPORT(55),GROWTHR(5,55),REGMKS(55),REGMKSR(55),
     +          REGMKM1(55),USGO(55),USGOT,T5M(55),T6M(55),T7M(55)
       COMMON/A2/CAPOIR(55),CAPPAR(55),EINVOI(55),EINVPA(55),
     +          INVLMA,INVMAT(55,55),INVLMC,OICAP(55),PACAP(55),
     +          PCHCOR(55),RINVOI(55),RINVPA(55),OHRWPW(55),AWKWPY(55)
       COMMON/A3/BINCH(55),BINCHR(55),BINCHT,ELASIN(55),ELASOWN(55),
     +          EXOGFD(55),EXOGFDR(55),EXOGOTT,EXOGOUT(55),EXPORTT,
     +          FD(55),FDT,FGOVE(55),FGOVER(55),FGOVET,GPCF(55),
     +          GPCFT,LELASIN(55),LELASON(55),PCE(55),PCESUBT,PCET,
     +          SGOVE(55),SGOVER(55),SGOVET,T5TM,T6TM,T7TM,T8TM
       COMMON/A4/ACNETBI(55),BUSINC(55),BUSINCT,BUSTAX,BUSTAXR(55),
     +          DEPROI(55),DEPRPA(55),DIT,DITM1,EARN(55),EARNT,
     +          EARPWK(55),EARPWKR(5,55),EMPCOM(55),EMPCOMR(55),
     +          EMPCOMT,IMPORT(55),IMPORTT,PCEIMP,PCER,PCHECR(55),
     +          PCHITR(55),PIDITR,PIEARNR,PIT,PITM1,PROPINR,
     +          REGIMPR(55),TMAX(55),TRANPYR,UNCOMPR,VALADR(55)
       COMMON/A5/EMPLOY(55),EMPLOYD(10),EMPLOYS(10),EMPLOYT,EMPM1T,
     +          EMPWFD(55),EMPWFDT,FCEMP,FCEMPR,FMEMP,HWORK,HWORKR,
     +          HRWPW(55),HRWPWR(55),HRWPY(55),OCUP(65,9),OGFDDIS(3),
     +          OUTPHW(55),OUTPHWR(5,55),OUTPWK(55),RFCEMP,
     +          RHWORK,RSGEMP,SGEMP,SGEMPR,UNEMP(10),UNEMPT,
     +          WKWPY(55),WKWPYR(55),T8M(55)
       COMMON/A6/LBFAGEG(12),LBFOCUR(10),LBFT
       COMMON/A7/ACFERTY(4,67),COMIN(10),COMINR(10),COMOUT(10),
     +          COMOUTR(10),CORTMVF(67),CORTMVM(67),
     +          DEATHRF(67),DEATHRM(67),FERTILY(67),INMIGF(67),
     +          INMIGM(67),INMIGOC(10),INMIGR(10),MFBIRTR,NEMDEPR,
     +          NMIGDIR(2,67),NMIGDIS(2,67),OTMIGOC(10),OTMIGR(10),
     +          OUTMIGF(67),OUTMIGM(67),POPF(67),POPFT,POPM(67),
     +          POPMT,POPT,POPTM1,RCOMINR(10),RCOMOTR(10),REMDEPR,
     +          RMIGDIR(2,67),RMIGDIS(2,67),RNEMDEP,RREMDEP
       COMMON/A8/LEMAT(55,55),X(55),XD(55),XDTOT,XLTOT,XM1(55),
     +          XS(55),XSTOT,XTOT,XTOTM1
       COMMON/A9/CHANGA(10),CHANGE(10),DUM(3,10),RIA(3,10),
     +          T1M(55),T2M(55),T3M(55),T1TM,T2TM,T3TM,
     +          LFPARF(12),LFPARM(12),LFPARFR(12),LFPARMR(12)
      COMMON/FUEL/YT(56),AA(55,3),DDUM(55,3),YB(56,3),PRICE(3),
     1PRATE(3),B(55,3),D(55,3),EIDOL(55)

       REAL LBFMG,LBFFG
       REAL LBFT,IMPORTT,NBUSINC,INVLMC,INVLMA
       REAL LELASIN,LELASON,INVMAT,NEMDEPR,MFBIRTR
       REAL NMIGDIS,NMIGDIR,INMIGM,INMIGF,LBFOCUR,INMIGOC,LBFAGEG
       REAL LEMAT,LFPARM,LFPARNR,LFPARF,LFPARFR,IMPORT,INMIGR
       INTEGER AY1,AY2,AY

      DIMENSION YN(56),GF(56),YF(56,3),ELAST(3,3),OWNEL(3),CONVF(3)
      DATA ELAST/-.0797,.424,.313,.01,-.952,.0923,.0023,.0288,-.797/
      DATA OWNEL/-.003,-.003,-.003/
      DATA CONVF/.74,.78,.75/
C...GETPF DATA FILE EIDFUEL
      IF(IYEAR.LT.1976) GO TO 330
      IF(IYEAR.GT.1976) GOTO 501
      DO 301 I=1,NIS
      YT(I)=YB(I,1)+YB(I,2)+YB(I,3)
```

```
C    BASE YEAR ENERGY INTENSITY PER DOLLAR OUTPUT DOES NOT INCLUDE
C    ELECTRICITY SELF-GENERATION.
C
       IF(I.EQ.5)YT(I)=YT(I)-23200.0
       IF(I.EQ.17)YT(I)=YT(I)-6606.0
       IF(I.EQ.28)YT(I)=YT(I)-9925.0
       IF(YT(I).LT.0.)YT(I)=0.
       EIDOL(I)=0.
       IF(X(I).NE.0.)  EIDOL(I)=YT(I)/X(I)
  301  CONTINUE
       GO TO 330
  501  CONTINUE
C
C    SUBTRACT TOTAL IN SECTORS 5,17 AND 28
C
       IF(IYEAR.GT.1977)GOTO 601
       YB(5,1)=YB(5,1)-5723.0
       YB(17,1)=YB(17,1)-3901.0
 601   CONTINUE
       YB(5,3)=YB(5,3)-23200.0
       IF(YB(5,3).LT.0.)YB(5,3)=0.
       YB(17,3)=YB(17,3)-6606.0
       IF(YB(17,3).LT.0.)YB(17,3)=0.
       YB(28,3)=YB(28,3)-9925.0
       IF(YB(28,3).LT.0.)YB(28,3)=0.
       DO 302 I=1,NIS
  302  YN(I)=X(I)*EIDOL(I)
       DO 331 J=1,3
  331  YB(NISP1,J)=0.
C
       DO 411 I=1,NIS
       DO 411 J=1,3
       YB(I,J)=YB(I,J)*CONVF(J)
 411   CONTINUE
C
C    CALL EVSUBS
C     SUBROUTINE EVSUBS
C......SHIFTS TO FUEL OIL......
C...........................
       DO 59 I=1,NIS
       YT(I)=YB(I,1)+YB(I,2)+YB(I,3)
       IF(YT(I).EQ.0.) GOTO 59
       CONVAV=(YB(I,1)*CONVF(1)+YB(I,2)*CONVF(2)+YB(I,3)*CONVF(3))/YT(I)
       YN(I)=YN(I)*CONVAV
 59    CONTINUE
       IF(IYEAR.NE.1977) GOTO 18
       DO 111 I=1,NIS
       YT(I)=YB(I,1)+YB(I,2)+YB(I,3)
       DO 212 J=1,3
       IF(YT(I).EQ.0.) GOTO 297
       YF(I,J)=YB(I,J)/YT(I)
       GOTO 212
  297  YF(I,1)=YF(I,2)=YF(I,3)=0
  212  CONTINUE
       IF(YT(I).EQ.0.) GOTO 69
       GF(I)=0.
       IF(YT(I).NE.0.) GF(I)=(YN(I)-YT(I))/YT(I)
       GOTO 111
   69  GF(I)=0.
  111  CONTINUE
```

```
*I 9995
      OVERLAY(SIMLAB,21,0)
      PROGRAM FUEL
*
      COMMON/NAME1/INDUSN(67),NAME(26),NAMER,NAMER1
      COMMON/A0/AY,AY1,AY2,DUMMY(1),IB(12),IC(60),ICOUNT,IDATA(60),
     +          IDEBUG,IFORM,IFUTURE(20),IHELP,INI,IPRINT,IYB,
     +          IYE,IYEAR,IV,MASK1,MODTIME,MPRINT,NIS,NISM1,
     +          NISP1,NOC,NOCP1,T,T1,T2,T3,T4,T5,T6,RHRWPW(55)
      COMMON/A1/EXPORT(55),GROWTHR(5,55),REGMKS(55),REGMKSR(55),
     +          REGMKM1(55),USGO(55),USGOT,T5M(55),T6M(55),T7M(55)
      COMMON/A2/CAPOIR(55),CAPPAR(55),EINVOI(55),EINVPA(55),
     +          INVLMA,INVMAT(55,55),INVLMC,OICAP(55),PACAP(55),
     +          PCHCOR(55),RINVOI(55),RINVPA(55),OHRWPW(55),AWKWPY(55)
      COMMON/A3/BINCH(55),BINCHR(55),BINCHT,ELASIN(55),ELASOWN(55),
     +          EXOGFD(55),EXOGFDR(55),EXOGOTT,EXOGOUT(55),EXPORTT,
     +          FD(55),FDT,FGOVE(55),FGOVER(55),FGOVET,GPCF(55),
     +          GPCFT,LELASIN(55),LELASON(55),PCE(55),PCESUBT,PCET,
     +          SGOVE(55),SGOVER(55),SGOVET,T5TM,T6TM,T7TM,T8TM
      COMMON/A4/ACNETBI(55),BUSINC(55),BUSINCT,BUSTAX,BUSTAXR(55),
     +          DEPROI(55),DEPRPA(55),DIT,DITM1,EARN(55),EARNT,
     +          EARPWK(55),EARPWKR(5,55),EMPCOM(55),EMPCOMR(55),
     +          EMPCOMT,IMPORT(55),IMPORTT,PCEIMP,PCER,PCHECR(55),
     +          PCHITR(55),PIDITR,PIEARNR,PIT,PITM1,PROPINR,
     +          REGIMPR(55),TMAX(55),TRANPYR,UNCOMPR,VALADR(55)
      COMMON/A5/EMPLOY(55),EMPLOYD(10),EMPLOYS(10),EMPLOYT,EMPM1T,
     +          EMPWFD(55),EMPWFDT,FCEMP,FCEMPR,FMEMP,HWORK,HWORKR,
     +          HRWPW(55),HRWPWR(55),HRWPY(55),OCUP(65,9),OGFDDIS(3),
     +          OUTPHW(55),OUTPHWR(5,55),OUTPWK(55),RFCEMP,
     +          RHWORK,RSGEMP,SGEMP,SGEMPR,UNEMP(10),UNEMPT,
     +          WKWPY(55),WKWPYR(55),T8M(55)
      COMMON/A6/LBFAGEG(12),LBFOCUR(10),LBFT
      COMMON/A7/ACFERTY(4,67),COMIN(10),COMINR(10),COMOUT(10),
     +          COMOUTR(10),CORTMVF(67),CORTMVM(67),
     +          DEATHRF(67),DEATHRM(67),FERTILY(67),INMIGF(67),
     +          INMIGM(67),INMIGOC(10),INMIGR(10),MFBIRTR,NEMDEPR,
     +          NMIGDIR(2,67),NMIGDIS(2,67),OTMIGOC(10),OTMIGR(10),
     +          OUTMIGF(67),OUTMIGM(67),POPF(67),POPFT,POPM(67),
     +          POPMT,POPT,POPTM1,RCOMINR(10),RCOMOTR(10),REMDEPR,
     +          RMIGDIR(2,67),RMIGDIS(2,67),RNEMDEP,RREMDEP
      COMMON/A8/LEMAT(55,55),X(55),XD(55),XDTOT,XLTOT,XM1(55),
     +          XS(55),XSTOT,XTOT,XTOTM1
      COMMON/A9/CHANGA(10),CHANGE(10),DUM(3,10),RIA(3,10),
     +          T1M(55),T2M(55),T3M(55),T1TM,T2TM,T3TM,
     +          LFPARF(12),LFPARM(12),LFPARFR(12),LFPARMR(12)
     COMMON/FUEL/YT(56),AA(55,3),DDUM(55,3),YB(56,3),PRICE(3),
    1PRATE(3),B(55,3),D(55,3),EIDOL(55)
*
      REAL LBFMG,LBFFG
      REAL LBFT,IMPORTT,NBUSINC,INVLMC,INVLMA
      REAL LELASIN,LELASON,INVMAT,NEMDEPR,MFBIRTR
      REAL NMIGDIS,NMIGDIR,INMIGM,INMIGF,LBFOCUR,INMIGOC,LBFAGEG
      REAL LEMAT,LFPARM,LFPARMR,LFPARF,LFPARFR,IMPORT,INMIGR
      INTEGER AY1,AY2,AY
*
     DIMENSION YN(56),GF(56),YF(56,3),ELAST(3,3),OWNEL(3),CONVF(3)
     DATA ELAST/-.0797,.424,.313,.01,-.952,.0923,.0023,.0288,-.797/
     DATA OWNEL/-.003,-.003,-.003/
     DATA CONVF/.74,.78,.75/
C...GETPF DATA FILE EDFUEL
     IF(IYEAR.LT.1976) GO TO 330
     IF(IYEAR.GT.1976) GOTO 501
     DO 301  I=1,NIS
     YT(I)=YB(I,1)+YB(I,2)+YB(I,3)
```

```
      DO 828 I=1,NIS
      DO 829 J=1,3
      DDUM(I,J)=D(I,J)+.0005
      GF(I)=GF(I)+(1.-B(I,J))*YF(I,J)
      IF(GF(I).LT.0) GF(I)=0.
829   CONTINUE
  828 CONTINUE
      DO 10 I=1,NIS
      DO 11 J=1,3
      UBOUND=1
      IF(D(I,J).EQ.0.) GOTO 13
      IF(D(I,J).EQ.UBOUND.OR.D(I,J).EQ.1.) GOTO 137
      IF(GF(I).LE.0.) GOTO 137
      PFACT=0.
      DO 12 K=1,3
   12 PFACT=PFACT+ELAST(J,K)*ALOG(PRICE(K))
      DDUM(I,J)=(B(I,J)*YF(I,J)+D(I,J)*GF(I))/GF(I)/(UBOUND-D(I,J))
     1/D(I,J)*UBOUND
      IF(DDUM(I,J).GT.50.) DDUM(I,J)=50.
      AA(I,J)=ALOG(UBOUND/D(I,J)-1.)+DDUM(I,J)*PFACT
      GOTO 11
   13 AA(I,J)=0.
      GOTO 11
  137 AA(I,J)=D(I,J)
   11 CONTINUE
   10 CONTINUE
   18 CONTINUE
C.......................................
      DO 21 I=1,NIS
      GF(I)=0.
      IF(YT(I).NE.0.) GF(I)=(YN(I)-YT(I))/YT(I)
      DO 128 J=1,3
      GF(I)=GF(I)+(1.-B(I,J))*YF(I,J)
      IF(GF(I).LT.0.) GF(I)=0.
128   CONTINUE
      GMS=YN(I)-YT(I)
*
      DO 22 J=1,3
      GMS=GMS+(1.-B(I,J))*YB(I,J)
      IF(GMS.LT.0.) GMS=0.
22    CONTINUE
      DSUM=0
      DO 23 J=1,3
      IF(GMS.LE.0.) GOTO 56
      UBOUND=1.
      IF(D(I,J).EQ.0..OR.D(I,J).EQ.1..OR.D(I,J).EQ.UBOUND) GOTO 23
      PFACT=0
      DO 25 K=1,3
   25 PFACT=PFACT+ELAST(J,K)*ALOG(PRICE(K))
      D(I,J)=UBOUND/(1.+EXP(AA(I,J)-DDUM(I,J)*PFACT))
      IF(J.NE.1) DSUM=DSUM+D(I,J)
   23 CONTINUE
      IF(DSUM.EQ.0.) GOTO 56
      DO 57 J=2,3
      D(I,J)=D(I,J)*(1.-D(I,1))/DSUM
   57 CONTINUE
   56 DO 26 J=1,3
      DIDI=D(I,J)
      IF(GMS.LT.0.) DIDI=YF(I,J)
      YB(I,J)=B(I,J)*YB(I,J)+DIDI*GMS
   26 CONTINUE
```

```
      YT(I)=YN(I)
      DO 257 J=1,3
      IF(YT(I).EQ.0.)  GOTO 2945
      YF(I,J)=YB(I,J)/YT(I)
      GOTO 257
2945  YF(I,1)=YF(I,2)=YF(I,3)=0
 257  CONTINUE
  21  CONTINUE
C    RETURN
C    END
C
      DO 412 I=1,NIS
      DO 412 J=1,3
      YB(I,J)=YB(I,J)/CONVF(J)
 412  CONTINUE
C
C
      DO 303 I=1,NIS
      DO 307 J=1,3
      YB(I,J)=YB(I,J)*(1.+OWNEL(J)*PRATE(J))
      YB(NISP1,J)=YB(NISP1,J)+YB(I,J)
 307  CONTINUE
      TEMPOR=YB(I,1)+YB(I,2)+YB(I,3)
      EIDOL(I)=0.
      IF(X(I).NE.0.)  EIDOL(I)=TEMPOR/X(I)
 303  CONTINUE
C
C    ADD ON ELECTRICITY SELF-GENERATION ON SECTORS 5,17,28
C
C
      YB(5,3)=YB(5,3)+23200.0
      YB(17,3)=YB(17,3)+6606.0
      YB(28,3)=YB(28,3)+9925.0
      YB(NISP1,3)=YB(NISP1,3)+23200.+6606.+9925.
C
      DO 324 J=1,3
      PRICE(J)=PRICE(J)*PRATE(J)
 324  CONTINUE
 330  CONTINUE
      END
 EOI ENCOUNTERED.
```

```
COPY,EDFUEL

00100 0 0 0
00110 0 0 0
00120 0 0 0
00130 43.9 20.3 0
00140 30394 10079.2 17477
00150 0 0 0
00160 0 0 0
00170 0 0 0
00180 0 0 0
00190 0 230.4 0
00200 0 0 0
00210 2.2 100.3 0
00220 100.2 0 0
00230 0 0 0
00240 19.6 235.2 0
00250 573.3 153.6 0
00260 13432.7 893.4 2705
00270 7.5 0 184.5
00280 4.5 0 0
00290 0 0 0
00300 264.1 2949.3 0
00310 0 0 0
00320 711.5 496.0 0
00330 0 0 0
00340 0 0 0
00350 0 0 0
00360 12.1 457.5 0
00370 109.8 551.3 9925
00380 79.4 55.7 0
00390 1.5 0 0
00400 43.9 95.7 0
00410 20.9 0 0
00420 74.6 1114.6 0
00430 0 0 0
00440 6.7 924.4 0
00450 0 0 0
00460 0 43.2 0
00470 895.5 2434.4 48301
00480 13.2 0 0
00490 419.8 0 583
00500 34.1 551.5 0
00510 366.1 1217.1 0
00520 32.6 99.1 0
00530 0 0 0
00540 363.3 1448.1 0
00550 32.2 190.8 0
00560 41.9 117.4 0
00570 76.9 19.3 0
00580 1053.7 617.6 79.7
00590 69.3 327.3 0
```

```
00600 55.1 26.7 0
00610 .4 0 0
 0620 0 0 0
 0630 1 1 1 0 1 0
00640 1 1 1 0 1 0
00650 1 1 1 0 1 0
00660 .205 .998 1 .827 .173 0
00670 .300 1 .639 .240 .200 .560
00680 .243 1 .639 .240 .200 .560
00690 .243 1 .639 .240 .200 .560
00700 1 1 1 0 1 0
00710 1 1 1 0 1 0
00720 1 1 1 0 1 0
00730 1 1 1 0 1 0
00740 .99 1 1 0 1 0
00750 .778 1 1 .861 .139 0
00760 1 1 1 0 1 0
00770 .337 1 1 .603 .397 0
00780 1 .756 1 1 0 0
00790 1 .756 1 1 0 0
00800 1 .756 1 1 0 0
00810 1 1 1 .989 .011 0
00820 1 1 1 0 1 0
00830 .18 .493 0 .430 .570 0
00840 1 1 1 0 1 0
00850 1 1 1 .517 .483 0
00860 1 1 1 0 1 0
00870 .271 1 1 .270 .095 .635
00880 1 1 0 .811 .189 0
00890 1 1 0 .244 .756 0
00900 1 1 1 .811 .189 0
00910 0 1 1 .898 .102 0
00920 .271 1 1 .270 .095 .635
00930 .271 1 1 .270 .095 .635
00940 1 1 0 1 0 0
00950 1 1 0 0 1 0
00960 1 1 1 0 1 0
00970 1 1 0 0 1 0
00980 1 1 1 0 1 0
00990 1 1 0 .859 .141 0
01000 .051 1 1 .510 .210 .280
01010 1 0 0 1 0 0
01020 .271 1 1 .270 .095 .635
01030 .939 1 1 .0004 .9996 0
01040 1 1 1 .140 .860 0
01050 .432 .882 1 .944 .056 0
01060 .432 .882 1 .944 .056 0
01070 1 1 1 0 1 0
01080 1 .923 .255 .838 0 .162
01090 1 1 1 .140 .860 0
01100 1 1 1 .992 .008 0.0
01110 .972 1 1 .086 .914 0
  120 1 1 0 .859 .141 0
 .130 1 1 0 .859 .141 0
01140 1 1 0 .859 .141 0
01150 1 1 1 0 1 0
 EOI ENCOUNTERED.
```

APPENDIX 5

DATA REQUIREMENTS FOR THE RESIDENTIAL MODEL

DESCRIPTION	SOURCE/PREFERRED SOURCE

```
120 DATA H7/16252.,5917.,1288.,67407.,10029.,4371.,9518.,1270.,783.,
121+5981.,2511.,1395.,2177.,0.,271.,101335.,19725.,8108./
```

NUMBER OF HOUSEHOLDS IN THE REGION (1976)	MEA ESTIMATES / HOUSEHOLD SURVEY
NATURAL GAS SINGLE FAMILY MULTI-UNIT MOBILE HOMES	MEA ESTIMATES / HOUSEHOLD SURVEY
FUEL OIL SINGLE FAMILY MULTI-UNIT MOBILE HOMES	MEA ESTIMATES / HOUSEHOLD SURVEY
LP GAS . . .	MEA ESTIMATES / HOUSEHOLD SURVEY
ELECTRIC . . .	MEA ESTIMATES / HOUSEHOLD SURVEY
OTHER FUELS	MEA ESTIMATES / HOUSEHOLD SURVEY

```
130 DATA HH/130983.,132555.,134146.,135755.,137384.,138868.,140368.,141883.
131+ 143416.,144965.,145501.,146040.,146580.,147122.,147667.,147472.,147277
132+ 147083.,146889.,146695.,146416.,146138.,145860.,145583.,145306./
```

FORECAST NUMBER OF HOUSEHOLDS IN THE REGION (1976-2000)	STATE DEMOGRAPHER OFFICE / SIMLAB

```
140 DATA YT/1056.8,1087.5,1119.0,1151.4,1184.8,1214.4,1244.8,1275.9,1307.8,
141+1340.5,1[illegible].0,1408.4,1443.6,1479.6,1516.6,1554.6,1593.4,1633.2,1674.1,
142+1715.9,1758.8,1802.8,1847.9,1894.1,1941.4/
```

TOTAL PERSONAL INCOME FORECASTS FOR THE REGION (MILLION 1967 $, 1976-2000) — U.S. BUREAU OF ECONOMIC ANALYSES / SIMLAB

```
150 DATA FADD1/.65,.64,.63,.60,.59,.56,.55,.53,.51,.51,.51,.51,.52,.53,.54,
151+10*.54/
152 DATA FADD2/.21,.24,.23,.23,.23,.25,.25,.29,.31,.30,.29,.29,.29,.28,.27,
153+10*.27/
```

PROPORTION OF NEW SINGLE FAMILY UNITS TO TOTAL NEW UNITS (1976 - 2000) — DATA RESOURCES INC. / DATA RESOURCES INC.

PROPORTION OF NEW MULTIUNITS TO TOTAL NEW UNITS (1976- 2000) — DATA RESOURCES INC. / DATA RESOURCES INC.

```
160 DATA ADDC3/25*0./
```

TEMPORARY HOUSING FOR CONSTRUCTION CREWS (1976-2000) — ASSUMED ZERO / SIMLAB

```
170 DATA EI/183.,81.,124.5,24898.,12449.,16939.,32.,14.,22.,5700.,2523.,3878.,
171+8.8,8.8,8.8,1476.,1476.,1476.,8.4,8.4,8.4,996.,996.,996./
```

SPACE-HEATING ENERGY INTENSITIES (MILLION BTU/UNIT) — MEA / MEA

SINGLE FAMILY
MULTI-UNIT
MOBILE HOMES

ELECTRIC SPACE-HEATING INTENSITIES (KWH/UNIT) — MEA/MEA

SINGLE FAMILY
MULTI-UNIT
MOBILE HOMES

WATER HEATING INTENSITIES — MEA/MEA

⋮

ELECTRIC WATER HEATING INTENSITIES — MEA/MEA

⋮

COOKING INTENSITIES — MEA/MEA

⋮

ELECTRIC COOKING INTENSITIES — MEA/ MEA

⋮

OTHERS — MEA/MEA

```
175 DATA EFF/-.17,-.17,-.17,-.228,-.228,-.228,1.6,2.1,1.0,1.4,1.4,1.4/
```

SHORT TERM PRICE ELASTICITIES FOR SPACE HEATING — MEA/MEA

SINGLE FAMILY UNITS
MULTI-UNITS
MOBILE HOMES

SHORT TERM PRICE ELASTICITIES FOR OTHER USES — MEA/MEA

SINGLE FAMILY UNITS
MULTI-UNITS
MOBILE HOMES

EFFICIENCY IMPROVEMENTS ON SPACEHEATING DUE TO BUILDING CODES — MEA/MEA

NEW SINGLE FAMILY UNITS
NEW MULTI-UNITS
MOBILE HOMES

EFFICIENCY IMPROVEMENTS ON NEW WATER HEATING UNITS — MEA MEA

SINGLE FAMILY UNITS
MULTI-UNITS
MOBILE HOMES

```
199C...... 1976 CONTROLS......
200 NYEAR=1976
201 HURB=.65
202 HUNG=.613
203 POILEL=.70
205 HUOIL=(1.-HUNG)*POILEL
206 HRNG=.070
207 HROIL=(1.-HRNG)*POILEL
210 REMOV1=.0059
211 REMOV2=.0117
213 REMOV3=.0392
220 RCONV1=.0918
221 PCONV2=4.
226 PC11=PC21=PC31=.88
```

NYEAR	START OF FORECASTING YEAR	MEA/MEA
HURB	PROPORTION OF URBAN GROWTH TO TOTAL HOUSEHOLD GROWTH	MEA/MEA
HUNG	PROPORTION OF URBAN AREA WITH NATURAL GAS	MEA/MEA
POILEL	PROPORTION OF NEW OIL FURNACE IN NON-NATURAL GAS AREA	MEA/MEA
HRNG	PROPORTION OF RURAL AREA WITH NATURAL GAS	MEA/MEA
REMOV1	REMOVAL RATES FOR SINGLE FAMILY UNITS	SPA/SURVEY
REMOV2	REMOVAL RATES FOR MULTI UNITS	SPA/SURVEY
REMOV3	REMOVAL RATES FOR MOBILE HOMES	SPA/SURVEY
RCONV1	CONVERSION RATE, SINGLE FAMILY TO APARTMENTS	SPA/SURVEY
PCONV2	NUMBER OF APARTMENTS PER CONVERTED HOME	MEA/SURVEY
PC11 PC12 PC13	PROPORTION OF NEW NATURAL GAS UNITS WITH GAS RANGES	MEA/SURVEY

```
227 XOELH=0.5108
```

XOECH	NATURAL LOGARITHM OF 1975 ELECTRIC ENERGY CONSUMPTION PER HOUSEHOLD FOR NON-SPACE HEATING, NON-WATER HEATING USES	MEA/MEA

APPENDIX 6

RESIDENTIAL FUEL DEMAND MODEL FOR REGION III AND DOUGLAS COUNTY, WISCONSIN

```
 78/10/24. 10.36.37.
MNF        PROGRAM   EVRESCN

10 PROGRAM EVRESCN(INPUT,OUTPUT)
11C......COPPER NICKEL RESIDENTIAL MODEL......
100 DIMENSION H7(3,6),HS(3,6),HH(25),YT(25),ADDC3(25),PADD1(25),PADD2(25)
101+ ,DEM(3,6),PFS(3,5),EI(3,8),EFF(3,4)
120 DATA H7/16252.,5917.,1288.,67407.,10029.,4371.,9518.,1270.,783.,
121+5981.,2511.,1395.,2177.,0.,271.,101335.,19725.,8108./
130 DATA HH/130983.,132555.,134146.,135755.,137384.,138868.,140368.,141883.,
131+ 143416.,144965.,145501.,146040.,146580.,147122.,147667.,147472.,147277.,
132+ 147083.,146889.,146695.,146416.,146138.,145860.,145583.,145306./
140 DATA YT/1056.8,1087.5,1119.0,1151.4,1184.8,1214.4,1244.8,1275.9,1307.8,
141+1340.5,1374.0,1408.4,1443.6,1479.6,1516.6,1554.6,1593.4,1633.2,1674.1,
142+1715.9,1758.8,1802.8,1847.9,1894.1,1941.4/
150 DATA PADD1/.65,.64,.63,.60,.59,.56,.55,.53,.51,.51,.51,.51,.52,.53,.54,
151+10*.54/
152 DATA PADD2/.21,.24,.23,.23,.23,.25,.25,.29,.31,.30,.29,.29,.29,.28,.27,
153+10*.27/
160 DATA ADDC3/25*0./
170 DATA EI/183.,81.,124.5,24898.,12449.,16939.,32.,14.,22.,5700.,2523.,3878.,
171+8.8,8.8,8.8,1476.,1476.,1476.,8.4,8.4,8.4,996.,996.,996./
175 DATA EFF/-.17,-.17,-.17,-.228,-.228,-.228,1.6,2.1,1.0,1.4,1.4,1.4/
195 PRINT 196
196 196 FORMAT(2/,5X,*RESIDENTIAL FUEL DEMAND MODEL--CUNI AREA (MEA-FORE*
197+,*CASTING)*)
198C......
199C...... 1976 CONTROLS......
200 MYEAR=1976
201 HURB=.65
202 HUNG=.613
203 POILEL=.70
205 HUOIL=(1.-HUNG)*POILEL
206 HRNG=.070
207 HPOIL=(1.-HRNG)*POILEL
210 REMOV1=.0059
211 REMOV2=.0117
2[illegible] REMOV3=.0392
2[illegible] RCONV1=.0918
221 PCONV2=4.
226 PC11=PC21=PC31=.88
227 XDELH=0.5108
```

```
C...... EFFCY IMPROVEMENTS ON NEW STOCK AND PRICE EFFECTS ON EXISTING..
      DO 305 I=1,3
      DO 305 J=3,4
  305 EFF(I,J)=1.-(EFF(I,J)/100.)
C... PRICE EFFECTS ON NEW STOCK...
      DO 315 I=1,3
      EFF(I,1)=1.+(EFF(I,1)*.0335)
  315 EFF(I,2)=1.+(EFF(I,2)*.0335)
      DO 805 I=1,3
      DO 805 J=1,6
  805 HS(I,J)=H7(I,J)
C...REPLACEMENTS EXCEPT N.GAS,LPG,ELEC. UP TO 1984...
      PFRT1=HS(1,6)-HS(1,1)-HS(1,3)-HS(1,4)
      PFRT2=HS(2,6)-HS(2,1)-HS(2,3)-HS(2,4)
      PFRT3=HS(3,6)-HS(3,1)-HS(3,3)-HS(3,4)
      DO 817 I=1,3
  817 PFS(I,1)=PFS(I,3)=PFS(I,4)=0.
      DO 830 J=2,5
      IF(J.EQ.3.OR.J.EQ.4)GO TO 830
      PFS(1,J)=HS(1,J)/PFRT1
      PFS(2,J)=HS(2,J)/PFRT2
      PFS(3,J)=HS(3,J)/PFRT3
  830 CONTINUE
      SUMHNG=SUMHOL=SUMHEL=0.
      SUMWNG=SUMWEL=0.
      SUMCNG=SUMCEL=0.
      SUMONG=SUMOEL=0.
C......
C......ANNUAL LOOPS......
 1000 PRINT 1010,NYEAR
 1010 FORMAT(3/,2X,I5)
C...... HOUSING STOCK BY TYPE, FUEL ......
C... REMOVALS...
      DO 1055 I=1,3
      DO 1055 J=1,6
 1055 DEM(I,J)=0.
      DEM1=HS(1,6)*REMOV1
      DEM2=HS(2,6)*REMOV2
      DEM3=HS(3,6)*REMOV3
      DO 1100 J=1,5
      IF(NYEAR.NE.1985)GO TO 1085
      DO 1084 I=1,3
      DO 1084 K=1,5
 1084 PFS(I,K)=HS(I,K)/HS(I,6)
 1085 DEM(1,J)=DEM1*PFS(1,J)
      DEM(2,J)=DEM2*PFS(2,J)
      DEM(3,J)=DEM3*PFS(3,J)
      DO 1100 I=1,3
 1100 DEM(I,6)=DEM(I,6)+DEM(I,J)
C......
C...... ADDITIONS AND CONVERSIONS......
      ADD=HH(NYEAR-1975)-HS(1,6)-HS(2,6)-HS(3,6)
      ADD1=(ADD*PADD1(NYEAR-1975))+DEM(1,6)
      ADD2=(ADD*PADD2(NYEAR-1975))+DEM(2,6)
      ADD3=ADD+DEM(1,6)+DEM(2,6)+DEM(3,6)-ADD1-ADD2+ADDC3(NYEAR-1975)
```

```
C... CONVERSIONS...
CONV2=(ADD1+ADD2+ADD3-ADDC3(NYEAR-1975))*PCONV1*4./3.
CONV1=CONV2/PCONV2
ADD3=ADD3-CONV2+CONV1
C......
C...... SPACEHEATING NEEDS......
DO 3120 J=1,5
H7(1,J)=H7(1,J)-DEM(1,J)-(CONV1*PFS(1,J))
HS(1,J)=HS(1,J)-DEM(1,J)-(CONV1*PFS(1,J))
H7(2,J)=H7(2,J)-DEM(2,J)+(CONV2*PFS(2,J))
HS(2,J)=HS(2,J)-DEM(2,J)+(CONV2*PFS(2,J))
H7(3,J)=H7(3,J)-DEM(3,J)
HS(3,J)=HS(3,J)-DEM(3,J)
3120 CONTINUE
PADDNG=(HURB*HUNG)+((1.-HURB)*HRNG)
PADDOL=(HURB*HUOIL)+((1.-HURB)*HROIL)
PADDEL=1.-PADDNG-PADDOL
HS(1,1)=HS(1,1)+(ADD1*PADDNG)
HS(1,2)=HS(1,2)+(ADD1*PADDOL)
HS(1,4)=HS(1,4)+(ADD1*PADDEL)
HS(2,1)=HS(2,1)+(ADD2*PADDNG)
HS(2,2)=HS(2,2)+(ADD2*PADDOL)
HS(2,4)=HS(2,4)+(ADD2*PADDEL)
HS(3,1)=HS(3,1)+(ADD3*PADDNG)
HS(3,2)=HS(3,2)+(ADD3*PADDOL)
HS(3,4)=HS(3,4)+(ADD3*PADDEL)
HS(1,6)=HS(2,6)=HS(3,6)=0.
H7(1,6)=H7(2,6)=H7(3,6)=0.
DO 3250 I=1,3
DO 3250 J=1,5
HS(I,6)=HS(I,6)+HS(I,J)
3250 H7(I,6)=H7(I,6)+H7(I,J)
C...... CUMULATE ADDITIONS AFTER 1975......
SUMHNG=SUMHNG+(ADD1*PADDNG*EI(1,1)*EFF(1,3))
SUMHNG=SUMHNG+(ADD2*PADDNG*EI(2,1)*EFF(2,3))
SUMHNG=SUMHNG+(ADD3*PADDNG*EI(3,1)*EFF(3,3))
SUMHOL=SUMHOL+(ADD1*PADDOL*EI(1,1)*EFF(1,3))
SUMHOL=SUMHOL+(ADD2*PADDOL*EI(2,1)*EFF(2,3))
SUMHOL=SUMHOL+(ADD3*PADDOL*EI(3,1)*EFF(3,3))
SUMHEL=SUMHEL+(ADD1*PADDEL*EI(1,2))
SUMHEL=SUMHEL+(ADD2*PADDEL*EI(2,2))
SUMHEL=SUMHEL+(ADD3*PADDEL*EI(3,2))
XHNG=XHOL=XHLP=0.
XHEL=XHOT=0.
DO 3280 I=1,3
XHNG=XHNG+(H7(I,1)*EI(I,1)*EFF(I,1))
XHOL=XHOL+(H7(I,2)*EI(I,1)*EFF(I,1))
XHLP=XHLP+(H7(I,3)*EI(I,1)*EFF(I,1))
XHEL=XHEL+(H7(I,4)*EI(I,2)*EFF(I,1))
3280 XHOT=XHOT+(H7(I,5)*EI(I,1)*EFF(I,1))
XHNG=XHNG+SUMHNG
XHOL=XHOL+SUMHOL
XHEL=XHEL+SUMHEL
```

```
7299C...... WATER HEATING..NG......
S   1 SUMWNG=SUMWNG+(ADD1*PADDNG*EI(1,3)*EFF(1,4))
3332 SUMWNG=SUMWNG+(ADD2*PADDNG*EI(2,3)*EFF(2,4))
3333 SUMWNG=SUMWNG+(ADD3*PADDNG*EI(3,3)*EFF(3,4))
3340 SUMWEL=SUMWEL+(ADD1*(1.-PADDNG)*EI(1,4)*EFF(1,4))
3341 SUMWEL=SUMWEL+(ADD2*(1.-PADDNG)*EI(2,4)*EFF(2,4))
3342 SUMWEL=SUMWEL+(ADD3*(1.-PADDNG)*EI(3,4)*EFF(3,4))
3350 XWNG=XWLP=XWEL=0.
7355 DO 3360 I=1,3
3357 XWNG=XWNG+(H7(I,1)*EI(I,3)*EFF(I,2))
3358 XWLP=XWLP+(H7(I,3)*EI(I,3)*EFF(I,2))
3359 XWEL=XWEL+((H7(I,2)+H7(I,4)+H7(I,5))*EI(I,4)*EFF(I,2))
33>0 3360 CONTINUE
3370 XWNG=XWNG+SUMWNG
3371 XWEL=XWEL+SUMWEL
3999C...... COOKING.. NG......
4000 SUMCNG=SUMCNG+(ADD1*PADDNG*PC11*EI(1,5)*EFF(1,4))
4001 SUMCNG=SUMCNG+(ADD2*PADDNG*PC21*EI(2,5)*EFF(2,4))
4002 SUMCNG=SUMCNG+(ADD3*PADDNG*PC31*EI(3,5)*EFF(3,4))
405 SUMCEL=SUMCEL+(ADD1*(1.-PADDNG)*(1.-PC11)*EI(1,6)*EFF(1,4))
4006 SUMCEL=SUMCEL+(ADD2*(1.-PADDNG)*(1.-PC21)*EI(2,6)*EFF(2,4))
4007 SUMCEL=SUMCEL+(ADD3*(1.-PADDNG)*(1.-PC31)*EI(3,6)*EFF(3,4))
4020 XCNG=XCLP=XCEL=0.
4021 XCNG=XCNG+(H7(1,1)*PC11*EI(1,5)*EFF(1,2))
4022 XCNG=XCNG+(H7(2,1)*PC21*EI(2,5)*EFF(2,2))
4025 XCNG=XCNG+(H7(3,1)*PC31*EI(3,5)*EFF(3,2))
4027 DO 4030 I=1,3
4028 XCLP=XCLP+(H7(I,3)*EI(I,5)*EFF(I,2))
4029 XCEL=XCEL+((H7(I,2)+H7(I,4)+H7(I,5))*EI(I,6)*EFF(I,2))
4030 4030 CONTINUE
4031 XCEL=XCEL+(H7(1,1)*(1.-PC11)*EI(1,6)*EFF(1,2))
4032 XCEL=XCEL+(H7(2,1)*(1.-PC21)*EI(2,6)*EFF(2,2))
4033 XCEL=XCEL+(H7(3,1)*(1.-PC31)*EI(3,6)*EFF(3,2))
4035 XCNG=SUMCNG+XCNG
4036 XCEL=SUMCEL+XCEL
4100C....OTHER USES...
4200 SUMONG=SUMONG+(ADD1*PADDNG*EI(1,7)*EFF(1,4))
4201 SUMONG=SUMONG+(ADD2*PADDNG*EI(2,7)*EFF(2,4))
4202 SUMONG=SUMONG+(ADD3*PADDNG*EI(3,7)*EFF(3,4))
4R05 SUMOEL=SUMOEL+(ADD1*(1.-PADDNG)*EI(1,8)*EFF(1,4))
4206C...THESE GO TO COMMER...  SUMOEL=SUMOEL+(ADD2*(1.-PADDNG)*EI(2,8)*EFF(2,4))
4207C SUMOEL=SUMOEL+(ADD3*(1.-PADDNG)*EI(3,8)*EFF(3,4))
4210 XONG=XOLP=XOEL=0.
4215C DO 4230 I=1,3
4217 I=1
4220 XONG=XONG+(H7(I,1)*EI(I,7)*EFF(I,2))
4225 XOLP=XOLP+(H7(I,3)*EI(I,7)*EFF(I,2))
4226C XOEL=XOEL+((H7(I,2)+H7(I,4)+H7(I,5))*EI(I,8)*EFF(I,2))
4230 4230 CONTINUE
4235 XONG=SUMONG+XONG
4P36 XOEL=SUMOEL+XOEL
4   8C......
```

```
4299C......RESIDENTIAL ELECTRIC EQUATION FOR OTHER USES...
4300 XDELH=1.16392-(7.511/(YT(NYEAR-1975)*1000/HH(NYEAR-1975)))+(.544*XDELH)
4301 XDEL=EXP(XDELH)*(HH(NYEAR-1975))/1000.
4497 PRINT 501
4499 501 FORMAT(*          NATURAL GAS  FUEL OIL  LPG    ELEC   OTHER*,
4500+*   TOTAL*)
4501 PRINT 4502,(HS(1,J),J=1,6)
4502 4502 FORMAT(1X,*SINGLE FAMILY*,6F8.)
4503 PRINT 4504,(HS(2,J),J=1,6)
4504 4504 FORMAT(1X,*MULTI UNITS*,2X,6F8.)
4505 PRINT 4506,(HS(3,J),J=1,6)
4506 4506 FORMAT(1X,*MOBILE*,7X,6F8.)
4510 PRINT 4520,HS(1,1)+HS(2,1)+HS(3,1),HS(1,2)+HS(2,2)+HS(3,2),HS(1,3)+
4511+HS(2,3)+HS(3,3),HS(1,4)+HS(2,4)+HS(3,4),HS(1,5)+HS(2,5)+HS(3,5),
4512+HS(1,6)+HS(2,6)+HS(3,6)
4520 4520 FORMAT(1X,*TOTAL*,8X,6F8.)
4599C......
4798C......
4799C...... EFFCY IMPROVEMENTS ON NEW STOCK AND PRICE EFFECTS ON EXISTING..
4800 IF(NYEAR.GT.1995)GO TO 4841
4801 EFF(1,3)=EFF(1,3)*.984
4802 EFF(2,3)=EFF(2,3)*.979
803 EFF(3,3)=EFF(3,3)*.990
4804 EFF(1,4)=EFF(1,4)*.986
$805 EFF(2,4)=EFF(3,4)=EFF(1,4)
T810C... PRICE EFFECTS ON EXISTING STOCK...
4820 DO 4825 I=1,3
4821 EFF(I,1)=EFF(I,1)*.994
4825 4825 EFF(I,2)=EFF(I,2)*.992
4840C...... TOTALS......
4841 4841 XTNG=(XHNG+XWNG+XCNG+XONG)/1000.
4842 XTOL=XHOL/138690.
4843 XTLP=(XHLP+XWLP+XCLP)/92000.
4844 XTEL=(XHEL+XWEL)/1000000.
4845 XTEL=XTEL+XOEL
4846 XTOT=XHOT/1000.
4850C....
94851 PRINT 4852, XHNG/1000.,XHOL/138690.,XHLP/92000.,XHEL/1000000.,XHOT/1000.
4852 4852 FORMAT(/,1X,*SPACEHEATING GAS,OIL,LP,ELEC,OTHER*,5F8.)
4860 PRINT 4861,XTNG,XTOL,XTLP,XTEL,XTOT
4861 4861 FORMAT(1X,*TOTAL*,29X,5F8.)
4900 IF(NYEAR.EQ.2000)GO TO 5000
4901 NYEAR=NYEAR+1
4902 GO TO 1000
5000 5000 STOP
5001 END
```

READY.
RUN,E=4

78/10/24. 10.42.04.
MNF PROGRAM EVRESCN

RESIDENTIAL FUEL DEMAND MODEL--CUNI AREA (MEA-FORECASTING)

PC

1976

	NATURAL GAS	FUEL OIL	LPG	ELEC	OTHER	TOTAL
SINGLE FAMILY	17004.	67458.	9518.	6289.	2155.	102424.
MULTI UNITS	6176.	10408.	1270.	2617.	0	20471.
MOBILE	1415.	4193.	783.	1447.	252.	8090.
TOTAL	24595.	82059.	11571.	10353.	2408.	130985.

SPACEHEATING GAS,OIL,LP,ELEC,OTHER	3765.	98.	21.	213.	423.
TOTAL	4755.	98.	26.	915.	423.

1977

	NATURAL GAS	FUEL OIL	LPG	ELEC	OTHER	TOTAL
SINGLE FAMILY	17684.	67442.	9518.	6567.	2134.	103345.
MULTI UNITS	6437.	10752.	1270.	2724.	0	21182.
MOBILE	1523.	3997.	783.	1491.	234.	8028.
TOTAL	25644.	82191.	11571.	10782.	2368.	132555.

SPACEHEATING GAS,OIL,LP,ELEC,OTHER	3897.	98.	21.	220.	415.
TOTAL	4923.	98.	26.	927.	415.

1978

	NATURAL GAS	FUEL OIL	LPG	ELEC	OTHER	TOTAL
SINGLE FAMILY	18366.	67420.	9518.	6846.	2112.	104263.
MULTI UNITS	6696.	11090.	1270.	2830.	0	21886.
MOBILE	1643.	3816.	783.	1540.	216.	7997.
TOTAL	26705.	82326.	11571.	11216.	2328.	134146.

SPACEHEATING GAS,OIL,LP,ELEC,OTHER	4029.	97.	21.	228.	406.

S TOT *TERMINATED*
READY.
BYE

ZEA6905 LOG OFF 10.43.04.
P [illegible]A022 SRU 1.481 UNTS.

APPENDIX 7

Fuel Price Projections and Elasticities

TABLE 64

REAL GROWTH RATES
(Do Not Include Inflation)

	Natural Gas	Fuel Oil	LPG	Electricity[1]	Coal	Gasoline[2]
Residential	5.1%	1.6%	2.4%	2.5%	—	—
Commercial	5.6%	1.7%	2.5%	2.5%	—	—
Industrial	6.3%	1.7%	2.5%	2.5%	2.5%	—
Transportation	—	—	—	—	—	2.5%

Source: Federal Register, Vol. 42, No. 125, June 29, 1977, p. 33171. (For FEA Region V)

[1] Based on coal growth rates in above source.

[2] Minnesota Energy Agency.

TABLE 65

SHORT-RUN PRICE ELASTICITIES FOR REGION 5, FEDERAL ENERGY ADMINISTRATION
1976

	Residential	Commercial	Industrial	Transportation
Electricity	−0.126	−0.247	−0.106	—
Natural Gas	−0.180	−0.282	−0.166	—
Distillate Fuel Oil	−0.165	−0.339	−0.209	−0.372
Residual Fuel Oil	—	−0.216	−0.130	−0.114
Liquefied Petroleum Gas	−0.442	—	−0.162	—
Gasoline	—	—	—	−0.229
Jet Fuel	—	—	—	−0.148

Source: Computer Output of FEA Regional Demand Interface Model, January 6, 1977.

TABLE 66

DEMAND CROSS PRICE ELASTICITIES FOR SPECIFIC FUELS, COMMERCIAL AND
INDUSTRIAL SECTOR, REGION 5
FEDERAL ENERGY ADMINISTRATION, 1976

	FUEL DEMAND					
Prices	Electric	Natural Gas	Distillate Fuel Oil	Residual Fuel Oil	LPG	Coal
			Commercial Sector			
Electric	−0.247	0.092	0.118	0.035	0.0	—
Natural Gas	0.047	−0.282	0.044	0.013	0.0	—
Distillate Fuel Oil	0.023	0.017	−0.339	0.006	0.0	—
Residual Fuel Oil	0.015	0.011	0.014	−0.216	0.0	—
			Industrial Sector			
Electric	−0.106	0.086	0.088	0.044	0.062	0.123
Natural Gas	0.034	−0.166	0.046	0.023	0.032	0.064
Distillate Fuel Oil	0.005	0.006	−0.209	0.003	0.004	0.009
Residual Fuel Oil	0.004	0.006	0.006	−0.130	0.004	0.008
Liquified Petroleum Gas (LPG)	0.003	0.004	0.005	0.002	−0.162	0.006
Coal	0.011	0.014	0.015	0.007	0.010	−0.261

Source: Computer Output of FEA Regional Demand Interface Model, Jan. 6, 1977.

APPENDIX 8

An Alternative Approach to Gasoline Forecasting

An alternative forecasting approach that extends the econometric method by decomposing further the structure of the model can be tested with more data at the state and regional level. Gasoline consumption is the product of average vehicle fuel economy (MPG_t) :

$$C_t = V_t R_t / MPG_t$$

Since fuel economies (and vehicle miles travelled) differ substantially between small and large cars:

$$C_t = V_t \left[\frac{R_{st}}{MPG_{st}} + \frac{R_{Lt}}{MPG_{Lt}} \right]$$

where V_t = miles travelled per car

R_{st}, R_{Lt} = total number of small and large cars, respectively

MPG_{st}, MPG_{Lt} = average miles per gallon of small and large cars, respectively

and V_t can be differentiated into recreation related and non-recreation related activities:

$$C_{Nt} = V_{Nt} \left[\frac{R_{st}}{MPG_{st}} + \frac{R_{Lt}}{MPG_{Lt}} \right]$$

$$C_{Vt} = V_{Vt} \left[\frac{R_{st}}{MPG_{st}} + \frac{R_{Lt}}{MPG_{Lt}} \right]$$

where C_{Nt} = Estimated consumption for non-recreational activities

C_{Vt} = Estimated consumption for recreational related activities.

Estimates of V_{Nt}, and V_{Vt} are obtained for the state by deriving the proportion of gasoline consumption used for non-recreation activities, i.e. gasoline consumption during the months of January to April. Estimates of the small car-large car breakdown of the automobile stock were made using new car registrations, and thirteen year average car life. Also, national MPG data for these two car types are adapted. Thus, a historical series can be constructed for the state:

$$\hat{V}_{Nt} = \hat{C}_{Nt} \Big/ \left[\frac{R_{st}}{MPG_{st}} + \frac{R_{Lt}}{MPG_{Lt}}\right]$$

Average vehicle miles for non-recreational activity can be related to:

$$\hat{V}_{Nt} = f\left[EMP_t, PG_t, \hat{V}_{Nt-1}\right]$$

where EMP_t = employment

PG_t = price of gasoline

Applying state estimates of V_{Nt} and split of car stocks between small and large cars, gasoline consumption in the region for non-recreational activities can be determined. The recreational related consumption is obtained as a residual (total regional consumption minus non-recreational estimates) and related to state economic conditions:

$$_R\hat{C}_{Vt} = f\left[Y_{st}, UN_{s,t}, PG_{s,t}, POP_{s,t}\ _R\hat{C}_{vt-1}\right]$$

In forecasting, $\hat{V}_{Nt}$ can be forecast independently for the region or state estimates can be adapted. Adjustments should be made for future changes in regional employment and the price of gasoline.

Additional equations are needed to forecast the desired stock of cars and the split of new cars into small (fuel efficient) cars and large cars. The desired stock of cars:

$$ {}_{R}R_{t} = f\left[Y_{R,t},\ {}_{R}PG_{(t)},\ UN_{R,t}\ R_{Rt-1} \right] $$

where $\quad {}_{R}R_{t}$ = total number of cars in the region at time t

$\quad {}_{R}Y_{t}$ = personal income in the region at time t

$\quad {}_{R}PG_{t}$ = price of gasoline in the region at time t

$\quad {}_{R}U_{t}$ = unemployment rate in the Region at time t

and the choice of new car types:

$$ \frac{d_{it}}{d_{it}} = f\left[Y_{R,t},\ PG_{R,t} \right]; $$

plus the constant:

$$ d_{it} + d_{2t} = 1.0 $$

where $\quad d_{i} = \dfrac{\text{new } R_{s}}{\text{new } R_{T}}$

$\quad d_{2} = \dfrac{\text{new } R_{L}}{\text{new } R_{t}}$

are used to derive desired total numbers of small cars and large cars:

$$ R_{it} = (1-D_{i})R_{it-1} + d_{it}\left[\sum_{j-1}^{2} D_{j}R_{j(t-1)} + G_{(t)} \right] $$

subscript i = 1 or 2 to designate small or large cars, respectively

D_{i} = proportion of R_{it} that is to be replaced at time t

d_{i} = allocation constant of the total new cars for type i

G_{t} = desired growth of car stock

The net additions to stock (G_{t}) represents the difference between existing stock and desired total stock for the next period. Replacements are assumed equal to the number of depreciated cars so that stock differences between two periods represent net growth in car numbers.

Forecasts of desired miles of travel for non-recreational activities, split of total number of cars according to small car-large car categories and fuel economy (MPG) targets of the automobile industry are combined to predict gasoline consumption for non-recreational activities:

$$\dot{C}_{R\,Nt} = \dot{V}_{R\,Nt}\left[\frac{\dot{R}_{R\,st}}{{}_{s}\widehat{MPG}_{st}}\right] + \left[\frac{\dot{R}_{R\,t} - \dot{R}_{R\,st}}{{}_{s}\widehat{MPG}_{Lt}}\right]$$

where $\dot{V}_{R\,Nt}$ = forecasted miles travelled for non-recreational activities per car in the region

$\dot{R}_{R\,t}$ = forecasted total numberof cars in the region

$\dot{R}_{R\,st}$ = forecasted total number of small cars in the region

${}_{s}\widehat{MPG}_{st}$ ${}_{s}\widehat{MPG}_{Lt}$ = estimated fuel economy for small and large cars

Added to forecasts of recreation type travel from the econometric model, total consumption for the region can be projected.

$$\dot{C}_{R\,t} = \dot{C}_{R\,Nt} + \dot{C}_{R\,Vt}$$